OUTLINE OF THE GEOLOGY AND PETROLOGY OF SURINAM (DUTCH GUIANA).

Plate 1.

OUTLINE OF THE GEOLOGY AND PETROLOGY OF SURINAM (DUTCH GUIANA)

PROEFSCHRIFT

TER VERKRIJGING VAN DEN GRAAD VAN DOCTOR IN DE WIS- EN NATUURKUNDE AAN DE RIJKS-UNIVERSITEIT TE UTRECHT OP GEZAG VAN DEN RECTOR MAGNIFICUS Jhr. Dr. B. C. DE SAVORNIN LOHMAN HOOGLEERAAR IN DE FACULTEIT DER RECHTSGELEERDHEID VOLGENS BESLUIT VAN DEN SENAAT DER UNIVERSITEIT TEGEN DE BEDENKINGEN DER FACULTEIT DER WIS- EN NATUURKUNDE TE VERDEDIGEN OP MAANDAG 8 JUNI 1931 DES NAMIDDAGS TE DRIE UUR

DOOR

ROBERT IJZERMAN
GEBOREN TE AMSTERDAM

KEMINK EN ZOON N.V. – OVER DEN DOM – UTRECHT

AAN MIJNE OUDERS.

Bij het beëindigen van mijne academische studiën is het mij een behoefte U, Hoogleeraren in de faculteit der Wis- en Natuurkunde, van wie ik mijn wetenschappelijke vorming mocht ontvangen, mijn dank te betuigen.

Met erkentelijkheid, Hooggeleerde Went en Pulle, denk ik terug aan de leiding die gij aan mijn botanische studies gegeven hebt. De groote belangstelling, die gij voor mijn werk in Suriname getoond hebt, wordt door mij ten zeerste op prijs gesteld.

U, Hooggeleerde Nierstrass en Oestreich dank ik voor hetgeen ik van U heb mogen leeren.

Gij, Hooggeleerde Brouwer, hebt mij op het belangwekkende der tektonische problemen gewezen.

Bij het onderzoek der jongste afzettingen in Suriname, Hooggeleerde Mohr, heb ik telkens weer gebruik kunnen maken van Uw introductie in de Bodemkunde.

Aan de omstandigheden is het te wijten, Hooggeleerde Schmutzer, dat ik niet meer van Uw voorlichting heb kunnen profiteeren.

Hooggeleerde Rutten, Hooggeachte Promotor, daar mijn studies onder Uw dagelijksch toezicht hebben gestaan, ben ik U in het bijzonder verplicht. Uw veelzijdige kennis en werkkracht hebben mij steeds met eerbied vervuld. De aangename wijze waarop gij mijn studies hebt geleid, zal mij steeds in dankbare herinnering blijven.

CONTENTS.

INTRODUCTION.

Our topographical knowledge of the little visited interior of Surinam, has been considerably augmented by the co-operation of three bodies, the "Maatschappij ter bevordering van het Natuurkundig Onderzoek der Nederlandsche Kolonien", the "Koninklijk Nederlandsch Aardrijkskundig Genootschap" and the "Vereeniging voor Suriname", in co-operation with the Government. They have, during the present century, sent out nine expeditions primarily carrying out topographical work. The progress of these expeditions has been described in the various volumes of the "Tijdschrift van het Koninklijk Nederlandsch Aardrijkskundig Genootschap".

The last expedition, in 1926, to the Wilhelmina mountains, bore a general character; those who took part in it were: a topographer, a botanist and a zoologist while I was charged with the geological reconnaissance. We set out for the Wilhelmina mountains along the Suriname river and the Lucie river. After reconnoitring the Wilhelmina mountains we went up the Courantyne as far as possible, and returned to the coast along the same river. When the expedition had finished its work, I made several excursions in the lowland, in connection with investigations of another nature.

In working out my geological data it appeared that the results would considerably gain in value, if, together with the data collected in the Surinam areas not visited by me, they should be compiled into an "Outline of the Geology and Petrology of Surinam". We find all the data obtained on our expedition worked out in this treatise; the brief bulletins which appeared during our expedition have been corrected wherever necessary.

It must be understood that this outline cannot be but incomplete; in the first place because quantitavely our knowledge of Surinam is highly inadequate, and secondly because the same may be said concerning the insight into the geological relation of the formations. The lack of quantitative knowledge (the distribution of the formations) is comprehensible, as vast regions of Surinam have never and others but superficially been explored while besides in extensive areas exposures are very scarce. The want of insight into the connection of the formations is due to the incompleteness of observations and to the fact that points where "contacts" are visible are scarce. Indeed this imperfect insight into the connection between the components greatly decreases the value of any geological outline. On the other hand it seems the time has come at last to study the available data and to compile them. It must be pointed out that the writer has tried to take the field-observations made in the Colony as much as possible into account and to refrain from theoretical speculations in judging the geological relations between the different formations.

The other investigations which I laid under contribution for my purpose are of divergent nature. A number of areas in the Colony have been systematically investigated out of geological interest in them, and even more so in view of their possible economical importance. Besides a great many researches have indirectly increased our knowledge. There do not exist any monographies treating Surinam as a whole.

With regard to the crystalline basal complex we have to mention the researches of Voltz (1853—1855) along the rivers of the lowlands, of Martin (1885) along the Suriname river, of Du Bois (1898—1901) who was especially engaged on the NE. part of the Colony between the Suriname river and the Marowyne, of Van Cappelle in the Nickerie district (1900), of the Governments Mining Exploration (1903—1908) which explored vast tracts between the Lawa and the Tapanahony and to the West of the Marowyne, and of Essed along the Coppename (1926). Researches into the crystalline basal complex are of special value when they are supplemented by petrographical research. Du Bois, himself, has worked out petrographically part of his material (1901), Kloos that of Martin (1889) and Beekman that of Van Cappelle (1907).

A second category of data on the crystalline basal complex is formed by the samples collected on various occasions, without geological notes. It comprises the material collected by the topographical expeditions, and smaller collections made by mining-engineers, travellers, and by those interested. This loose sample material was partly not investigated at all, partly provisionally or fully studied. The latter applies to the material of the Tumuchumac expedition investigated by Grutterink (1908) and a collection from the Coppename described by Bergt (1902). Among the sample material we may also include the extensive collections of the Government Mining Exploration; although geological reports were published, the material was still undescribed.

Data about the latest deposits which cover the basal complex only occur as stray notes in a large number of writings which are difficult to obtain. Only the important monography by Du Bois on Surinam laterites (1903) forms an exception to this. Full data concerning the results of former researches will be found in the historical outline of this book.

My interpretations of the geological relations in so far as they concern the basal complex in particular, differ much from those of my predecessors. The same also holds good for the nomenclature and the views about the genesis of the rocks. This is not to be wondered at in view of the number of investigators whose knowledge and accuracy differed considerably, and in view of the long period during which petrology has greatly developed. Consequently petrographic research was set up anew. Besides the material already used for former publications, I had at my disposal an at least equally large collection of rock samples that had never been studied. For petrographical study, thin sections were always used, constituting in all several thousands. Chemical analyses have been made, but, although many more interesting facts might be brought to light in this way, the number of analyses could not be indefinitely continued, for pecuniary reasons.

The petrographical descriptions go into great detail. Although personally convinced that these descriptions do not provide very readable material and generally speaking will not be read, completeness has been my aim, with the intention that it may be possible later to refer to the types described in this "outline". Those who want a summary of the Surinam geology such as the writer has figured to himself, are referred to the short outline on p. 13. For the rest the reader will easely find his way, by referring to the table of contents. A geological sketch-map of Surinam will be found in the "short outline" (Map I); our knowledge is still too slight to publish a detailed geological map. In addition to this there is a map giving the localities where all the rocks described were found (Map VI). Some maps giving details are to be found in the text.

One single subject has been left out of consideration in this work, viz. the geology of the Surinam gold. Several of my predecessors have gone into this subject in detail. In so far as the geological relations are concerned they have not been able to agree. Seeing that no new data are available and seeing that I have not been able to study the geology of the gold in the field, I have abandoned working in this direction.

The text of this outline has originally been written in Dutch, but in order to make it more accessible, it has been translated into English.

In conclusion I want to express my thanks to many who made the production of this work a possibility:

To the "Maatschappij ter bevordering van het Natuurkundig Onderzoek der Nederlandsche Kolonien" and to the "Koninklijk Nederlandsch Aardrijkskundig Genootschap" for the confidence placed in me.

To Prof. Dr. G. Stahel, at Paramaribo, leader of our expedition, for his friendship during our stay in the interior, his interest in my work, and the cordial hospitality enjoyed under his roof.

To many at Paramaribo for their cordiality.

To Prof. Dr. L. M. R. Rutten, of Utrecht, who has had the supervision of my study and whose clear criticism has been of the greatest importance in carrying out these researches.

To Prof. Dr. J. A. Grutterink, of Delft, for his permission to work out the Surinam Collections of the Polytechnic.

To Prof. Dr. G. A. F. Molengraaff, of Delft, for placing his collection of pseudotachylytes from South Africa at my disposal for purposes of comparison.

To Prof. Dr. J. Mekel, of Delft, through whose kind intermediary the material of a Surinam boring was handled to me.

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To Dr. Ch. Bayer, Curator at " 's Rijks Museum van Natuurlijke Historie" at Leyden, for the nomenclature of Surinam molluscs.

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To Mr. F. C. Barker, at Zeist, for the translation of this work from Dutch into English.

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Finally to those who have supplied me with information and directions of all kinds or who have been of assistance to me with regard to the technicalities in this work.

A few technical hints for the reader.

The technical hints have reference to the following points:

A. The collections of Surinam rocks available when writing this "Outline": the manner in which they are referred to in the text, and the places where the rocks are kept at present.

B. The maps on which the localities are marked.

C. The references to the literature.

D. The use and the orthography of local names and technical terms.

A. The collections are preserved in the "Gebouw voor Mijnbouwkunde" of the Delft Polytechnic, in the "Geologisch Rijks-Museum" of the State-University of Leyden, in the "Mineralogisch Geologisch Instituut" of the State-University of Utrecht, and in the "Koloniaal Instituut" at Amsterdam.

By far the greater part of the material is at Delft; the following collections may be found there:

Collection Government Mining Exploration (1903—1908).
Collection Gonini Expedition (1903—1904) (samples collected by the members of the expedition).
Do. (samples collected by B. von Faber Eng.).
Collection Tapanahony Expedition (1905).
Collection Tumuchumac Expedition (1907).
Collection Saramacca Expedition (1902—1903).
Collection Prof. Dr. K. Martin (1884—1885) (duplicates).
Collection W. L. Loth (described by Prof. Dr. W. Bergt, 1902) (duplicates).
Collection G. C. Du Bois Eng. (1897—1901).
Collection B. P. F. Römer Eng.
Collection Government Mining Exploration (second sending).
Collection Suriname Expedition (1908).
Collection Dr. H. van Cappelle (1901).
Collection G. Duyfjes, Eng. (1914—1915).
Collection G. E. Wiessink Eng.
Collection A. H. van Lessen Eng.
Collection E. Essed (1926).
Collection E. A. Douglas Eng.
Collection Courantyne Expedition (1910—1911).
Collection Prof. Dr. J. A. Grutterink (1920).
Collection Dr. J. H. Verloop Eng.

The rock samples of all these collections present at Delft are numbered as in this order. They were designated in Delft as: V. 1098, V. 2110 etc. I have adopted the same numbering, except for those rock-samples designated by me "B". 20 etc. Such numbers have been borrowed from Bergt's publication of Loth's collection (1902). (Duplicates of the material described by Bergt are present at Delft V. 1461—1476).

The collection of Dr. F. Voltz (1853—1855), of Prof. Dr. K. Martin (1884—1885), of the Coppename Expedition (1901) and of W. L. Loth (described by Bergt in 1902) are all to be found in the "Geologisch Rijks-Museum" at Leyden. A few unimportant collections may be passed unnoticed.

The findspots of many of Voltz's rock-samples are unknown. I selected the samples with reliable labels and termed the samples "Vtz." 180 etc. Because duplicates with accessory thin sections of Martin's collection are present at Delft, I have adopted for this collection the Delft numbers (V. 1372—1460) and not Martin's. The rock samples of the Coppename Expedition I have designated "C." 20 etc. As stated before the W. L. Loth collection is numbered as in Bergt's publication (1902): "B." 26 etc.

My own collection (1925—1927) is placed in the "Mineralogisch Geologisch Instituut" at Utrecht. The rock samples have been designated "Y." 200 etc. The rock-samples collected by others are named G. 1923. 163, etc. according to their year-, and serial number in the Institute's catalogue.

The "Koloniaal Instituut" possesses some rock-samples from the Lower Marowyne river collected by Jhr. L. C. van Panhuys (1896). They are designated by me "P." 19 etc.

B. The following remarks refer to the maps on which the rock-findspots have been marked. I had all the archives and maps bearing upon the collections at my disposal.

On Map VI all the rock-samples have been marked that are described in this Outline, with some exceptions; first some rock-groups quantitatively of little importance (e.g. the lamprophyres, aplites, pegmatites etc.); secondly such rocks whose findspots will be understood clearly from the text (e.g. the rocks of the Roraima formation collected by our expedition, etc.); thirdly the rocks whose findspots are only known by approximation; the latter I have partly indicated with question-marks on the map. The archives bearing on some areas of very complicated topography give no sufficient data to retrace the findspots of most of the petrographical material (e.g. in the Gran creek bassin). In many regions the data are too numerous to be inserted on Map VI. Sketch-maps of these regions may be found in the text of several chapters. On map VI these regions have been outlined. Indications are given there as to the chapter where these sketch-maps are to be found. The letters "V." "B." "Y." before the numbers of the rocks indicate the collections to which the rocks belong. All place-names used in the text are to be found on Map VI.

C. Publications to which reference is made, are mentioned in notes at the foot of the pages. Moreover a list has been annexed of the publications cited, relating to "Surinam and its surroundings". The latter includes the region sometimes called "The Guiana Highlands" comprising French, Dutch, British, Venezuelan and Brazilian Guiana. This list, therefore, does not contain all the geological literature about the region, but only that which has been referred to in the text. The publications have been arranged chronologically. In the notes at the foot of the pages the reader will find the number and the name of the writer of the article mentioned in this list.

D. As often as possible the topographical names and the geographical terms have been written as in English. In the English and the Dutch literature there is no uniformity in the spelling of topographical names in the Guianas. Consequently I have indulged in some latitude in this respect.

The rivers, often mentioned in English writings, have been given English names, e.g. Courantyne (Dutch Corantyn), Curuni (Dutch Koeroeni), etc. Geographical names in Surinam, not used (or seldom so) in the English literature, have not been translated (this also applies to Suriname river in stead of Surinam river). Terms have been left untranslated, if the English translation is not usual, e.g. Tappawatra-*dam* ("dam" = "weir") etc. Neither did we translate a few Dutch geographical terms that will be understood also by English speaking people, e.g. Hendrik "top" (= "summit"). For petrographical and geological terms we consulted as much as possible the literature to find the English equivalent. In a few cases we failed, so that e.g. the term "Schalstein" we borrowed from the German.

GENERAL GEOGRAPHICAL DATA.

Situation and extent.

Surinam forms part of Guiana, a tract situated between the Orinoco and the Amazon. It is divided into Venezuelan, British, Dutch, French and Brazilian Guiana, of which the Dutch Territory, Surinam, lies between the English and the French Colonies. Surinam is bounded by the river Courantyne on the West, by the river Marowyne on the East, by the watershed of the Amazon system (the chain of the Tumuchumac mountains) on the South and by the Ocean on the North. It may be said to lie between the meridians of 54° and 58° western longitude and the parallels of 2° and 6° northern latitude.

The area covers about 160.000 km^2.[1]).

Physical features.

With the exception of those parts of the soil that have been put under culture and of open savannahs in various places, Surinam is covered by dense primeval forests. At the coast flat, fluvio-marine deposits rise gradually from the sea. The land changes gradually into a muddy seabottom. It is surrounded by mangrove-woods and in a few places by a narrow strip of sandy beach. Especially these fluvio-marine deposits, and in particular the heavy clays furnish the soil for the agriculture of our days. The fact that the land is low, below the level of springtide, renders it necessary to protect it against the sea by means of dykes. The Dutch colonists, taught by experience at home, have made dykes at the mouths of the Suriname and Commewijne rivers; the other parts of the coast are unprotected. Ranges of low sandreefs, often rich in shells, the so called "Schulpritsen", run parallel to the shore. Stretches of stagnant water between them sometimes form extensive swamps. As one goes up the country the level of the soil rises very gradually till one reaches a second zone of land, at some places practically flat, at others characterized by gentle undulations. The soil consists of sand, sandy loam and clay which are not fertile. Groups of hills here and there indicate that the crystalline subsoil comes near the surface. In this second zone the monotony of the primeval forest is broken in several places by savannahs; here the soil consists of quartz-sand and loam. The vegetation is sparse; the Mauritia palms (Mauritia flexuosa) and occasionally hard grasses are most conspicuous. These savannahs are found all over the second zone, which also shows the first traces of solid rock in the riverbeds. The eastern part of the zone at the mouth of the Marowyne river is narrow but becomes broader and broader as one approaches the Courantyne. The interior of the country in a narrower sense is

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1) This is about four times the size of Holland.

Plate 2.

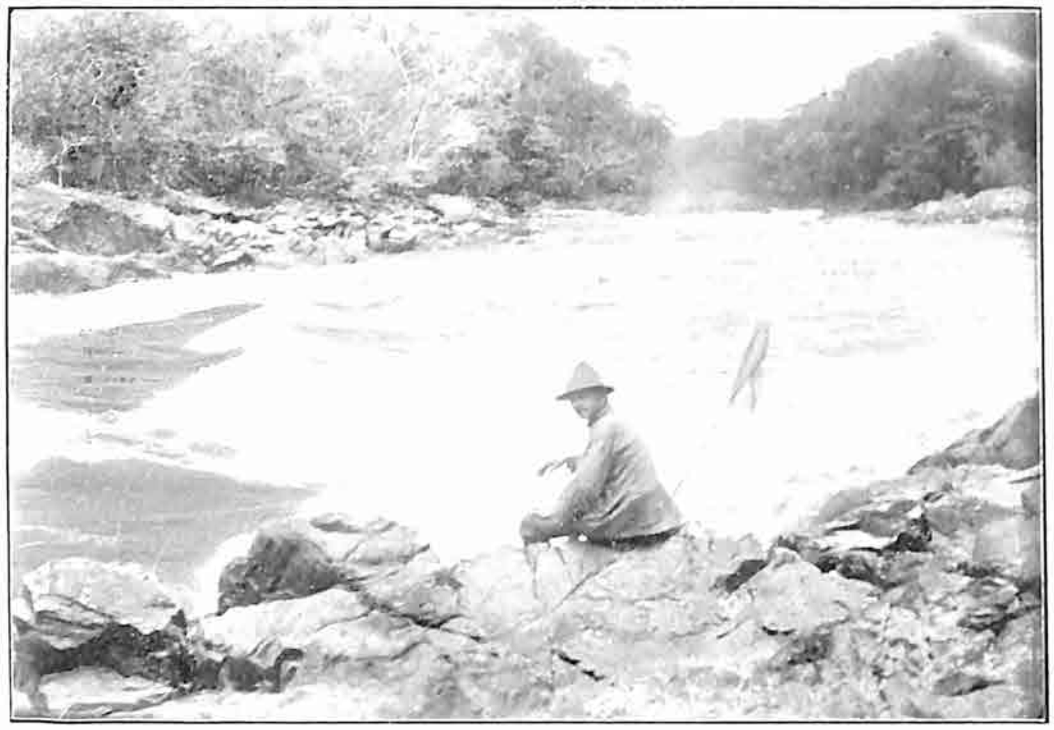


Fig. 1. Rapids below King Frederick William IV falls, Courantyne; channel at Dutch bank.

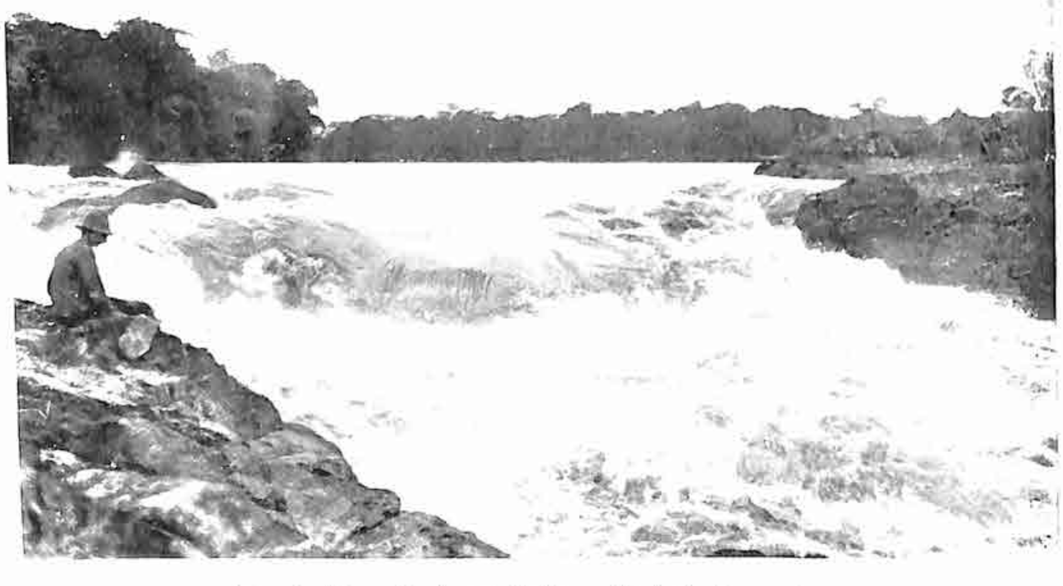


Fig. 2. King Frederick William IV falls, Courantyne; one of the falls at Dutch bank (August 1926).

occupied by hills and mountains. The change is gradual. Following the course of the rivers the flat lowland extends a long way to the South. Towards the South the hills begin more and more to form groups, spurs of low mountain-ranges stretching away in a direction NNE. between the principal rivers in the northern part of the Colony. In the centre of Surinam the highlands lie in a hilly or gently undulating country, which is elevated only a few hundred metres above the sea-level. Mountain-tops higher than 1000 metres hardly occur and the highest point of Surinam is about 1280 metres. As the hilly country is very extensive, especially along the large rivers, and as many of the groups of mountains are more or less isolated, the whole makes the impression of a very old landscape in an advanced state of erosion.

Intense disintegration leads to a thick covering of laterite, overgrown with primeval forest so that the solid rock is generally hidden from view. Fantastically shaped cupolas of rock, generally composed of granite are an exception to this general rule; in the river-beds, too, the solid rock is often visible.

In the South of the Colony a few savannahs are again found.

Topographic maps.

The topographic examination of the Colony has to a certain extent been completed, in so far as a map is available which meets the requirements of the state of affairs at the present moment.

The maps used at present, as far as they relate to the northern half of the Colony are based on the survey of J. F. A. Cateau van Rosevelt and J. F. A. E. van Lansberge, to a scale of 1 : 100.000 (1860—1879) published to a scale of 1 : 200.000. Down to 1900 very little was known of the southern half of the Colony, except the Marowyne, the Lawa and the Courantyne. In the present century several expeditions have made a triangulation-net of the principal mountain-tops, whilst the course of all rivers of any importance has been mapped and fixed in connection with the triangulation-net.

A topographic map in sixteen sheets, to a scale of 1 : 200.000, containing the whole Colony has recently been published ("Kaart van Suriname" L. A. Bakhuis and W. de Quant, sold by J. Smulders & Co. Ltd., The Hague).

For general orientation the "Overzichtskaart van Suriname" 1 : 800.000 by F. E. Spirlet, 2nd impression, 1927 can be made use of, (sold by J. Smulders & Co Ltd., The Hague).

Obsolete, but none the less useful on account of the great number of topographical names, the situation of estates etc. is the "Kaart van Suriname" 1 : 500.000 by W. L. Loth 1899 (J. H. de Bussy, Amsterdam).

Climate.

Surinam, as is to be expected, owing to its situation near the equator has a tropical climate. The average temperature throughout the year is 26° on the coast and about one degree higher in the interior. Temperatures above 36° and below 18° are rare. The average rainfall for Paramaribo is 2280 mm. Rain falls at irregular intervals. The Colony has two rainy periods: the long rainy period and the short one. There are also two periods of drought: the long dry period and the short one. As a rule the long rainy period lasts from May till the end of August and is followed by the long period of dry weather. The short rainy period lasts from December till the end of February. It would seem that far in the interior of the country the succession of these periods in less strongly marked, whilst much more rain falls. For want of data it is impossible to say whether these local deviations are caused by the mountains. What was sketched above must not be taken as a hard and fast rule; as a matter of fact there may be great differences between the seasons in different years. About once every ten years periods of great drought occur, especially when no rain falls during the short rainy season. These may be fatal to the harvest. Owing to the luxuriant vegetation there is little evaporation, so that Surinam has a moist, tropical climate.

Districts, population and settlements.

The Colony is divided into one town-district (Paramaribo) and twelve country-districts. The division is of importance only for administrative purposes.

The inhabitants belong to different races and nationalities. By far the greater part are negroes and coloured natives (98000); the others are: natives of British India (30.000), of the Dutch Indies (chiefly Javanese, 15.000), Chinese (4000), aboriginal Indians (2500) and a small number of Whites. The total population is 150.000. Among the negroes the descendants of the slaves who fled to the interior of the country, the "Bushnegroes" (abt. 17.000) take an independent place. They live till far in the interior of the country along the middlecourse and the uppercourse of the rivers, with the exception of the Courantyne. Here and there missionaries have established schools. Among the Bushnegroes are the best boatmen in the Colony.

The Javanese and the natives of British India have been brought to the Colony as estate-labourers. Many established themselves in the Colony for good and all after the termination of their contract.

The aboriginal Indians are the remnant of what was at one time a mighty tribe. They are divided into Benedenlandsche (Lowland) and Bovenlandsche (Highland) Indians, in accordance with their dwelling-places. The Lowland Indians (Arawaks, Karaibs and a few Warraus) live on the lower courses of the rivers and in the savannahs. None of these lowland tribes inhabit a well-delimited territory. They regularly come into contact with the rest of the population. The Highland Indians may be subdivided into many small tribes. They live on the Upper Courantyne or Curuni, the Upper Tapanahony and the Lawa with their tributaries and along the Brazilian frontier, in a word, in the extreme South of the Colony. They do not come into contact with the population of the low-lying lands, yet they obtain several things from them for which they barter with the Bushnegroes, who sometimes undertake long trips for this purpose. Since 1900 several expeditions have visited these Indians.

It goes without saying that in a territory inhabited by people belonging to so many different nations and tribes the number of languages spoken will also be great. Of these the English spoken by the negroes (Takki-Takki) has the widest range.

Among the settlements Paramaribo is by far the most important. This town with its surroundings is inhabited by about one third of the population. Paramaribo is also the only harbour worth mentioning. The only other government settlements worth mentioning are Nickerie (on the Nickerie river, near the mouth of the Courantyne): Coronie (on the coast between the Courantyne and Coppename rivers) and Albina (on the lower Marowyne river). Of special importance is the new settlement of the Surinam Bauxite Company at Moengo, on the Upper Cottica. The greater part of the rest of the population has settled down in the agricultural districts. With the exception of the Bushnegro-villages on the rivers, the interior is uninhabited.

Agriculture.

Agriculture is the chief means of subsistence. The centres of cultivation are the estates near Paramaribo, on the Suriname river below the town: those on the two banks of the Lower Commewijne, on the Lower Saramacca and near Nickerie. In the days when the Colony was flourishing, the areas, covered by estates were more extensive than at present. Agriculture, organized on a large scale, for purposes of export occupies itself above all things with the cultivation of coffee and sugar. Cocoa, at one time an important product, has practically disappeared through plant-disease. The cultivation of rubber, bananas and cotton for export-purposes has not been very successful upon the whole. Some coconut-plantations are found at Coronie and near Galibi on the mouth of the Marowyne. The so-called "Kleine Landbouw" (agriculture on a small scale) which supplies the local wants, is practised especially in the neighbourhood of Paramaribo and the other settlements. Agriculture on a large scale is hampered by the lack of cheap labour, which must be imported from elsewhere.

Resources from the interior.

Among the many products of the tropical forest wild rubber "Balata" (from the Bolletrie, Mimusops balata) stands first. The adventurous life in the interior of the country which "Balatableeding" offers is more attractive to the negro population than regular work at the estates. The export of valuable kinds of timber has thus far not led to any big industry.

Mining.

a. Bauxite.

At present bauxite is the most important object of the mining industry in Surinam. Bauxite of a good quality is found in the low-lands near Moengo on the Upper Cottica, on the Para river and near Rorac on the Suriname river. It is also found in the interior, among other places on the Browns mountain on the Colonial railway and in the Nassau mountains. The Surinam Bauxite Company, a subsidiary of the Aluminium Company of America, has founded a modern establishment at Moengo. The ore is crushed, washed and dried mechanically after which it is shipped off to North America. The place is conveniently situated, as sea-going vessels can sail up the very narrow but deep lowland rivers and thus reach the company's establishment. The Kalbfleisch corporation exploits the bauxite deposits in the neighbourhood of Ongelijk on the Para river on a smaller scale. This company is now considering plans to establish a bauxite industry on the Browns mountain. The annual export of bauxite in the last three years was 300.000 tons.

b. Goldmining.

At one time goldmining was a great success. The maximum annual yield between 1905 and 1910 was from 1100—1200 kilograms; at present however, it is practically of no importance. The yield decreases continually and the quantities produced in the last five years were successively 309, 259, 240, 171, 111 (1929) kilograms. The metal is found in the interior as alluvial gold. Formerly great number of companies worked with varying success; at present there are only subtenants ("Pork-knockers") and small concessionaries. In view of local circumstances simple appliances such as sluices and longtoms have proved to be the most successful ones, larger plants (e.g. dredgers) appeared to be no good.

c. Other mineral deposits that have not yet been exploited.

Lateritic iron-ore deposits are found in many places all over the Colony. Cinnabar is found in the shape of boulders in brooks or valleys near the Nassau mountains and the upper course of the Tempati creek.

Alluvial deposits of kaolin are found in several places: but Moengo is the only place that has exported some.

In 1928 traces of oil were found near Nickerie in the extreme North-West of the Colony. These traces were found rather near the surface, in the latest deposits. As a result of this discovery of oil, borings have been made near Nickerie. The Surinam Oil Company had the exclusive exploration rights in by far the greater part of the Colony. It is generally not thought very probable that remunerative quantities of oil will be found in Surinam.

d. Mining act.

The landowner has a right to the minerals on and under the surface of that part of the soil which is his property (Section 626 Sur. B.W.). The greater part of the soil, however, under the name of „domain" is in the possession of the Government so that in reality there is but little conformity between the law in Surinam and the Anglo-Saxon mining-law.

According to the "Goudverordening" (G.B. 1908, 80) only Dutchmen, inhabitants of Holland or Surinam, and limited liability companies established in either of these two countries can obtain a licence to prospect for minerals and they only can obtain concessions. Licensees have first claim when concessions are granted. Such concessions can be obtained for a maximum period of forty years; the size of the area for which a concession is granted is no less than 200 ha. A fixed tax of 10 cents per ha. for each of the first two years, 25 for each of the next two, and 50 cents for the following years must be paid by those to whom a concession has been granted. Besides this,

Plate 3.

Fig. [illegible]. Exposure of biotite granite, Upper Suriname river, near Ferodaki falls.

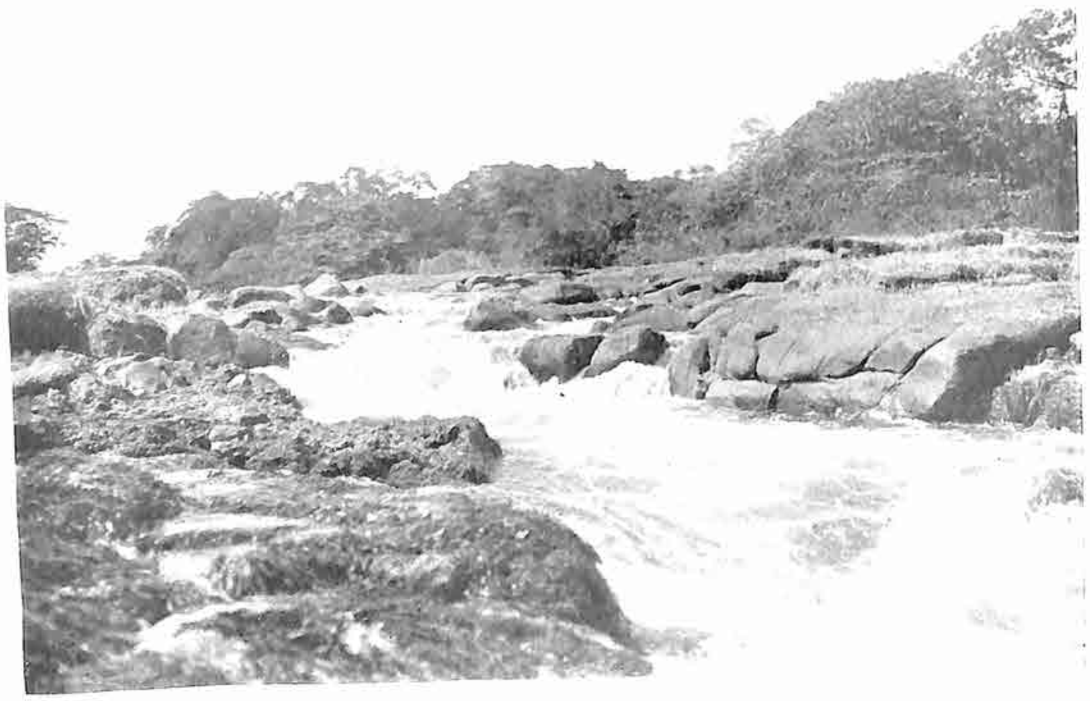


Fig. [illegible]. Rapids over biotite granite, Louis dam, Gran-rio.

another tax, based on the yield, is levied, the amount of which is fixed for each concession separately.

A tax of 7 cents is levied on every gram of gold found. The "Goudverordening" does not apply to all objects. Some (such as oil, bauxite) may be explored and exploited only when a special licence has been granted.

Means of communication.

Roads are found only in that part of the coastal area which lies in the vicinity of Paramaribo. The communication between the settlements on the various rivermouths is kept up by Government-steamers. The lower courses of the rivers are navigable for shallow-draught vessels.

From Paramaribo in a southerly direction to a point 173 km. distant from it, runs a railway which touches the Saramacca (km. 79), crosses the Suriname river (near Kabelstation km. 133) and then runs on some way along the Sara creek, a tributary of the Suriname river. This railway, completed in 1912 has not opened up the interior of the Colony. For the rest the rivers are the only means of communication in the interior. They are navigable for motorboats to a point where rocks obstruct the passage. Beyond such spots open boats are made use of, which are either rowed or paddled. Among these the so-called "korjalen", boats made of one treetrunk take a prominent place. Rapids and waterfalls are found in many places whilst especially the Suriname and the Courantyne rivers are covered over a considerable distance with a regular archipelago.

Although there are good boathands among the negro population of the lowlands, especially in Nickerie, it is above all others the Bushnegroes who show great skill on the rivers. Hence those who wish to travel in the interior cannot do without the help of these people, except on the Courantyne. When one leaves the river one has to cut one's way through the dense primeval forest. Only in the extreme South have some expeditions been able to travel along the existing trails made by Indians.

Progress is slow, whether one travels by land or on the rivers. Rapids and waterfalls are obstacles to navigation, which is broken off by many portages. In the rainy season the strong current may make navigation to the upper courses of the rivers impossible, whilst on the other hand the water may be extremely low in the dry season. When new paths must be cut, it is generally impossible to travel more than 4 km. a day.

Hints to expeditions.

When one travels in the interior, the help of the natives of the colony, chiefly blacks, must be called in. Their labour in the gold- and balata-industries has taught them all about life in the forest. They are engaged day by day and their wages are about *f* 2.50. They buy their own food — for which they pay about 50 cents a day — from the supplies of the expedition. Foremen and cooks get extra wages. It is customary to pay a rather considerable part of the wages in advance, but the final settlement does not take place until the expedition has returned to the town. All contracts are signed at the police-station. The natives take part in all kinds of work that have to be done during the expedition, except in river-transport which is generally the task of Bushnegroes. Every carrier is expected to convey about 30 kg. a day over a distance of 8 km. It is advantageous to both parties to reward the carriers by the payment of a premium. The fact is that many carriers can convey heavier burdens when once they are accustomed to the work and prefer to carry overweight, for every kg. of which they receive a reward. The more rapid advance serves as a compensation for the money spent on such premiums. Bushnegroes are engaged only for river-transport. They are no good either as carriers or as cutters. Besides a Bushnegro will hardly ever be found prepared to enter the primeval forest for a considerable length of time. An agreement is made with the Bushnegroes to convey the expedition the whole way at a fixed price per barrel (about 100 kg.) or per boatload. This price includes the hire of their "korjaal", with two men, one at the bow and one at the helm. The Bushnegroes get their food gratis. The cargo may be put under their care without there being any necessity to accompany them. People wishing to travel up the Marowyne can engage Bushnegroes through the government official for the district at Albina. On the Suriname, Saramacca and Coppename rivers no assistance is available until the first villages up the river have been reached. It is easy enough to get the required help for smaller trips; for larger expeditions one has to apply to the chiefs, after which the matter is amply discussed at a meeting (kroetoe). When one wants to travel up the rivers a very long way, it is necessary to find fresh boathands and boats halfway. Such things and the fact that the Bushnegroes are not accustomed to any kind of regime, may cause much delay and all kinds of troubles. When once the expedition has started it is advisable not to travel in too large groups, for the Bushnegroes are accustomed to assist each other when rapids or falls are reached and no boat continues its way until all have passed an obstacle. Hence the greater the flotilla, the more slowly the expedition advances. On the Courantyne boathands from Nickerie must be engaged.

The expedition must take its food-supply along with it. It consist chiefly of rice, flour, dried beans and biscuits; also salt meat, fish (bakkeljauw), vegetables and sugar; it is necessary also to take a ration of tobacco and rum. Game and fish can be caught only in the uninhabited districts. In the parts where the Bushnegroes dwell, game is shy and there is hardly any fish. Though there are more than a thousand kinds of trees, it must not be thought that fresh fruit can be had all the time.

The food supplies are very generally packed in oil-tins, which are soldered watertight. As long as one is in the neighbourhood of settlements it is advisable to boil water. In other places the water of rivers and brooks can be taken without any danger.

The outfit must be as simple as possible. It is necessary to have very strong shoes, because they wear terribly. Hammocks with a blanket to protect the sleeper against the cold mornings, are indispensable. A campbed is a thing unknown in the colony. Much care must be bestowed upon mosquito-netting to protect the members of the expedition against malaria-fever. The best thing to do is to take a netting with only three larger openings: two through which the cords of the hammock pass and a third in the shape of a tube, to get into the hammock and out of it, and which closes when it is not used. The roof of the camp is formed by waterproof oil-cloth or tarpaulins the size of a hammock, which are stretched between two trees. Boathands and carriers make their own palmleaf shelter every evening in a short time. Folding-chairs and tables can be easily taken along as long as one is on the river. It is advisable not to take them when the expedition travels by land; the heavy tarpaulins may in that case be replaced by a palmleaf shelter.

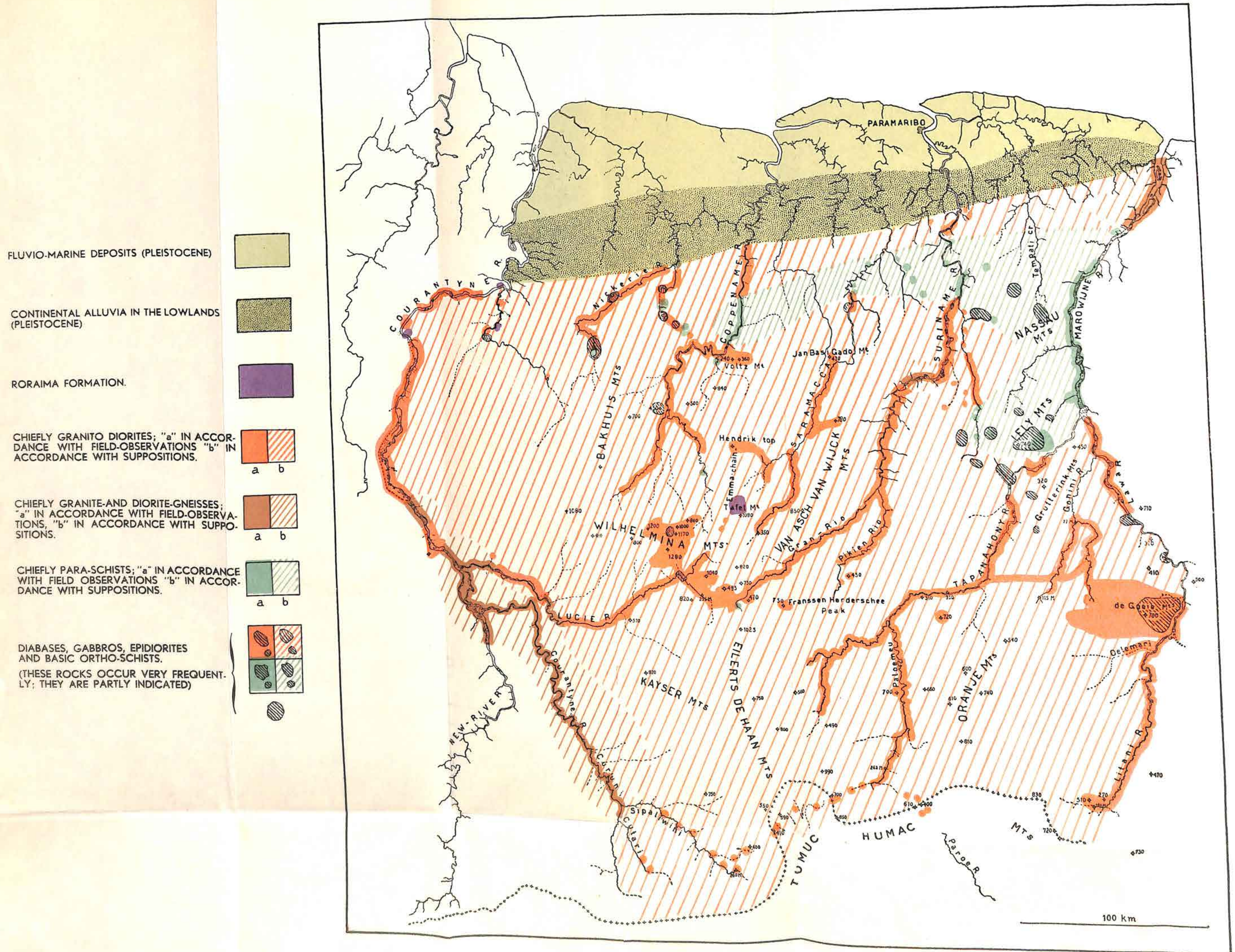
The packing of books and instruments requires special care. Leather bags or trunks are no use, because they are destroyed by the damp. It is better to take iron boxes. All things that are affected by damp, such as aneroid barometers, chronometers and above all the photographic outfit must be kept in lime boxes.

All things that have not been made of metal attract ants and termites ("houtluizen" in Dutch). They must never be left unguarded in camp. Clothes hung up thoughtlessly may even be utterly destroyed in one night.

The medical outfit must not be without a quantity of quinine. The necessity to take precautionary measures against malaria fever in the interior cannot be insisted upon too strongly because in Surinam it is of a virulent nature. All districts visited by prospectors and bleeders and especially the districts inhabited by Bushnegroes are infected with malaria fever. But one must be on one's guard in the so-called uninhabited parts as well. Practically all natives are infected so that one is everywhere surrounded by the danger of being infected too. In the parts inhabited by the Bushnegroes a quinine prophylactic of one gram a day should be taken; in the uninhabited regions the same quantity every fourth day has proved to be adequate. Every white man who fails to do this risks his life needlessly. Beriberi is also a dreaded illness for those who are staying a long time in the bush. The negroes set a high value upon several medicines: Sloan's liniment, pain-killers, salicyl, and so on. A physician should accompany expeditions of long duration, to subdue the neglected illnesses to which the natives are liable, and which manifest themselves when heavy work is done. Among the inhabitants of the Colony skillful physicians, well versed in the care of tropical diseases are found.

On Sunday no work is done, except when one travels on the river with Bushnegroes. There is no danger of large wild animals in the primeval forests, however, travellers should be on their guard against venomous snakes; fortunately the dangerous kinds are not often found. Jaguars are sometimes very audacious. Upon the whole it is advisable to keep a light burning in the night to keep unwelcome visitors at a distance.

MAP I.



GEOLOGICAL SKETCH-MAP OF SURINAM.

A SHORT OUTLINE OF THE GEOLOGY AND PETROLOGY OF SURINAM.

The subsoil of Surinam is formed by a crystalline basal complex. This complex belongs to the pre-Paleozoic core of South America, largely exposed in the Guianas and along the Ocean, South of the Amazon basin.

The study of this basal complex is practically identical with that of the geology of Surinam. Besides this basal complex we know three later formations that occur much more infrequently:

1° the basal complex is traversed by basic igneous rocks of later age; 2° in the centre of the Colony we know a sandstone formation which has been little disturbed tectonically. It overlies the basal complex almost horizontally; 3° the coastal area of Surinam is characterized by recent deposits of great thickness. Taking these components as our starting point we shall discuss the geology of Surinam, beginning with the basal complex.

In the basal complex we meet with a great variety of rocks. Two formations may be differentiated. First a formation of schists of prevailing sedimentary origin, para-schists. Secondly igneous rocks. This differentiation is not only a petrographical but also a geological one. Most of the schists, namely, may be assumed to be older than the igneous rocks.

The igneous rocks belong exclusively to the calc alkali series. Granites and quartz mica diorites predominate. Granites are represented by biotite granites, biotite hornblende granites, and to a less degree by bi-mica granites, hornblende granites, aplitic granites, and granite-aplites. The first two types may be porphyritic, with coarse microcline phenocrysts. The granites vary considerably in the composition of the plagioclase: the first two granite types we mentioned very often contain oligoclase-andesine or oligoclase. It strikes us that as a rule the granites contain microcline and microperthite. Orthoclase has only been found locally (Nickerie basin).

Among the diorites acid, quartz-bearing members prevail by far. Quartz mica diorites and quartz mica hornblende diorites are represented in the largest number; besides these we also know quartz hornblende diorites and hornblende diorites. Among the quartz mica diorites an almost aplitic type poor in biotite is frequent.

The granites and diorites are petrographically united by transitions. Through decrease of potash feldspar the granites pass into quartz diorites, with intermediate types which might be called granodiorites. These intermediate forms are known between granites and diorites of different basicity, e.g. between biotite granite and quartz mica diorite, but just as well between granite rich in hornblende and quartz hornblende diorite, etc.

Locally the variation is still more marked. In the De Goeje mountains, for instance, we have gabbros of different mineral combinations: troktolites, olivine gabbros, norites, hornblende gabbros and normal gabbros. The latter gabbro type passes into quartz diorites with the intermediate form of quartz gabbros. They contain orthorhombic and monoclinic pyroxene and hornblende in varying combination. In their turn these diorites pass into quartz mica diorites and granites. Something like this we see in the Nickerie basin. But there the basic members of the transition-series do not contain olivine.

Besides these mineralogical differences the Surinam igneous rocks show also considerable differences in structure and texture [1]). Ortho-gneisses are frequent. These rocks are characterized by the lack of crystallization-sequence of the colourless main minerals. We know ortho-gneisses with parallel texture, and likewise with granitic texture. So there is no connection between the lack of crystallization-sequence and the texture. In many rocks the gneiss-characteristics can only be established microscopically, which may lead to confusion in the field. Structurally all intermediate forms to rocks with normal crystallization-sequence, are present. The intermediate forms we know are gneissic granites, gneissic diorites, etc.

It is an important fact that mineralogically the ortho-gneisses are the equivalent of the above-named igneous rocks, even in details. Most numerous are granite-gneisses and diorite-gneisses namely quartz mica and quartz mica hornblende gneisses. The equivalent of the pyroxene-bearing quartz diorites we find in the pyroxene gneisses (Nickerie region). Pyroxene gneisses that are the equivalent of gabbros are rare.

The Surinam igneous rocks generally have an even texture. Banded textures, variation of zones or lenses of various composition, and streaky texture are rare. Banded texture of some significance is known locally at the Surinam river. Parallel texture occurs rather frequently.

The gneiss-characteristics of most Surinam ortho-gneisses are primary. This conception clashes with what is often assumed regarding ortho-gneisses elsewhere. The arguments for our view may be found in the chapter in question. The term "primary nature" does not apply to those ortho-gneisses, whose gneiss-characteristics were caused by cataclasm. Signs of pressure, namely, are very frequent in the Surinam igneous rocks. This phenomenon may become so intense that the primary structure and texture of the rocks is destroyed, and the rocks adopt a parallel texture, in which the minerals are partly rolled out, and partly greatly bent, or pulverized. Relics of primary structure show that normal igneous rocks as well as ortho-gneisses (with primary gneiss-characteristics) may have been the original material. Many granite- and diorite-gneisses have been formed in this way, also gneisses which are the equivalent of gabbros. The same applies to eye-gneisses.

We have one more group of ortho-gneisses whose ortho-gneiss characteristics are of secondary nature, viz. hornblende gneisses, garnet hornblende gneisses, etc. which are the re-crystallized equivalents of basic igneous rocks. Geologically speaking, however, these gneisses do not seem to have anything to do with the igneous rocks alluded to before. They are probably much older. Lower down we shall revert to them.

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1) By "structure" we here mean the form and the size of the mineral grains. "Texture" refers to their stereometric grouping.

About the geology and the consanguinity of the Surinam igneous rocks we can impart the following. Chemically they furnish all together a normal differentiation-diagram of the calc alkali series. Only part of the basic rocks seem to show a distinct local character in different directions. The ortho-gneisses behave entirely like the normal igneous rocks.

The general distribution of the mineral orthite in the igneous rocks and gneisses throughout the Colony, and to a less degree also the occurrence of monazite, point to the fact that cerium, and possibly also other rare earths have been constant accessory components of the magmas. These facts speak for the differentiation of rocks coming from only one original magma.

Of most of the rocks-types we enumerated, it is known that they are united by intermediate forms not only petrographically but also in the field. In many areas there are intermediate series of granites to diorites rich in quartz and locally to less acid diorites. These rocks are, therefore, different petrographical facies of the same magma. The composition of the rocks varies very irregularly in the field. Several extensive areas are occupied uniformly by biotite and biotite hornblende granites, in part porphyritic. In other areas, however, frequent alternations of acid and less acid rocks are to be seen, often within some tens of metres and all united by intermediate forms. In the areas of uniform composition granitic texture prevails. In others frequent alternation of distinct and indistinct parallel texture may be observed. This variation in texture is especially developed in regions where variability in mineralogical composition is to be noted, and may even exist in one and the same rock-group. A third complication is formed by the ortho-gneisses and gneissic rocks. They, too, may be very frequent in the areas of varying mineralogical composition. Within a few tens of metres the gneisses may pass into normal igneous rocks. However, we also know areas where ortho-gneisses predominate. (Upper Courantyne, very likely also Lower Marowyne). From the above the important fact may be inferred that *the ortho-gneisses are of the same age as the granitodiorites.* All these facts together render it highly probable that vast regions in the Colony are part of enormous "massifs", whose dimensions equal those of the largest batholiths known elsewhere. We believe that all the granitodiorites of the centre and the South-east of the Colony belong to one and the same coherent massif.

We know some local complications. In the Nickerie region the basic and the acid rocks appear to break through each other.

Dykes of small dimensions are frequent. They are granite-, and diorite-aplites, and pegmatites. There are also pegmatites rich in quartz, muscovite and tourmaline. They cut the granitodiorites, and ortho-gneisses. The lamprophyric dyke-rocks, represented by kersantites, odinites and malchites, are interesting from a petrographical point of view. In fine we want to make mention of local dykes of dioritic composition, which also cut the granitodiorites. The greater part or the total number of these dyke-rocks is to be considered as magma-differentiations of the granitodiorites in an acid or basic direction.

It is still an open question whether the vast regions of granitodioritic composition are of the same age. There are no indications pointing to differences in this respect. In this connection we must contravene the old hypothesis that the granites which build up the mountains in Surinam, are later than the rest of the basal complex. These granites are of the same composition as those that are exposed in the rivers. They are more resistant groups carved by erosion from a formation approximately of the same composition. It is assumed that all these rocks are of pre-Paleozoic age. The basal complex namely extends into the adjoining Amazon basin and is covered there by Paleozoic sediments beginning with those of the Silurian system.

Intense pressure may have formed secondary gneisses, as alluded to heretofore. Cataclasm has locally formed mylonites. In some localities in Surinam there were found the so-called pseudo-tachylytes (ultramylonites), those remarkable rocks, which have been recognized among other places in South Africa and on the Outer Hebrides as new formations because of intense pressure and mylonisation. Finally we mention quartz porphyries among the igneous rocks of the basal complex. They have been met with in a number of localities in small quantities. They are sometimes accompanied by porphyroids. We are completely in the dark about their geology. Several highly metamorphic porphyroids may as well be called schists. It is doubtful whether the latter are geologically allied to the quartz porphyries or must be referred to the schist formation.

We now pass on to discuss the crystalline schists of the basal complex. A glance at the sketchmap (Map I) shows us that quantitatively they are greatly in the minority with respect to the granitodiorites. In the schist region hatched green extensive schist complexes are present along the Marowyne, Suriname and the Coppename rivers. This hatched field illustrates *where schists are frequent.* However, also granitodiorites are found in it.

Quantitatively para-schists appear to be prevalent. The composition of the schists and their degree of recrystallization is variable. The para-schists are represented by strongly metamorphic sillimanite, cordierite, staurolite, garnet and mica-bearing gneisses and schists. Another schist series in less metamorphic. Often it still shows remnants of the primary, clastic structures. We shall specify them by the term graywacke formation. This formation comprises mica quartzites, crystalline graywackes, graywacke-quartzites, metamorphic conglomerates and conglomerate-schists, so that it is a true clastic formation. The mineral combination of the quartz, chlorite, sericite, albite, or calcite-bearing schists is very variable. These minerals seldom exhibit remnants of clastic nature and apparently had fine, detritic matter for original material. A number of these schists appear to be metamorphic basic tuffs. Basic tuffs with distinct relics of primary structure (Schalsteine) are not frequent. Phyllites and clay-slates are often met with; some are chloritoid-bearing. Quartzites of sedimentary origin show a great variety of accessoria. Of petrographical interest are kyanite, staurolite or chloritoid-bearing types. In the foregoing we have enumerated the principal para-schists. From this specification it follows that the metamorphic schists are principally of terrigenous-detritic origin. Crystalline limestones and in general such rocks as are derived from "chemical sediments", we do not know in Surinam.

The ortho-schists appear to be principally the equivalent of basic igneous rocks (we have already made mention of some porphyroid-schists). They are amphibolites and hornblende gneisses, among which garnet, pyroxene and epidote-bearing types are frequent. Some of them come near to eclogites. Furthermore we have quartz hornblende schists, hornblende schists and hornblendites. The epidiorites which are widely distributed in the Colony, appear to be derived for the greater part from the later diabase- and gabbro intrusions to be discussed later on.

The geology of the para-, and ortho-schists we may discuss separately. It appears that the schists of the graywacke formation form two extensive complexes: on the Marowyne and on the Coppename river. A third important schist complex, on the Suriname river comprises chiefly quartz, chlorite, sericite, albite and calcite-bearing schists, phyllites and quartzites. The schist association of the latter region is also known in a number of other localities, where we cannot judge of the extent of the formation. The para-schists generally dip steeply. We know that in some regions they show surprisingly constant strike along great distances. The assumption is justified that we have to do with systems of strongly compressed folds.

We can only surmise the mutual connection between these schist complexes. It is remarkable that the graywacke formation and the quartz-, chlorite-, sericite-, albite schists etc., where they occur together, have the same chief tectonic direction. Moreover the members of the one schist group may occur in the other and the reverse. It is probable that these schist groups have belonged to one and the same sedimentation complex.

Sillimanite-, cordierite-, staurolite-, garnet- and mica schists we know in a number of places in the Colony, they cover, however, smaller areas than the schists discussed above. The geological relation between these schists and the preceding ones is not established yet. The intensely metamorphic schists may, from a petrographical point of view, very well be the equivalent of the less metamorphic schists.

Let it be observed in passing that the signs of cataclasm appearing in the granitodiorites, also occur in the coarsely crystalline para-schists.

The ortho-gneisses of basic composition belong partly to massifs in the South-east of the Colony. The massifs are formed by amphibolites, and hornblende gneisses, and apparently were originally massifs of gabbros or diabases.

As was said before, it has been established for part of the strongly metamorphic schists that they are older than the granitodiorites (consequently also older than most of the ortho-gneisses). The granitodiorites break through these schists. Very likely they already found the latter in an intensely metamorphic state. The same sequence of age has been established for the crystalline graywackes. This formation owes its recrystallization chiefly to regional metamorphism. We are less certain of the respective ages of the quartz-, chlorite-, sericite-, albite schists etc. and the granitodiorites. A number of contact-metamorphic schists support the probability that the same age relation also holds good here; corroboration by observations in the field is, however, greatly desirable. Concerning the basic ortho-gneiss massifs in the South-east of the Colony it may be assumed that they are older than the granitodiorites and gabbros. Whether these hornblende gneisses represent the igneous part of the schist formation is not known.

For briefness'sake we may speak of the *"schist formation"* in contradistinction to the igneous part of the basal complex. The schist formation must for the greater part or entirely be of pre-Paleozoic age considering what has been said above about the age of the granitodiorites. Fossils have never been found in the schists. In some of them, however, we find a rather large percentage of graphite.

Diabases and gabbros, and epidiorites derived from them, are of later age than the basal complex. These rocks have a great distribution in the Colony, although they do not cover vast regions. In a large number of localities the granitodiorites, the ortho-gneisses and also the schists are intersected by dykes. We also know some massifs. It is doubtful whether these rocks have also extended over the basal complex as sheets. In this writing the rocks are arranged under the name of "intrusive diabases, gabbros and epidiorites". Microscopically the dykes show diabase structure, while gabbro structure is developed in some broad dykes and in a few massifs. It is common knowledge that these differences in structure are of little consequence, so that little value is attached here to the difference between diabase and gabbro.

Quartz diabases appear to be very common. They contain granophyre of quartz and potash feldspar; the latter may show microcline structure. Through diminution of the granophyre percentage the rocks pass into normal diabases and gabbros. Olivine is frequent as an accessory component. Olivine diabases are rare, though. It is striking that olivine and free quartz may occur in the same rock. We have a few hypersthene diabases. Orthorhombic pyroxene occurs more frequently in the gabbros. The gabbros may also contain granophyre.

In many of these rocks pyroxene has been superseded by uralite (epidiorites). In the field it has been ascertained that geologically these rocks behave like the unchanged types. In other rocks the changes reach much farther. It is assumed that the metamorphism of the Surinam epidiorites cannot result from stress.

It is still an open question whether all diabases, gabbros and epidiorites belong to one single intrusion period. Contacts that might give an answer to this question are unknown in Surinam. In adjoining states (British Guiana and the State of Para in Brazil) we know diabases of Paleozoic and possibly also of Mesozoic age. With regard to a number of intensely metamorphic epidiorites, inter alia epidote hornblende schists it is doubtful whether they are geologically allied to the instrusive diabases and gabbros; they might just as well belong to the older schist formation.

We want to state emphatically that (older) gabbros, belonging to the basal complex should be distinguished from later gabbros and diabases. The former are petrographically related to the granitodiorites: they show local charateristics and no free potash feldspar, in contradistinction to those of the diabase-gabbro group.

Additionally we may observe that the diabase-gabbros show few signs of cataclasm, which on the contrary are frequent in the basal complex.

We are bound to mention for the sake of completeness that we know some porphyrites (or andesites) from Surinam. Their relation to the intrusive diabases and to the basal complex we cannot establish.

The Roraima formation is superposed unconformably on the basal complex as a nearly horizontal cover. This formation consists of sandstones, conglomerates, and some insignificant porphyry tuffs. The thickness was locally determined at 650 m. at least. We know the formation in its typical shape only locally in the centre of the Colony. There it forms a table mountain, surrounded by an escarpment and a talus of boulders. The highest top is 1080 m. The foot is (on the S. West side) about 400 m. above sea-level. This table mountain occupies about 70 km^2. In the gently undulating hill-country this formation round the mountain is exposed over a distance of many kilometres, so that the extent of the sandstone base of the mountain is considerably larger. This mountain was discovered by our expedition. In the extreme West of the Colony (near the mouth of the Kabalebo river) some sandstone exposures are known to exist in the rivers. Following the example of Brown and Martin they are classed with the Roraima formation. In my opinion this hypothesis requires further corroboration.

The sandstones and quartzites of the table mountain microscopically show much rounded grains of quartz, and also of plagioclase and microcline mostly with cementing of crystalline quartz, so that they come near to quartzites. The colour of the sandstones is brick-red, pale red and sometimes yellowish. Cross-bedding is fairly common and also ripple marks were found. The finely grained sandstones pass into types of a coarser grain and into conglomerates. The latter cover the top of the plateau. Of most frequent occurrence is a variegated conglomerate type rich in waterworn quartzite boulders, white quartzes, fragments of slates and jasper. Boulders of igneous rocks are rare.

The lithological composition of the formation is like that of the extensive Roraima formation in British Guiana. Intrusive sheets of diabases, however, are not known from Surinam. Neither in Surinam, nor elsewhere in the formation have fossils been found. The age is not known.

The latest deposits overlie the basal complex. They appear to be for the greater part of Pleistocene and Holocene age. They build up the coastal plain. This plain is narrowest in the East (along the Marowyne river), and broadest in the West (along the Courantyne river). In the West the first rock exposures appear at more than 100 km., in the East in the Marowyne at 30 km. from the Ocean. In the other rivers the first exposures are lying in an almost straight line connecting these two points (see Map I). The latest deposits in the interior are of comparatively inconsiderable thickness, whereas they attain to a great thickness in the coastal area (at Paramaribo at least 180 m, near the mouth of the Courantyne at least 300 m). However, nothing points to the fact that the deepest parts are of Tertiary age.

The latest deposits comprise fluvio-marine and continental deposits and laterites. The fluvio-marine deposits are found in a broad zone along the Ocean. The name fluvio-marine has been selected, because these sediments have been deposited in the sea, and their material has been largely influenced by the rivers. They are heavy clays, and sands partly mixed with shells. The latter also partake in the building up of the sand-, and shell-reefs, which run parallel to the coast (called "Schulp-ritsen" in Surinam). The reefs were built up by the surf and are now to be seen streching inland up to a distance of some tens of kilometres. The mollusca are the same as those which now live near the coast. The fluvio-marine deposits overlie continental alluvia. Their depth reaches to some tens of metres: in the Courantyne-basin to about 100 m. The material appears to be largely of local origin and not chiefly supplied by the equatorial current after having originally been carried out to sea by the Amazon river (as was assumed in former times). The following scheme of development of the coastland is adopted in this writing:

1) Transgression of the sea over continental alluvia to the boundary of the fluvio-marine deposits. The cause of the transgression is left undecided.
2) Regression of the sea and increase of land, during which a slight uplift of the coastal area probably took place (judging from the present high position of the reefs). The regression possibly extended farther than the present coast-line.
3) Cessation of the formation of bays [1]) and of increase of land; some loss of land in the present time.

The continental alluvia adjoin the fluvio-marine deposits more inland. They cover a zone of gently undulating country and extend into the broad river valleys and plains in the interior. In this zone many savannahs are to be found. They are less frequent in the interior. The continental alluvia are built up of clays, partly very rich in kaolin, sands and gravels and sometimes also of vegetable matter. In some places we find cemented sands and gravels, which because of their hardness simulate older deposits.

The continental sands are little worn and are often coarse, in contradistinction to the sub-equigranular and well rounded sands, which are so frequent in the fluvio-marine deposits. The accessory components, the heavy minerals, in both groups of sediments show differences indicative of the origin of the material. Vertical profiles through the continental alluvia show frequent alternation of the components named. The continental alluvia are partly of local origin, and partly carried a long way by the rivers.

The profiles of the thick continental deposits underlying the fluviomarine for all we know do not show any essential differences in facies as compared with the deposits found nowadays in the interior.

The laterites overlie the hills and the mountainous country, unless they are found in a secondary locality. Besides real laterites motley weathering soils are widely distributed. These soils are probably more silicic and do not contain free hydrated aluminium oxide, consequently they are not laterites sensu stricto.

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[1]) "Haffs" in German.

Plate 4.

Fig. 1. Voltz mountain (240 m.), seen from the East. Monadnock of porphyritic biotite granite. Bare granite exposures in the foreground.

Fig. 2. Rock-plate (of aplitic granite) interrupting the primeval forest, Wilhelmina mountains. Vegetation of "Iengi-sopo" (Fourcroya) and Orchids in the foreground.

They are the weathering soils known elsewhere in the tropics by the name of "Braunerden", "Rotlehm", etc.

We are better acquainted with the lateritic iron-ores and bauxites: the products of a far advanced state of lateritic weathering. The bauxites are in part oolitic. They pass into ferrous bauxites, and these again into lateritic iron ores. The bauxites cover flat-topped hills in the lowland, or cover flat-topped mountains in the interior. The bauxite profile is the same as that found elsewhere in the tropics, lying on kaolin. What the bedrock is from which the bauxites have been derived, is not known for certain. An investigation into the accessory components of the bauxites yields unexpected results. Staurolite namely occurs frequently in part of the bauxites, so that incidentally para-schists may have contributed to the original material of the bauxites.

The lateritic iron ores ("Kakkerlakiston" called in Surinam) are slaggy, compact or show oolitic structure. Lateritic iron-ores cover hills in the interior, their dimensions are often enormous, not only horizontally but also vertically. A number of observations point to the fact that in all probability these ores have been derived from basic or metamorphic basic, igneous rocks.

The formation of these enormous masses of laterite, which is still in progress nowadays, dates perhaps farther back than the Diluvial period. However there is no certainty whatever about this. The latest deposits overlie the foot of the bauxite hills in the lowland.

Now that all the formations have been discussed we have still to impart something about their influence upon the geomorphology.

As stated before, it is the granites that build up the mountains. The latter consist of groups of mountains and mountain-ridges showing a very irregular relief. Bare granite faces are often visible at the tops. Granite cupolas, typical monadnocks are frequent. They occur among the mountains but are also seen in the lowland (Voltz mountain etc. Pl. 4 fig. 1). In some places we know mountains that consist of gabbros and their allied rocks. We have already mentioned that the Roraima formation yields quite another type. Granites and acid diorites also partake in the upbuilding of the hilly country. This also holds good for schists of various composition, even for phyllites. The diabases form elongated ridges and cupolas.

The mountainous country has the character of a very old landscape. The mountain groups are separated by extensive regions of the hilly country and strips of slightly undulating territory along the rivers. The base of the mountainous country lies in the interior only some hundreds of metres above the sea-level. The highest point of Surinam (in the centre of the Colony), only attains 1280 m. In the North the mountain system gradually slopes down into the lowlands.

Before concluding this short outline we are bound to say something about the probability of the distribution of the formations as marked on Map I. Our data are principally derived from the exposures in the rivers. About half the stretches along the rivers have been explored by geologists. For the rest the geology has been marked on the basis of rock samples collected and handed in by non-geologists. The findspots of these samples are known however. The fields in the interior indicated by full signature, have been examined more or less in detail. Findspots bearing on loose samples and on fields of scanty distribution are marked by dots and patches on the map. Of the very numerous find-spots of the intrusive diabases and gabbros we have only been able to mark a few on the map, in connection with the scale.

The distribution of the rocks along the rivers, which was ascertained, together with the fact that geomorphology renders it highly probable that the mountains are of granitic composition, justifies the supposition that the subsoil of the Colony is for by far the greater part composed of acid igneous rocks.

GEOMORPHOLOGICAL DATA. RELATION BETWEEN THE FORMS OF THE LANDSCAPE AND THE GEOLOGICAL STRUCTURE.

Upon the whole, in the Surinam landscape there are no striking contrasts between plateaus, lowland and high mountain ranges; on the contrary, the lowland gradually passes into hilly country, which, in its turn passes into mountains, whilst low and practically flat tracks of land are found even far into the interior. The following four elements are characteristic of the landscape: mountain-ranges and mountains, hilly country, broad river valleys and plains. We shall discuss them in this order and at the same time examine in how far it may be possible to indicate any connection between their presence and the geological composition of the subsoil.

The shapes of mountains. It may be considered an established fact, that the cores of the great majority of Surinam mountain-ranges consist of granite. Three principal types of mountainshapes may be distinguished. First mountain tops, from which ridges descend in various directions. This type is very generally found (Fig. 1). The ridges are characterized by an irregular course; they may be split up into smaller ridges and sometimes end in isolated foothills. The shape of the top is sometimes rounded off, sometimes obtusely conical. Bare granite faces are often visible at the top; for the rest the whole is covered with laterites. The sides of the ridges, especially, have steep slopes. The foothills are small and may be situated quite near each other so that narrow valleys with steep walls lie between them. Such foothills are found especially where the group of mountains lies in an undulating part of the country. If, however, the mountain group is more or less isolated, the ridges descend gradually into the plain. When once one has climbed the foothills, the mountain top can be easily reached by following one

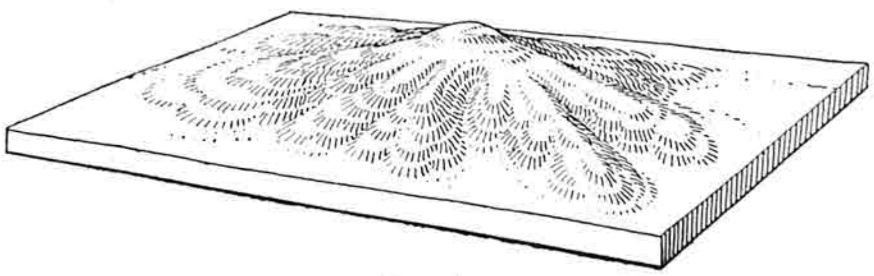

Fig. 1.

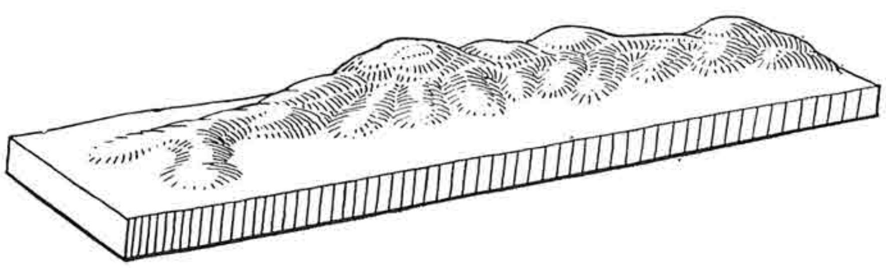

Fig. 2.

of the minor-ridges. Descriptions of suchlike ascents may be found in the reports of almost all expeditions in search of triangulation-points.

The second type is characterized by a main ridge, which often extends a long way. The crest of this ridge is characterized by undulations and often shows some cupolas with bare granite faces (Fig. 2). Quite near the crest the sides are steep, but they get flatter and flatter as they slope downwards. The third type is formed by bare granite-cupolas, rounded or conical in shape, typical monadnocks, rising suddenly from a gradually descending base (Pl. 4 fig. 1).

These three types cannot be sharply separated. Mountains of the first type may pass into ridges, or may be connected by them. Monadnock-like granite-cupolas are either found as separate mountains, or on groups of mountains and mountain ridges. The three types together, form a mountainous country, presenting fantastic and unexpected shapes, carved out of the basal complex. A mountain group situated in the central Wilhelmina mountains, the main peak of which has a height of 1280 m., might serve as an example of complex nature (see outlined area on Map V).

This group lies North of the point, where the Lucie river runs nearest to the mountains. To the South, East and West the group is bounded by a gently sloping base and by a hilly tract of land, the height of which increases but slowly as it approaches the group of mountains. It forms part of the lowland along the Lucie river (abt 250 m.). To the North the group is linked up with other mountainranges. The main top (1280) is obtusely conical in shape and covered with woods. It has a bare granite surface on the South. Fantastically shaped ridges extend from the top downwards; one to the SW., one to the NNE.; and one to the SE., the last of which splits up into two branches; one stretching away to the NE., the other to the SW. The ridges in as far as they have a height of more than abt 600 metres, are strikingly narrow and rounded off at the crests, where they are only a few tens of metres broad, and descend into the valley with steep slopes of 45—25°.

The ridges are of the type described above (second type). The ridge, which extends to the NNE., especially has a number of branches, at right angles to the main ridge. In their turn they split up into lower branches which again pass into foothills. The three main ridges have undulating crests with several granite cupolas e.g. tops 910, 1030, and 1170; the latter is entirely overgrown. The shape of the rocky cupola 910 (see Plate 1) presents a striking contrast to the profile of the ridge opposite in the W. The latter, a continuation of the ridge, which slopes down from top 1280 in a SW. direction, has rather gentle slopes, a broad foot and some very obtusely conical tops (870, 850). The ridge covered by the rocky cupolas 910 and 1130 forms a sharp curve at the Eastern extremity and gets lost in complicated systems of low ridges and hills. The valley approaching top 1280 from the SW. and W. is more than 1 km. broad. The bottom of this valley lies not far from the point, where it comes to a dead end no more than some ten metres above the Southern plain. With the exception of a few places here and there along the creek, the valley is not flat, but undulating.

Similar fantastically shaped groups of mountains are spread all over the interior. Side by side with them there are also chains of mountains characterized by long ridges, which upon the whole extend regularly. Generally speaking, in

Fig 1 PANORAMA FROM SUMMIT 1065, CENTRAL WILHELMINA MOUNTAINS

Fig 2 PANORAMA FROM CAMP 40A, CENTRAL WILHELMINA MOUNTAINS

the Northern part of the Colony, the ridges run the same way as the rivers (NNE.). The Emma chain and the Van Asch van Wyck mountains, though they have not been examined in detail, seem to consist of similar ridges.

When travelling among the mountains one is apt to overrate the number of ridges and mountain-chains of the second type. The groups of mountains one sees in a certain direction, though in reality they are situated at quite different distances, are projected against each other and seem to form one chain (see panorama Pl. 5 fig. 1 and 2). Shadows of clouds floating across the landscape sometimes reveal the real perspective.

The cupolar or cone-shaped granite mountains, the monadnocks mentioned above, occur in the interior as well as in the lowland. The Magneet rock, the Teboe, and the Rosevelt peak on the Tapanahony and the Kassikassima with its several cupolas on the Paloemeu, may serve as typical examples. The same may be said of the Voltz mountain near the Raleigh falls on the Coppename river, which, may be recognized at a great distance, owing to its isolated position.

It may be taken for granted, as we stated before, that the cores of most of the mountain ranges in Surinam consist of granite. Some few, built up of other rocks, do not give an essentially different aspect to the country. Gabbroid rocks near the Tonckens falls on the Coppename river form mountains with radially down-sloping ridges, the Hebiweri (450 m.). The De Goeje mountains composed of gabbros and related diorites, form an undulating ridge, having a length of several km., with not a few minor ridges and many foothills. The description on page 116 shows, that a broad gabbro dyke in the centre of a mass of granite in the Wilhelmina mountains caused the existence of an extensive mountain ridge. A gabbro core is found in the Ebba top (780 m.), which chiefly consists of granite. Epidiorites and phyllites are spread allover the Lely mountains, consisting of ridges extending in a NE. direction. Though probably the epidiorites form the ridges proper, this is not certain.

Judging from the boulders on the slopes, it appears that a small mountain in the Wilhelmina mountains is composed of quartz porphyry.

Quite different forms are shown by the Table mountain, where the Roraima formation, which lies as a nearly horizontal cover over the basal complex in the centre of the Colony, forms a plateau surrounded by escarpments and by a talus of boulders (see panorama Pl. 5 fig. 1 left upper corner).

The hilly country.

The hilly country consists of numberless little mountains of different forms, now domeshaped, now forming ridges varying in height from some dozens to some hundreds of metres. They are covered by laterites and grown over with primeval forest. Characteristic are steep slopes, sometimes of 40°. Sometimes the hills are very near each other, separated by narrow swampy valleys. This part of the country is drained by a complicated system of creeks. Plate 5 fig. 3 gives the reader an idea of the strongly dissected landscape. The same is shown by other trails, which served for purposes of surveying and others. A considerable part of the country is covered with these hills. They occupy large tracts among what are really groups of mountains. The hills may also form the watershed of the main rivers. The formations that built up the hilly country are of various kinds. Though, as has been said, the mountains consist of granites, these granites and the acid diorites related to them, build up the hilly country too. This holds good for many tracts in the interior. Dome shaped hills and ridges often have diabase cores, instances of which are given on p. 120. Gabbros, quartz gabbros and related diorites form rounded-off cupolas and ridges in the Nickerie region and in the hills N. of the De Goeje mountains. Among the metamorphic rocks epidiorites may form cupolas, ridges and hills in the same way as the diabases do. In the area of the goldplacers on the Colonial railway, phyllites, phyllitic slates, conglomerates, schists and possibly also porphyroids take part in the formation of low, but steep hills. An instance of a hilly tract built up by amphibolites and hornblende gneisses is found in the Grutterink-mountains and the hills south of the Tosso creek. Among the rock formations the diabases above all built up very steep hills and ridges, which extend over a considerable distance.

Broad valleys and plains.

We have seen that the coastal area consists of an extensive plain getting broader in a direction from East to West. The coastal plain is quite flat, except for old sand- and shell reefs, some metres high. The latter run parallel to the coast and to each other and are found as far as several tens of km. inland. Swamps and boggy tracts, with clay soil are found between them. The land passes gradually into a muddy seabottom, and an extensive shelf. The sea is remarkably shallow, the 25 fathomline (150 ft) running 65—150 km. away from the shore. Inland the coastal plain passes into a gently sloping tract and into river valleys. This may be illustrated by the following examples. The Courantyne flows through a broad valley as far as the Wonotobo falls; here and there a break occurs, where hills approach the river; e.g. at the Cow falls, at the narrower part of the river below the Governor falls and in the neighbourhood of these falls themselves. The broad valley of the Lower Coppename river extends upstream to a point near Kaaimanston; in some places however hills reach to the right bank. Along the Saramacca the land is flat a long way into the interior of the country, broken at Mamma-dam and near the Jan Basi Gado. The report of the Saramacca expedition [1]) makes mention of but little undulating country, as far as 8 km. from the river along the trail from Mambabasoe to the Ebba top. The same is found along the Suriname river; the land is low along the lower course of the river; broken at Morea and Berg en Dal, where the river valley is considerably narrowed by the "Blauwe berg" and Pilatus. Further upstream hills are found along the right bank till Boschland is reached; here they recede, but at Koffiekamp the valley is once more narrowed by them. Above this place as far as Goddo broad strips of lowland are found along the banks, occasionally alternating with hills. On the Marowyne river, however, the hills approach the river rather near the coastal area.

But also away from the real river-valleys flat tracts of land are found

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[1]) 53. p. 1036—1037.

extending far into the interior, e.g. along the trails cut last century by Mr. Loth, a government surveyor. Along a trail from Brokopondo at the Suriname river to the Pedrosoengoe falls at the Marowyne river (Plate 5 fig. 3) slightly undulating ground was found over a distance of 26 km., while 12 km. are practically flat. This was also found to be the case along a trail cut from Brokopondo to Awara island (Saramacca river). Our trail from the Lucie river to the Central Wilhelmina mountains ran through nearly flat country as far as 4 km. from the river.

The coastal plain forms a topographical and at the same time a geological unit in as much as the subsoil consists everywhere of loose sedimentary deposits. There is no connection whatever between the basal complex beneath and the surface form of the coastal plain.

The exposures in the rivers shows that all kinds of rocks form the subsoil of the broad rivervalleys, but here and there rather thick sedimentary deposits are found as well. Among the solid rocks that have been exposed, granitodiorites and ortho-gneisses are most frequent. In some areas metamorphic schists predominate. These are found on the Marowyne river from the Armina falls upstream, on the Suriname river between the mouth of the Sara creek and the isle of Tafra, and on the Coppename below the Raleigh falls.

Frequency of hills and mountains.

The land from which the mountains rise is pretty low: the principal rivers near the watershed of the Amazon system lying but a few hundred metres above the level of the sea, even at about 20 km. from their source. The Litanie, one of the headwaters of the Lawa-Marowyne lies about 150 m. above sealevel; the Paloemeu, one of the headwaters forming the Tapanahony 262 m.; the Curuni or Upper Courantyne 260 m., the New river (according to Brown) 670 ft., or 220 m. For other rivers, from the centre of the colony these heights are: the Lucie river 225 m., the Gran-rio 180 m., the Pikien-rio 150 m. It may be observed that these rivers have cut no deep valleys into the surrounding country, but on the contrary very often flow through broad strips of land which are entirely flat or but slightly undulating. Thus along the Lawa, Tapanahony and Litanie the hilly country rises but little above the river. In the SW. part of the Colony the mountains recede East of the Curuni, while between the Curuni and the New river lies a stretch of low hilly country. All these tracts which occupy a large part of the Colony lie on an average only little above 250 m.

In the other parts of the Colony the mountains appear to be less extensive then was thought formerly. Till recently it was supposed that the centre of the Colony was formed by mountain chains connected with each other. It was thought that the Tumuchumac mountains, the watershed with the Amazon system, had several branches viz.: the Oranje mountains in the E. and a more important branch in the centre, supposed to consist of the groups of mountains, now called the Eilerts-de-Haan- and Käyser mountains, which in their turn were thought to be connected with the Wilhelmina mountains discovered in 1901. The Wilhelmina mountains were believed to stretch from East to West and to pass into a group extending in a NW. direction to the Courantyne near the Kabalebo river. In a Northerly direction the important Bakhuis mountains were thought to be a branch of the Wilhelmina mountains and also the Emma chain, running parallel to the Bakhuis mountains.[1])

The expeditions between 1901 and 1926 have brought to light that these connections between the mountain chains do not exist, and that the following more or less isolated groups of mountains may be distinguished:

1) The Oranje mountains appear to have a connection with the Tumuchumac mountains which are low at the point where the connection was found. 2) The Eilerts de Haan mountains, and the Käyser mountains are branches of the Tumuchumac mountains. 3) The Wilhelmina mountains are no mountain-chain, but consist of several groups, for the greater part extending in a direction to the NNE. and separated from each other by low hills. The Wilhelmina mountains are separated from the Eilerts de Haan mountains by the low watershed between the Lucie river and Gran-rio, and by the Lucie river itself. On our expedition we found that the streamlets, forming the Coppename originate rather far to the S. with broad stretches of low land along the banks, and that the watershed between the Northern and Southern part of the Colony is not, as was formerly thought, a high crest, running from East to West, but consists for the greater part of low hills. 6) The Bakhuis mountains are separated from the Wilhelmina mountains. 6) There is no chain which extends into the Kabalebo area.

General data about the rivers and the river profiles.

The riversystem as a whole shows no remarkable points, except the rivers in the coastal area. The rainfall in different seasons of the year causes great differences in the water capacity and the whole aspect of the rivers. The upper courses have a "banjir"-like character in the rainy season. Every rainfall does not cause a proportional rise of the rivers. On the upper course no rise is noticed at first, when the rains set in after a period of drought: evidently the soil is very dry and absorbs all the rain. In the rainy season, however, it is just the other way round. Then a slight rainfall is sufficient to raise the level of the water; evidently the soil is saturated and the water at once comes streaming down to the rivers.

It goes without saying that the relief of the soil is of great influence on the water supply. In the mountains the water streams down fast; the hilly country with the complicated drainage system of strongly curved creeks, retains the water longer, whilst those parts of the colony that are nearly flat, and which, as we have seen, are also met with in the interior, may be covered by stagnant water. Whilst in these regions in the dry season one has to dig for water, they may be overflowed in the rainy season. The swamps, the places where stagnant water is found all the year round, are of great importance for the regulation of the water level in the rivers. The swampy places, with undergrowth of pina-palm (Euterpe spec.), tas-palm (Geonoma spec.) and paloeloe's (Heliconia spec.) are found in those parts, where the land is flat, both along the

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[1]) This representation is found for instance on Middelberg's Map, **64**.

rivers and among the steep hills, though among the hills the areas are small. The stagnant water has the colour of teawater. The rivers are fed by the swamps in the dry season. In several rivers the colour of the water betrays its origin.

In places, where the rivers do not flow over solid rock, steep sandy or clayey banks are developed as a rule which may be several metres high. In the curves they may be five metres in the outer bends, whilst the inner bank has the shape of a very flat conical segment, often developed into a sandbank, overgrown with plants. In the rainy season these forms cannot be seen, the river is full to the brim of the steep profile or overflows its banks. Where there are many bends, the water takes the shortest way and flows through the primeval forest in the inner bends. It is remarkable, that sometimes quite near the source the river valley is anything but deep; swamp vegetation is found along the banks and the river in such places has a lowland character: for instance here and there on the Upper Gran-rio, the Upper Lucie river and the Cutari.

Where the river valley is not deep, natural dykes, up to one metre in height are found along the bank (fig. 3). Behind them the soil is swampy with an undergrowth of tas-palm etc. The dykes are thrown up when the water flows

Fig. 3. Section of the Gran-rio near the source.

very rapidly during the rainy season. It is a well-known fact, that in that case two currents rushing downstream are formed, moving spirally in opposite directions, in such a way that components rising from the middle of the bottom of the river run up against the banks and lead to sedimentation in the flooded area.

Terraces.

Terraces of pretty large size are known to exist along the middlecourse of the rivers, especially along the Suriname. A detailed description of them has been given by Martin [1]). Is is noteworthy, that with a few exceptions only simple terraces are known to exist in Surinam. On the river Marowyne near the Merian creek a rather low bank is seen forming the edge of a first terrace, a ten minutes walk broad. It is shut off on the landside by an escarpment of from 5 to 6 m. high. In places where a creek has worn away part of this escarpment, which is in a rather advanced state of erosion already, it is seen to be a deposit rich in quartz pebbles, nutsized, presenting a striking contrast to the clayey soil of the terrace just passed. I had no opportunity to examine, how far this deposit, which in all probability must be looked upon as a second terrace, extends. Van Cappelle [2]) mentions remnants of an old terrace near the Nickerie, lying far from the river.

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1) K. Martin. **26.** p. 170.
2) H. van Cappelle. **91.** p. 383.

Islands.

The map teaches us that in the middle course of the Suriname river a number of islands are found. Above the Wonotobo falls the Courantyne also flows among many islands, some of which are very large ones, as shown by the name of "Eight-mile-island". Consequently the river is 5 km. there wide in some places. There are more islands near the King Frederick William IV fall, where an archipelago is found and the river is 7 km. wide. The Courantyne archipelago is continued in the New river. Numerous islands are also found in the Marowyne: the well-known "Langa tabbetje" has a length of several km. The islands are overgrown with forests, which, as a rule, are lower than the "gran-boesi" along the riverbanks.

The islands may be of two different kinds. Some consist of young sediments, others are rocky, whilst possibly some of the first type hide a rocky core. A good many islands of the first type have steep banks and, when the water is low, it may be seen that the profile is the same as that of the steep river banks near it: the same succession of sands, and clays etc. may be visible there and hence it is evident that these islands are cut out of the banks by the splitting up of the river. Though, of course, in case of floods there is sedimentation on the islands, just as on the terraces, generally speaking the islands are in state of disintegration. It will be seen that here we differ from Martin [1]) who thinks that up to this day these islands have been built up by the river itself. The islands of the second type show masses of rock along their shores. The shape of the islands of this second type is generally more oval, and less pointed than that of the former kind. Islands may also be formed by sand deposits behind masses of rock.

Sandbanks.

Sandbanks are generally found in the middle course of the rivers. The sand is coarsegrained and consists chiefly of quartz; the grains have a light brown colour owing to the fact that they are covered with limonite.

Influence of the rocks on the course of the rivers.

When one examines the riversystem as a whole, the attention is drawn by the fact that in a direction from West to East the course of the Courantyne-, the Saramacca- and the Suriname river all show a bend in the same direction, at about the same latitude. The bend of the Courantyne is seen between the Temeri rock and the mouth of the Kabalebo river, that of the Coppename above the Raleigh falls, that of the Saramacca near the Jan Basi Gado mountain and that of the Surinam near the Bushnegroe-village of Pada. It is not probable that this change in the course of the various rivers is caused by a change in the nature of the rocks: an opinion expressed by Middelberg and Van Loon. I do

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[1]) K. Martin. **26**. p. 172.

not know, what is the cause of this phenomenon, or whether it must be looked upon as something accidental.

In some places, however, it may be proved that there is a connection between the texture of the rocks and the course of the rivers. The Upper Courantyne or Curuni at "Point right about" for example changes it course, from the direction South-North to one that runs from East to West. This is presumably caused by the parallel texture of the ortho-gneisses which may be very pronounced in that part of the river and which trends from East to West and causes plate-shaped rockmasses, parallel to the course of the river. In the same way it may be possible to account for the queer meandering course of the Lucie river, not far above the point where it approaches the Upper Courantyne, by the NW. trend of the ortho-gneisses which are exposed in the river. That granites are not necessarily found in the areas studded with islands in some of the rivers (as opposed to the view held by Martin) will be discussed later. On a smaller scale the composition of the rocks may have some influence on the shape of the riverbeds, viz. in the waterfalls and rapids. Real falls, where the water is running over one step of considerable height are not generally found in Surinam. Examples are found in the Tapawatra-dam, which shuts off the mouth of the Gran-rio (biotite granite) and in the three stages of the Wonotobo falls (biotite granite) which together have a fall of 30 meters. For the rest the name "fall" or "soela" in Surinam is given not to a single stage, but to a series of stages and rapids, which together may have a considerable fall. Such rapids, often running between islets, flow over different kinds of rocks. Practically every river has falls over granites and the acid diorites which occur with them; we know them to flow over ortho-gneisses of the same composition (Kotilolo fall in the Gonini; Mamma dam and Madiengo fall in the Suriname river); over gabbro (Avanavero falls in the Kabalebo river; Blanche Marie fall in the Nickerie river); over diabases and epidiorites (in the Courantyne, Lucie river, and Biabia fall in the Suriname river); over crystalline graywacke and mica quartzite (Armina falls in the Marowyne) over sillimanite gneiss (Blanche Marie fall in the Nickerie river) etc. These falls are caused by masses of rocks which offer a greater resistance to the water streaming over it, for instance by gabbros and diabases in comparison with adjoining granites. But they may also be caused by differences in rocks of the same kind: most of the falls occur in areas where only granite is found, so that evidently they are caused by local differences in hardness, as is the case also with the monadnocks. Above the falls there usually occurs a stretch of remarkably deep and stagnant water, a fact, that has been stated in quite a number of writings. The obstructions formed by the rocks serve to a high degree to keep op the height of the water in the dry season. It is very doubtful whether the waterfalls are ever affected by retrogressive erosion and gradually move upsteam, for if this should be the case, the deep and quiet stretches above them would not exist.

A remarkable example of how the heterogeneous composition of the rocks may influence the course of the river is found in the Ston-Portoe on the Gran-rio.

The uppercourse of the river is here narrowed to a channel of only a few metres wide.

The "Ston-Portoe", equivalent to Stone-gate, does credit to its name. On either side the stream there are granite hills, the foot of which is so close to the water that it is difficult to walk along the bank. On the left-bank, the sides of the hills, form a precipitous wall of granite into which the rain has hollowed out vertical erosion-gullies. The right-bank is less steep, so that we were able with some difficulty to drag the boats over land, while the river-channel itself is obstructed by accumulated, rounded off granite-boulders, sometimes several cubic-metres in size, which have rolled down the adjoining hills (Fig. 4). The water flows through these obstructions. We observe a channel hollowed out of the granite with a breadth of 7 m. The walls are smooth and vertical. Here we find indications explaining its origin. During the abnormal drought in Februari 1926 there was a diabase dyke just visible in the channel running parallel to the steep walls: N. 40° E. It is probable that near the right-bank there is still at least one dyke submerged, the contact-face of which is now visible as a vertical wall. It is likely that the diabase-dykes have furthered the formation of the channel. The eroding action of the river has happened to strike a spot easier to wear away than the granite alone: the diabase-dykes, disintegrated by their contraction-cleavage, perpendicular to the trend of the dykes, were easier to carry off than the granite, hence the parallel channels came into being. The narrow walls of granite between the channels were easy to erode, so that one large passage arose, until the granite-boulders tumbled down the hills. As we see on the map the trend of the river is remarkably constant for over a distance of 2 km. below the "Stone-gate". Above the "Stone-gate" the same North-East-South-West trend continues, interrupted locally by a hair-pin bend. Here and there, especially above the gate, the river flows between vertical walls of the granite, reminding us of the channel described above, even if the walls are not so high. The low water in February 1926 showed this better than ever. It is likely that the river follows the same diabase-dykes over a distance of several km. above the Stone-gate, taking the straight course into consideration. At the spot where the river above the gate definitely changes its direction, its former direction is continued by a side-creek.

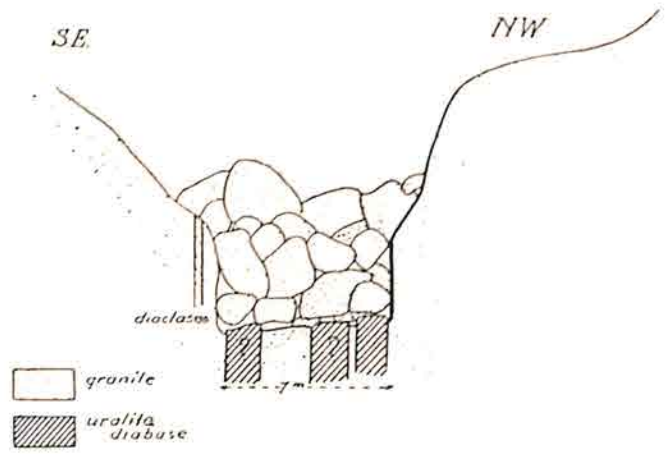

Fig. 4. Section of the "Ston-Portoe", Gran-rio.

The rivers in the lowland.

As long as the river flows through the area of the eluvial and alluvial deposits the general aspect of the river is the same as further upstream. The sandy, clayey or loamy banks are steep as in the interior and quite different from what is found in the fluvio-marine area. The sandbanks in the belt of transition, also where they join the islands are often more or less pointed in front and at the rear, evidently as the result of the upstream and downstream transport of material by the tides. The composition of the islands is the same here as in the interior, except that they never consist of rocks.

There are no steep banks along the estuaries. When the water is low one sees a muddy flat as far as the mangrove border extends; at the river side it is fringed by a muddy slope, pretty steep, intersected by ditches through which the water from the tidal forest flows back.

The following phenomena are found almost exclusively in the lowlands:

Bifurcations forming a connection between two rivers. Thus the Wayombo and the Arawara creek form a link between the Nickerie and the Coppename river; in the same way the Coermotibo and Wane creek link up the Cottica and Marowyne rivers.

Meanders that have been cut off. In the lowland rivers have a more winding course than in the interior; they form many meanders. When the water is high the convex banks may be flooded, in consequence of which a new channel is cut out which ultimately shortens the course of the river. These channels are very numerous: on the Coppename (the "eerste" and "tweede doorsteek"), on the Tibiti (two), on the Coesewijne (two), on the Nickerie (two), on the Maratakka (one), on the Para (two), where the Commewijne and Cottica meet (one), on the Perica (little branchriver of the Cottica). Most beautiful however, is a series of three cut off curves on the Cottica (fig. 5).

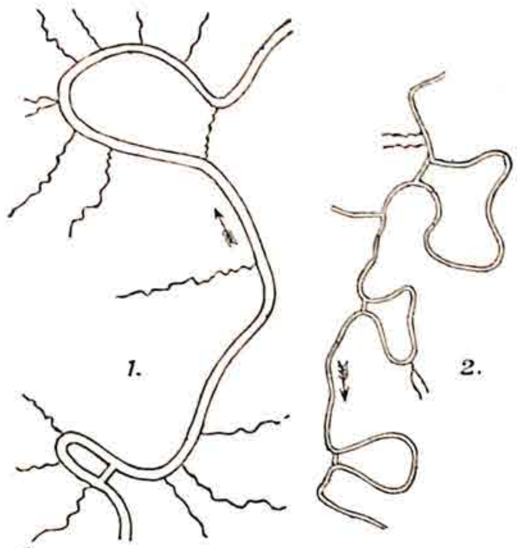

Fig. 5. Meanders that have been cut off: Coppename (1) and Cottica (2). $\frac{1}{200.000}$ After Martin.

The mouths of the principal rivers are very wide and not very deep, so that they may be navigated by moderate sized steamers only. Mudbanks may cause shallows. Very deep in proportion to their width are the meandering rivers of the coastland, a phenomenon which holds good for all of them, though no exact data are available.

A phenomenon which already attracted the attention of the first investigators is the remarkable bend in the lower course of the Surinam rivers. The minor rivers, the Nickerie, the Coesewijne, the Saramacca, the Commewijne, and the Cottica, after having flowed in a direction which runs practically from South to North, all bend to the West and fall into the sea after having flowed a considerable way in a direction parallel to the coast. The same phenomenon is occasionally seen in the mouths of the Coppename and Suriname rivers, which flow with greater force, whilst it is not found in the case of the largest rivers, the Courantyne and the Marowyne. In this respect the aspect presented by the rivers does not differ from what is found in the lowland between Essequibo and Orinoco delta.

The explanation of the phenomenon (which was given by Martin already) is offered by the action of the equatorial-stream, which runs along the coast from East to West. Under the influence of this stream there is loss of land on the western side and sedimentation on the Eastern bank of the river, so that the tongue of land on the Eastside gets larger and larger. By new deposits on the seaside and slight elevation of the soil the river bed thus formed might recede from the ocean. This displacement in a Westerly direction also accounts for the fact, that minor rivers and those, which flow with greater force, have the same mouths, e.g. the Nickerie and Courantyne, the Coppename and the Saramacca.

Conclusions regarding the stage of erosion of the Surinam landscape.

The mountains are for the greater part carved out of a basal complex of nearly the same composition; they bear a monadnock-like character. The landscape presents isolated mountain-groups separated by vast areas of insignificant height, now forming a hilly country, now again slightly undulating. The *mountainous country bears the character of a very old landscape.* As has been described, the mountain system on the North side slopes gradually down into low-lands. Here the peneplainisation is as good as accomplished. The very low watersheds and some hills show a core of firm rock; for the rest the crystalline basal complex is buried under sediments of considerable thickness.

While we have to do here with old or very old forms, it is just the other way about with the coastal plain; this plain is very young, and was formed in the plistocene and holocene epoch, by accrescence of land, which has come to a standstill in recent times. The history of the origin and development of the coastal plain is fully traced on page 55—62.

A terrace structure which is recorded in the literature (by Martin) [1]) is nowhere to be found. Nor do the lines which connect the big falls in the rivers, correspond with a terrace-margin.

We do not know any arguments for important young uplifts; the river valleys do not present a young character, and composite terraces have been almost unknown up to the present day. Some spots are even known, where the land between two main rivers lies lower than the rivers at the same latitude [1]). This finds its explanation in the heterogeneous hardness of the basal complex. It is clear that all these phenomena point to a gradual development of the present landscape.

There are indications that the formation of the present landscape did not begin in a very remote geological period. The existence of remnants of the above. mentioned Roraima-formation, which forms a cap over the denudated basal complex, indicates, that there have been a least two cycles of erosion, and that the beginning of the present cycle is post-Roraima or possibly even much younger.

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[1]) K. Martin. **27.** p. 453; do. **99.** p. 281—282.

THE LATEST DEPOSITS.

The latest deposits comprise fluvio-marine deposits, continental alluvia, and laterites.

The fluvio-marine deposits are found in a broad zone along the coast; they are heavy clays and sands. The name "fluvio-marine" has been selected because they have been deposited in the sea and their formation has been materially influenced by the rivers. These deposits rest on the continental alluvia, which, farther inland supersede the fluvio-marine ones on the surface. The laterites, although they may sometimes be alluvial, are kept apart from the continental alluvia. They cover the hills and mountains in the interior.

Fresh data concerning the latest deposits in the lowlands have been provided by the borings which have been made recently in connection with the Paramaribo waterworks. The drill-samples have been given to me for investigation.[1]) A deep bore near Nickerie (1929) is of importance for our knowledge of the coastal-region. This bore was made by order of the Surin Oil Company. The samples from this bore have been examined by J. ter Meulen, engineer, at Delft. Through the kind assistance of Professor J. Mekel of Delft, I have been able to avail myself of this material and have also been permitted to utilize the results of the first investigation.

A. *The Components of the Fluvio-marine Deposits.*

The fluvio-marine deposits consist of clays, sands, and on a smaller scale also decayed vegetable matter. The clays and sands may be copiously mixed with marine-shells; the latter are particularly conspicuous in the littoral reefs ("schulpritsen"), met with far inland.

The clays are heavy; in a dry state the colour is bluish-gray or greenish, sometimes showing brown spots (iron-oxide). Harrison [2]), Sack [3]), and Miss Van Amstel [4]), have made partial analyses and diverse researches in the interest of agriculture. Van Bemmelen [5]) gives some complete analyses of these clays. The fluvio-marine clays often bear a quantity of fine to very fine-grained quartz-sand. Shells are often mixed with them; besides sponge spicules and a few foraminifera. The fluvio-marine quartz-sands vary considerably in the size of the grain and in the extent to which the grains are water-worn. Very fine-grained sands are extremely common (in four different sands the average size of the grains was found to be 0.4, 0.15, 0.13, 0.09

[1]) Through the kind help of Dr. J. W. Jenny Weijerman, Manager of the "N.V. Surinaamsche Waterleiding Maatschappij". A provisional identification of the samples by myself has already been printed in Dr. Weijerman's reports. The samples have now been worked out in detail.

[2]) J. B. Harrison. **33.**

[3]) J. Sack. **60.**

[4]) Miss C. E. van Amstel. **98.**

[5]) G. M. van Bemmelen. **48, 52** and **74.**

mm.; these numbers were obtained by direct measurement of numerous grains). The grains of fine sands are generally strikingly well-rounded, or sub-angular, and sub-equi-granular. Some clay is usually mixed with these sands, and all transitions to sandy clays occur. Some samples of these sands in a dry state have a distinct brown or yellowish brown colour, as a result of the presence of clayey substance, presumably rich in limonite, which usually covers the grains and which also appears in aggregates. Other sands again are grayish-green and purer. Shells, sponge-spicules and foraminifera occur. Foraminifera of the Rotalia-type are common; those of the Textularia-type are rarer. Sponge spicules are very common. They are of the Tetractinellida-type; fragments are cylindrical in shape with a central channel.

Molluscs may share considerably in the upbuilding of the fluvio-marine deposits. All the mollusc remnants belong to recent species, still living in the shallow sea N. of Surinam. The accompanying list [1]) gives the names of the most frequent species:

Littorina (Melaraphe) nebulosa Lam.
Calyptrea c.f. mamillaris Brod.
Natica marochiensis Gmel.
Natica canrena Lin.
Bursa (Marsupina) crassa Dillw.
Nassarius (Phrontes) antillarum Phil.
Thais (Thalessa) coronata Lam.
Thais floridana Conr.
Murex (Chicoreus) salleanus A.Ad.
Marginella (Prunum) prunum Gmel.
Olivella spec.
Leda spec.
Arca (Argina) campechiensis Gmel.
Arca (Cunearca) brasiliana Lam.
Arca (Noetia) Martinii Recl.
Cardium (Trachycardium) muricatum Ch.
Venus (Timoclea) cardioides Lam.
Venus (Chione) Portesiana D' Orb.
Meretrix (Tivela) mactroides Born.
Donax (Latona) striatus L.
Donax (Chion) denticulatus L.
Tagelus gibbus Speng.
Mactra (Mulinia) guadelupensis Born.
Corbula c.f. biradiata Sow.
Pecten spec.

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[1]) K. Martin. **26**. p. 200—201, has already given a list of fossils, from the material collected by Voltz at several locallities, and identified by Schepman. **25**. Martin's list gives more species, but the nomenclature of the present list is more up to date, thanks to the obliging collaboration of Dr. Ch. Bayer, Curator of molluscs at the " 's Rijks Museum van Natuurlijke Historie", Leyden.

Anomia Humphreysiana Rve.
Ostrea (Lopha) c.f. frons. L.
Modiola spec.

Old littoral reefs occupy an important place among the fluvio-marine deposits. They have already been admirably described by Martin (l.c. p. 199—203) and there is little to be added here. They are low ridges, often separated by swamps, and characterized by a peculiar vegetation. They consist of sand. Shells and fragments of shells are often found in them in abundance, in which case they are called "schulpritsen" in the Colony. Shell-breccias have been formed by re-crystallization of calcite. Now the shells have remained intact, now we find internal casts. In places also fine shell sand is met with. The shells are weathered by leaching in the upper-layers. Where the rivers intersect the cemented breccias the latter fall into large boulders as e.g. near the "Marine trap" at Paramaribo, at the landing-place at Groningen on the Saramacca etc. The littoral reefs generally run parallel to the coast, several behind each other, separated, as has already been said, by swampy soil. Their height is of great significance to settlements and roads. Some of the ridges depart from the direction mentioned, as, for instance, those upon which some of the streets of Paramaribo have been built, running NW.—SE. Besides this the reefs may form branches.

B. *The Components of the Continental Alluvia.*

The continental alluvia are built up of clays, partly very rich in kaolin, sands, gravels, and a mixture of these, and sometimes also of vegetable matter.

The continental clays vary considerably. In colour they vary from white through gray, to ash coloured, or green, or nearly black. The white clays are pure kaolin (called "Pimba" in the Colony). The coloured clays are in parts not to be distinguished in habitus from fluvio-marine deposits. The dark colour of others is caused by finely distributed humus. Now the clays are quite homogeneous, now they show red or brown spots or flames of ferruginous substance, which may go on to such an extent that the clay is quite of a reddish-brown colour, and strongly resembles the red laterites. [1]) Unlike the latter, however, the clays are in a greater or less degree plastic. We often find the clay, no matter of which type, mixed with quartz-sand. The grain of the latter varies greatly in size, even in the same clay sample, so that we meet with sharp quartz grains of 1 mm. and more in size, by the side of finer likewise sharp sand. Transitions to the clay-bearing quartz-sands arise by an increase of the percentage of quartz.

Among the quartz-sands, those with little-worn grains occupy a very important place; these sands, moreover, are coarse: a considerable part of them consists of grains measuring 1—2 mm., and sometimes even more, in

[1]) In the provisional identification of the drilling samples of the Paramaribo waterworks several samples were called "laterites" by me; closer inspection proves this to be inaccurate.

which case they approach gravels. They may be very pure when of course they allow water to drain through easily. Occasionally the grains are coated with a limonite pigment giving the sands a pale brown tint. A quantity of clay may appear, sometimes so much so that transitions in the direction of sandy clays are found. We also know of sands with more intensely worn grains, which are generally finer than the coarse sharp quartz-sand.

Natural concentration forms sands of another composition locally. The so-called "kruitzand" (see p. 55) is an instance of this. It is a heavy residue.

It may have attracted the readers' notice that in naming the continental alluvia the term "loam" has not been made use of; typical loamy soil has a wide distribution, it is true, in the interior proper, but is classified here under the laterites in a wide sense. Among the material appearing in the zone succeeding the fluvio-marine alluvia, we find no typical loams, at any rate if, with Ramann, we mean by loam in a strict sense, clay-bearing soils the proportion of sand in which only becomes visible in elutriating, and which are, at the same time too poor in clayey components to be plastic when in a moist state. Most of our sandy clays or clayey sands namely contain such a percentage of comparatively coarse sand, that the former preserve their plasticity and the latter are too rich in coarse sand to show a typical loam habitus. So merely speaking of sand and clay will suffice here.

True gravels are not frequent. It is true we often do find the term "gravel" or "grebbe-laag" employed in the gold-industry for deposits rich in quartz, resting directly on the weathered bedrock, but they are not true gravels. They are clay copiously mixed with angular pieces of quartz, fragments of diverse rocks etc. We know of water-worn quartz-gravels here and there: for instance those found at the mouth of the Marowyne river, containing the smoothly worn, sometimes clearly transparent quartzes which we find in different collections under the name of "Maroni-topazes" etc.

Of more significance are cemented quartz-sands and gravel which pass into recent sandstones and recent conglomerates. These formations vary considerably, both with regard to the shape of the cemented quartz-material and to the cementing-material itself. Now the quartz is intensely worn, sometimes forming large boulders, now we are concerned with sharper quartz-sand, or sharp, apparently very little removed, quartz fragments. There are also fragments of other rocks present besides quartz, in varying quantities. We are also acquainted with polygenic conglomerates; the thick weathering-crusts of the rock fragments in that case contribute considerably to the cementing of the mass and these crusts are apparently formed in "situ". The cement is now clayey, now ferruginous; the latter type, brown in colour, is particularly common.

C. *The Mineral Composition of the Fluvio-marine and Continental Sands.*

As usual the light minerals of the sands s.g. < 2.9) are chiefly quartz. Feldspar is invariably present, often in considerable quantities. It is always potash feldspar. Plagioclase has not been recognized, and therefore seems to be less resistant. Among the light minerals we sometimes meet with some chalcedony, and some glauconite in the marine-sands.

Among the heavy minerals we came across: ore, leucoxene, green hornblende, brown hornblende, diopside, biotite, chlorite, chloritoid, muscovite, epidote, staurolite, kyanite, sillimanite, andalusite, garnet, rutile, spinel, corundum, tinstone, titanite, zircon, monazite, apatite, tourmaline, topaz, anatase, and brookite. Secondary minerals found in the heavy portions are: pyrite (markasite?) and vivianite. The characteristics and methods of identification of some of these minerals may be mentioned; the remainder behave as elsewhere.

Potash feldspar: is mostly conspicuously angular. Microcline structure, and sometimes also microperthite, have been recognized.

Hornblende: by the side of the common hornblende the brown variety may also be present.

Diopside: the grains, which are very seldom found, are angular, pale-green and non-pleochroitic.

Chloritoid: leaflets, irregular in shape, but slightly worn, and flattened according to the base, occur. Sometimes the mineral is distinctly pleochroitic on a basis: of green ($n\alpha$) to indigo ($n\beta$).

Staurolite: varies considerably in shape; mostly angular or splinter-shaped; extremely minute granules may be well-rounded-off. Now and again fragments of intersecting twins are found. The darkest obsorption-tints of staurolite are gold-brown (c) or amber colour. The latter tint, it is true, is shown by thick fragments, but may just as well be connected with a special variety prevailing in some preparations. Inclusions of ore are common.

Kyanite: is quite colourless, now clearly transparent, now crowded with inclusions.

Sillimanite: appears as distinct crystals, or as fibres (fibrolite). The former type is by far the most common. Sillimanite is but little water-worn; the prism-zone is well-developed or the crystals are splinter-shaped. Fragments according to (001) which yield beautiful interference figures are common. Red spots (particularly //c), feebly pleochroitic, are also frequent. In that case inclusions //c are as a rule present too.

Andalusite: small crystals are clear, larger ones often crowded with inclusions. The pleochroism varies in intensity, many grains are colourless. The chiastolite type is wanting.

Garnet: shows irregular fragments, colourless or red. Brown garnet occurs fairly often in the Nickerie bore.

Spinel (Pleonast): is invariably irregular in shape, and often shows a splinter-like fracture. The colour is a bluish-green, rarely grass-green or blue.

Corundum: invariably appears in the form of irregular, minute fragments. Good interference figures (uniaxial, negative) are often seen. The colour is blue or bluish-green, with weak pleochroism; mostly, however, the mineral is colourless, and in that case difficult to identify.

Zircon: varies very considerably in habitus. Transitions from beautiful crystals to quite worn down, round grains, occur. Zonal structure is frequent. Colourless to pale mauve red. The crystals are often richly provided with inclusions.

Monazite: usually shows a rounded-off shape, and not a single crystal face. The comparatively large grains are oblong-shaped according to the c-axis. Smaller grains are generally egg-shaped. The largest grains attain to a size of ½ mm. The colour is yellowish, sometimes with a brown tint. The interference figure shows a very small optical axial angle. The mineral can be spectroscopically identified. A projecting-lantern having a microscope and a hand-spectroscope fitted to it, has been successfully used for the purpose. The grains may be examined separately in the balsam preparation, provided they are comparatively large. We have to use a powerful magnification. If the grains are very minute, several are placed together in a drop of balsam on an object-glass. The absorption-spectrum shows a group of bands in the yellow, and a few in the green and in the blue. The magnesium-ammonium-phosphate reaction was used micro-chemically. A small number of minute grains, boiled with nitric-acid, yielded a decided reaction. Derby [1]) states that Brazilian monazite yields crystals of cerium-phosphate when boiled with sulphuric-acid, the acid subsequently being evaporated. In the same way we obtained crystals of dydimium-phosphate, but not of cerium-phosphate.

The small monazite grains are difficult to identify, when once embedded in balsam preparations.

Tinstone (Cassiterite): is found in a number of boring-samples. There are two types of cassiterite. The first, is brown and speckled, and with colourless bands; the second is of a pale yellowish-green colour. Both types exhibit some pleochroism (//c largest absorption). The first type shows a uniaxial positive interference figure, the other a more or less clearly biaxial figure, with a distinctly opening axial-cross. The shape is oblong to c, now rounded-off, now angular, or pyramidal, and in the form of poorly developed prisms. The size amounts to 1 mm. Inclusions are met with. After melting with anhydric thiosulphate, tin was micro chemically identified as stanno-oxalate. Spectroscopically the yellow variety may be easily identified in the same way as has been mentioned for monazite: absorption bands occur in the green and in the blue. The darker variety, however, is but slightly transparent.

Topaz: appears in plate-shaped crystals (001), irregular in form; it often yields a good optical axial figure.

Anatase: is rarely bi-pyramidal, and usually worn down.

Brookite: The small crystals, in as far as they are present, are yellowish or brownish. Striae parallel to the c-axis. Typical interference-figure.

D. *Remnants of decayed vegetable matter in the latest deposits. Indications of oil.*

Vegetable matter.

As said, remnants of decayed vegetable matter occur in the fluvio-marine and continental alluvia. We add a few remarks.

[1]) O. A. Derby. Notes on Monazite. Amer. Journ. Science. (IV). X. 1900. p. 217.

In the upper strata of the continental alluvia there are layers of vegetable matter, mixed with sand or clay. This vegetable matter has decayed so as to destroy the cellular-system, excepting the wood remnants which are of general occurrence in the sands and clays. In the layers of the boring Nickerie deeper than 100 m. the wood-remnants have been carbonized and have the habitus of lignite. Below 200 m. the vegetable matters in this boring have altered even more, viz. to pieces of carbon with lamellae-structure. On the whole carbonization increases with the depth. There are some exceptions: at a depth of 36 and 77 m. of the said boring there is carbonized wood in which cellular-structure is just noticeable. It is compressed considerably; it has the lustre of pitch and a shelly fracture. These remnants are strongly rounded and weathered on the outside, the material has evidently been removed and has not been metamorphosed in situ.

In the interior we have found fragments of wood that have changed in a remarkable way. On an exposure of granite of large dimensions (see Pl. 4 fig. 2) we found black pieces of wood entirely carbonized. (See Y. 209 B). However, the cellular-structures have mostly been preserved in detail; the medullary rays are discernible under the lens. It is obvious that charcoal from fires is out of the question. The place where these fragments were found implies that the strong carbonization occurred in situ and that the wood does not originate from sedimentary deposits of great thickness. The wood remnants in the damp forest are liable to decay soon. The wood on the rocks mentioned, however, has dried up entirely for a long time in the dry season at a high temperature. Have we to do here with carbonization consequent on a process comparable with "dry distillation"?

The appearance of pyrite is again undoubtedly connected with the organic substance. Some sands are exceedingly rich in pyrite. It assumes various forms; now fine grains, now rounded off concretions to the size of a cm.; sometimes we see by the shape that it has deposited itself around a branch of a root as a covering. From one of the borings (near Republiek) a mass has even been brought to the surface, consisting of acute-angled quartz-gravel, some muscovite and copious pyrite cement. The forming of ferro-sulphate in many drill-samples leads to suppose a once larger percentage of pyrite. The CO_2 found in the water of some of the test-pumpings, may also find its explanation in the decay of the vegetable remnants.

Indications of oil:

Surinam, like the other Guianas, does not as yet belong to the oil producing countries. The search for oil in Surinam goes back to pre-war days. Indications in favour of oil viz: traces of oil, of pitch, salt-water wells, the discovery of marly limestone, now appeared to be based on their being confused with matters that have nothing to do with oil, now were sent into the world by company promoters. I have experienced this personally and as far as I know, not a single indubitable oil-indication was proved till 1928.

In November of 1928 a report was published by two experts, indicated by the Government, about indications of oil which were said to have been found in the extreme NW. of the Colony, near Nickerie. This report confirms the occurrence, and gives the result of the examination of samples that were taken by the experts. It shows that we are concerned with mineral oils. [1]) With these facts the oil-problem has entered a new phase.

It may be accepted as a fact, that the interior of Surinam no oil is to be found; the composition of the basal complex excluding any oil-possibility; so does the composition of the Roraima formation, while the thickness of the alluvia and residual deposits, is far too slight to yield a concentration area; borings would soon reach the crystalline system everywhere. The conditions, however, are more favourable in the coastal region, and as it will be clear from what will be discussed below, more particularly in the NW.-corner of the Colony, where the loose sediments attain a considerable thickness.

The occurrence of oil indications in Nickerie is as follows, according to the signers of the said report: The oil was found at a very slight depth, not deeper than 12 m., in sand and clay. These deposits belong to the fluvio-marine. At the raising of a short pipe, which had been filled with water before in such a manner that the water inside and outside the pipe was in level, some oil was floating on the water. No welling-up of gas was observed then.

From the distillation-products it appears that the samples contained an extremely large percentage of kerosene, n.l. as much as 82 % in one of the samples (while the distillation was continued only up to 270°). Such queer composition is not entirely unknown in natural oils elsewhere. Besides this, one of the samples shows fatty oils; it is not impossible that these fatty oils did come from the same sediments but in that case probably have nothing to do with the origin of the rest of the components of the sample.

We can not solve the problem as to whether these oils have been formed in situ, in the very young deposits near the surface, or that we are concerned with a case of migration from deeper strata.

As we shall see lower down the deeper layers of the boring near Nickerie (lower than 100 m.) are chiefly continental deposits. In these deposits no marked quantities of oil can have been formed. There is, however, still a possibility that the oil has originated from other sediments lying deeper than the lowest point of the boring. It may also be that it has migrated from elsewhere. Any theory concerning the genesis and the origin of this oil will have to make allowance for its peculiar composition.

Some asphalt has been met with in the Nickerie boring. At a depth of rather more than 100 m. a thin layer of asphalt has been recorded. Samples of it are pure asphalt. This occurrence falls within the deposits considered by me as fluvio-marine. Traces of asphalt are extant at larger depth. Fine asphalt granules stick quartz grains together. These traces of asphalt appear in a number of samples down to the deepest layers the boring has reached.

The above-mentioned reporters record pitch-like stones, which have been found in the neighbourhood of Nickerie, viz. on the littoral along the estuary of the Courantyne. They consider them to be indurated (?) old pitch.

In sum we conclude that the origin of the oil under consideration is still a matter of conjecture.

[1]) O. M. de Munnick and J. W. van Dyk. **110.**

E. *On the Distribution of the Fluvio-marine and Continental Alluvia and Further Details about them.*

The fluvio-marine deposits form a zone along the ocean the narrowest part being found in the East and the widest in the West (see Map I). In how far the fluvio-marine extends inland is only known schematically. The boundary line with the continental alluvia is not sharp; indeed the force of the tides and the water supply of the rivers from the interior is subject to variation so that fluvial and marine deposition takes place alternately along the banks, hence the line marked on the map can only be a schematic one.

The boundary line seems to take the following course. On the Courantyne river, the coast-deposits, not far from the Apoacka creek on the English bank, pass into gently undulating land with continental alluvia [1]). On the Nickerie river the transition region seems to lie in the neighbourhood of the Ceder creek; near the meanders cut off farther upstream follow deposits which may be better compared with the inland soils [2]); while the latter in their typical form are exposed all along the Wayombo, and also along the Coppename river below the mouth of the latter. The boundary line on the Coppename runs near the mouth of the Tibiti [3]). It is not known where it passes the Saramacca river. On the Suriname river, the fluvio-marine deposits seem to extend to above Gr. Chatillon and Bethesda; at any rate, according to Voltz [4]), old littoral reefs are found near the "Para-doorsteek" (a canal connecting the Suriname river with the Para creek). This agrees with the fact that fluvio-marine deposits are found in the borings near Lelydorp (Colonial railway km. 17) and probably the material from the boring near km. 23 of the Colonial railway is also partly marine. Going Eastwards we have only Van Rosevelt's map [5]) to go by, on which shell-reefs give an idea of the distribution of the fluvio-marine. Shell-reefs are met with to the South of Slootwyk (Upper Commewyne) and near this river half way between Slootwyk and Potribo; on the Perica river at the same latitude about, and further towards the East not far South of the Cottica river in front of the Oranje creek. Between the Coermotibo-Wane creek and the ocean the map shows both savannahs and shell-reefs; the fluvio-marine deposits, however, do not extend far inland here.

For the distribution of the sand- and shell reefs we still only have Van Rosevelt's map to go by. According to this they mainly appear in the Eastern half of the coastal zone, but they are not wanting in the Western one either. The settlement of Coronie, with its coco-plantations, lies on a "schulprits", and others are situated East and West of it. On the Coppename river the reefs are developed as far as the mouth of the Tibiti; on the Nickerie river and Marataka not far below the Karapana and Bigibere creek etc. The distribution in the Eastern half of the Colony has already been mentioned above.

The continental alluvia adjoin the fluvio-marine deposits inland. They cover a zone of gently undulating country. No definite line of demarcation can be given at the Southern side, they are found among the hills covered with laterites, continue in the broad river valleys and share in the upbuilding of the terraces along the river banks. But we may even meet with them far inland: we have seen that among the mountains and hills, regions have been found which are almost "peneplainized"; here the continental alluvia appear in extensive tracts, probably of the same composition as in the lowlands.

Our knowledge of the structure of these alluvia in a vertical direction, for

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1) C. B. Brown. **10**. p. 203.
2) H. van Cappelle. **62**. p. 47.
3) E. Essed. **105**. p. 332.
4) see K. Martin. **26**. p. 202.
5) J. F. A. Cateau van Rosevelt. **18**.

TABLE I.

		Minerals	Ore	Leucoxene	Staurolite	Kyanite	Sillimanite	Andalusite	Tourmaline	Zircon	Muscovite	Rutile	Garnet	Hornblende	Epidote	Rarely occur
Fluvio-marine deposits	Combé boring, Paramaribo	4.50 – 5.00 clayey sand	52	4	43	2	—	5	8	20	—	—	1	9	8	Sillimanite, titanite, brookite
		5.00 – 11.00 clay	50	5	35	1	2	8	11	30	—	1	1	5	1	Muscovite
	Vaillaint plein boring, Paramaribo	1.50 – 2.50 clay	63	2	24	—	2	—	2	54	—	1	1	8	6	Andalusite, muscovite
		4.00 – 7.20 clayey sand	51	7	27	1	1	3	7	37	—	1	3	10	3	Muscovite
		15.20 – 17.00 clayey sand	49	10	33	3	—	5	20	21	2	1	—	3	2	Sillimanite
	Botanical garden, Paramaribo	– 1.00 clayey sand	72	13	34	—	—	4	8	20	1	2	2	7	9	Kyanite, sillimanite, brookite
Continental alluvia	Lely-dorp boring	29.50 – 30.50 sand	50	5	52	1	2	1	5	34	—	—	—	Are lacking in these borings		Garnet
		38.60 – 40.50 sand	58	7	36	1	3	2	5	42	4	—	—			Spinel
		47.50 – 50.80 sand	82	5	5	—	—	—	2	88	—	—	—			Andalusite, rutile
		56.00 – 58.00 sand	72	4	56	—	2	—	4	14	20	—	—			
		65.00 – 66.80 sand	54	4	61	—	1	1	6	21	6		—			Kyanite, garnet
		71.00 - 74.20 sand	56	3	33	—	—	1	6	47	10		—			Sillimanite, rutile, garnet, titanite
	Onverwacht boring	31.50 – 32.80 sand	50	2	55	—	1	1	7	34	—	—	—			Kyanite, rutile
		38.50 – 40.00 sand	85	4	80	5	—	—	10	1	—	—	—			Sillimanite, andalusite, garnet
		43.00 – 44.40 sandy clay	70	4	66	—	—	2	8	17	—	—	3			Kyanite, rutile
		44.40 – 44.70 sandy clay	65	4	53	1	—	1	4	36	—	1	—			Kyanite
	Republiek boring (III)	3.10 – 3.80 sandy clay	43	1	32	—	—	1	4	60	—	2	—			Sillimanite
		5.10 – 6.20 sandy kaolin	47	2	36	—	—	—	5	54	—	3	—			Kyanite, sillmanite, andalusite, garnet
		10.00 – 12.60 sand	70	2	42	—	1	1	8	42	2	2	—			Kyanite, monazite
		18.50 – 19.80 sand	(2)	—	74	—	—	14	12	—	—	—	—			
		21.00 – 21.20 sandy clay	9	—	86	—	—	6	7	1	—	—	—			
	Savannah, path Republiek Matta	1.80 – 2.50 sand	8	—	—	—	—	1	2	92	—	5	—			
		6.10 – 6.80 sandy clay	← Ore and some zircon →													Staurolite, tourmaline
		12.00 – 16.20 sand	88	4	52	—	—	1	10	32	—	1	—			Kyanite, muscovite, garnet
		17.40 – 18.25 sand	72	3	21	—	—	—	2	66	6	2	—			Andalusite, monazite
		21.60 – 23.80 sandy clay	47	2	72	—	—	—	15	3	8	—	—			Kyanite, andalusite, monazite

TABLE 2.

COMBÉ BORING, PARAMARIBO.

0.00— 1.00	clay with shells and town-grit
1.00— 1.80	clay with traces of shell-fragments
1.80— 2.70	clay
2.70— 4.50	clay with some shells (Arca brasiliana Lam.)
4.50— 5.00	very fine-grained, clayey quartz-sand with some shells
5.00— 11.00	clay with some fragments of shells
11.00— 13.50	the same
13.50— 14.00	clay
14.00— 15.50	clay, very rich in shells (chiefly Anomia Humphreysiana Rve.)
15.50— 19.50	clay with traces of shell-fragments

VAILLANT PLEIN BORING, PARAMARIBO.

0.00— 1.00	clay with shells and town-grit
1.00— 1.50	very fine-grained quartz-sand, rich in clayey substance
1.50— 4.00	clay
4.00— 8.00	very fine-grained quartz-sand containing clayey substance and some fragments of shells
8.00— 12.00	clay
12.00— 13.50	clay, rich in shells, (chiefly Anomia Humphreysiana Rve; moreover: Venus Portesiana D'Orb., Arca campechiensis Gmel, Arca Martinii Recl., Cardium muricatum Ch.)
13.50— 15.20	clay, with some fragments of shells
15.20— 18.00	very fine-grained, clayey quartz-sand

LELY DORP BORING (COLONIAL RAILWAY KM. 17)

0.00— 0.70	very fine-grained humus-bearing soil, with rootlets, containing very fine-grained quartz-sand
0.70— 1.60	very fine-grained clayey quartz-sand
1.60— 4.40	very fine-grained quartz-sand, rich in clayey (?) substance
4.40— 5.75	very fine-grained quartz-sand, rich in clayey substance flamed brown
5.75— 7.00	sandy clay, flamed brown
7.00— 9.60	sandy clay (contains very fine-grained quartz-sand)
9.60— 11.00	sandy clay, containing weathered fragments of shells and Corbula biradiata Sow.
11.00— 18.80	clay
18.80— 25.00	clay, iron-stained
25.00— 29.50	clay
29.50— 32.40	coarse, sharp quartz-sand containing some clayey substance
32.40— 34.00	clay
34.00— 34.50	coarse, sharp quartz-sand containing some clayey substance
34.50— 35.00	clay
35.00— 35.30	coarse, sharp quartz-sand containing some clayey substance
35.30— 35.60	clay, in part sandy, containing some decayed vegetable matter
35.60— 36.80	coarse, sharp quartz-sand containing some clayey substance
36.80— 38.00	clay
38.00— 38.40	coarse, sharp quartz-sand containing some clayey substance
38.40— 38.60	clay, containing decayed vegetable matter and some coarse quartz-sand
38.60— 40.50	coarse, sharp quartz-sand containing some clayey substance
40.50— 42.20	sandy clay
42.20— 43.30	red flamed clay
43.30— 44.50	clay, rich in kaolin
44.50— 45.00	coarse, sharp quartz-sand containing some clayey substance
45.00— 47.50	humus-bearing quartz-sand
47.50— 50.80	coarse, sharp quartz-sand
50.80— 51.20	clay with decayed vegetable matter
51.20— 54.50	quartz-sand with humus and some mica
54.50— 54.70	clay
54.70— 58.00	quartz-sand, with some humus
58.00— 61.00	coarse, sharp quartz-sand, with some humus
61.00— 65.00	coarse, sharp quartz-sand
65.00— 66.80	coarse, sharp quartz-sand, with some decayed vegetable matter
66.80— 71.00	clay
71.00— 74.20	sharp quartz-sand
74.20— 74.50	clay

TABLE 3.

BORING COLONIAL RAILWAY KM. 23.

0.00—	1.10	red and brown stained sandy clay
1.10—	1.80	very fine-grained quartz-sand
1.80—	4.00	very fine-grained quartz-sand, highly ferruginous
4.00—	6.40	very fine-grained quartz-sand strongly clay-bearing
6.40—	9.80	sandy brown clay
9.80—	12.70	very fine-grained clayey sand
12.70—	18.60	clay

ONVERWACHT BORING (COLONIAL RAILWAY KM. 29.394, 125 m E.)

0.00—	0.70	clay
0.70—	3.20	clay iron-stained
3.20—	3.80	clay
3.80—	4.00	dark clay
4.00—	5.00	clay
5.00—	6.50	clay, red flamed
6.50—	7.70	clay
7.70—	8.80	clay, red flamed
8.80—	11.80	clay, multicoloured
11.80—	14.60	clay
14.60—	16.70	clay, brown-flamed
16.70—	19.30	dark clay, brown flamed
19.30—	28.50	dark clay
28.50—	29.50	coarse, sharp quartz-sand containing some clayey substance
29.50—	31.50	coarse, sharp quartz-sand
31.50—	32.80	coarse, sharp quartz-sand containing some clayey substance
32.80—	34.50	coarse, sharp quartz-sand containing lumps of kaolin
34.50—	38.50	coarse, sharp quartz-sand, at 38.50 m. with decayed vegetable matter
38.50—	40.00	coarse, sharp quartz-sand containing some humus
40.00—	43.00	do. containing some clayey substance
43.00—	44.40	sandy clay containing coarse, sharp quartz-sand, humus and mica
44.40—	44.70	sandy clay containing some humus and mica
44.70—	46.60	coarse, sharp quartz-sand containing some clayey substance, humus, mica, and rich in pyrite
46.60—	47.80	dark clay containing some pyrite concretions
47.80—	50.40	soil rich in humus containing sharp quartz-pebbles, contains pyrite
50.40—	54.80	sandy kaolin containing sharp quartz, mica and rich in pyrite
54.80—	59.80	sandy clay, rich in mica
59.80—	62.85	clay, highly sandy, containing red potash feldspar (microcline): a washed sample consists of coarse, sharp gravel of quartz and red microcline containing some clayey substance
62.85—		quartz, red microcline and mica with clayey cement: weathered bedrock in situ, probably pegmatitic granite

BORING COLONIAL RAILWAY KM. 35.815

0.00—	0.45	clay with rootlets
0.45—	8.40	clay, red-stained and flamed
8.40—	9.10	clay, brown-stained
9.10—	9.80	clay
9.80—	10.10	clay, red-flamed
10.10—	10.70	kaolin
10.70—	11.30	sharp quartz-sand, with lumps of clay
11.30—	12.50	kaolin
12.50—	12.80	sandy kaolin
12.80—	13.90	sandy clay or clayey sand containing very fine-grained quartz-sand
13.90—	14.10	kaolin
14.10—	16.50	sharp quartz-sand, rich in clayey substance
16.50—	17.60	kaolin
17.60—	19.90	sharp quartz-sand, rich in clayey substance
19.90—	22.50	coarse, sharp quartz-sand
22.50—	22.70	highly sandy clay containing sharp quartz-sand
22.70—	24.10	sharp quartz-sand, containing some clayey substance 24.00—24.10 decayed wood
24.10—	24.80	sharp quartz-sand with some quartz-pebbles and some decayed vegetable matter, very rich in pyrite concretions
24.80—	25.00	dark, highly sandy clay containing coarse, sharp quartz-sand, some decayed vegetable matter and some pyrite

TABLE 4.

BERSEBA BORING (COLONIAL RAILWAY KM. 40.270)

0.00— 0.30	clay with rootlets
0.30— 3.50	clay, red-flamed
3.50— 4.00	kaolin
4.00— 5.30	clay, red-flamed
5.30— 5.50	kaolin
5.50— 5.70	sandy clay, rich in sharp quartz-sand
5.70— 6.10	sharp quartz-sand, very rich in ferruginous substance
6.10— 6.90	clay, red-flamed
6.90— 7.20	clay, red-stained, rich in sharp quartz-sand
7.20— 7.90	kaolin
7.90— 8.55	sandy kaolin containing coarse, sharp quartz-grains
8.55— 11.00	sharp quartz-sand containing some clayey substance
11.00— 12.00	coarse, sharp quartz-sand and grit containing some clayey substance

REPUBLIEK III BORING (COLONIAL RAILWAY KM. 41.200)

0.00— 0.30	clay with rootlets
0.30— 2.90	clay, red-flamed
2.90— 3.10	sharp quartz-sand containing some clayey substance
3.10— 3.80	clay, in part sandy
3.80— 5.10	sharp quartz-sand containing some clayey substance
5.10— 6.20	kaolin rich in sharp, coarse quartz-sand
6.20— 8.40	coarse, sharp quartz-sand, with some lumps of clay
8.40— 14.00	coarse, sharp quartz-sand
14.00— 14.90	coarse, sharp quartz-sand containing some pyrite
14.90— 15.80	dark clay, in part sandy containing some decayed vegetable matter
15.80— 18.20	coarse, sharp quartz-sand and gravel with some humus and rich in pyrite
18.20— 18.50	highly sandy clay containing coarse, sharp quartz-sand and some pyrite
18.50— 19.80	quartz-sand
19.80— 20.00	kaolin, in part sandy containing coarse, sharp quartz-sand
20.00— 21.00	quartz-gravel
21.00— 21.20	sandy clay containing coarse, sharp quartz-sand and mica
21.20— 23.00	coarse, sharp quartz-sand and gravel, in part cemented by pyrite

SAVANNAH BORING PATH REPUBLIEK TO MATTA.

0.00— 1.80	sharp quartz-sand
1.80— 5.00	coarse, sharp quartz-sand
5.00— 6.10	sharp quartz-sand, rich in humus
6.10— 8.50	clay, in part sandy
8.50— 10.00	clay
10.00— 10.25	sand rich in humus
10.25— 10.50	coarse, sharp quartz-sand containing lumps of clay
10.50— 10.70	dark clay, in part with coarse, sharp quartz-sand containing some pyrite
10.70— 16.20	coarse, sharp quartz-sand containing decayed vegetable matter
16.20— 17.40	coarse, sharp quartz-sand and gravel containing some decayed vegetable matter and pyrite
17.40— 18.25	coarse, sharp quartz-sand containing some vegetable matter, and a concretion of pyrite with enclosed quartz-grains
18.25— 18.65	dark clay containing humus, sharp quartz-sand and pyrite concretions
18.65— 19.00	decayed vegetable matter containing coarse quartz-sand, some mica and pyrite
19.00— 21.60	quartz-sand containing humus and pyrite
21.60— 23.80	dark clay, in part sandy, containing mica
23.80— 26.00	sandy clay

ZANDERIJ I BORING (COLONIAL RAILWAY KM. 44.750)

0.00— 0.60	coarse, sharp quartz-sand (gravel)
0.60— 2.20	coarse, sharp quartz-sand
2.20— 3.10	quartz-sand, rich in humus
3.10— 6.00	kaolin
6.00— 8.00	quartz-sand
8.00— 10.00	quartz-sand containing some humus
10.00— 10.40	coarse, sharp quartz-sand with lumps of clay and pyrite
10.40— 11.00	coarse, sharp quartz-sand containing some clayey substance, rich in pyrite concretions

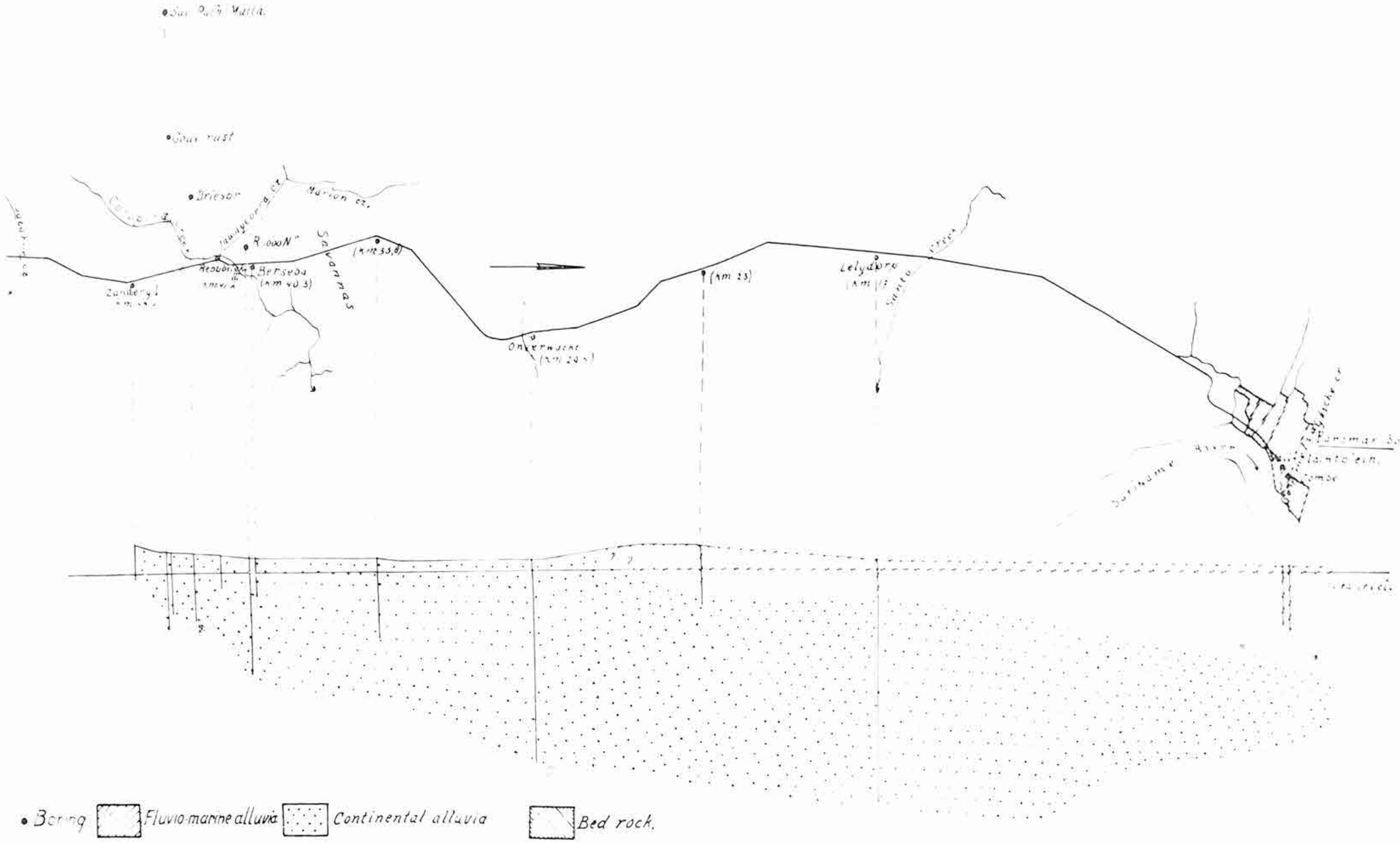
TABLE 5.

BORING NEAR NICKERIE [1]).

9.20— 12.00	very fine quartz-sand
12.00— 27.00	sandy clay containing fragments of clay shale. Natica marochiensis Gmell.; Corbula biradiata Sow.
27.00— 30.50	sandy clay containing very fine quartz-sand
33.50— 35.00	sandy clay containing rare fragments of shells
35.00— 36.60	sandy clay containing rounded pieces of lignite
36.60— 37.80	quartz-sand containing rare fragments of shells
37.80— 38.25	clay
42.90— 43.20	clay containing totally decayed wood
54.00— 54.50	coarse quartz-sand. Corbula biradiata Sow.
57.00— 60.20	coarse quartz-sand (gravel). Olivella spec.
71.00— 77.00	coarse quartz-sand
77.00— 77.50	sandy clay containing rounded pieces of lignite
82.00— 84.00	coarse quartz-sand
84.00— 84.80	sandy clay, containing coarse quartz-sand and quartz-pebbles
84.80— 89.60	coarse, sharp quartz-sand. Venus Portesiana D'Orb.
89.60— 90.00	coarse quartz-sand. Corbula biradiata Sow.
90.00—100.50	sandy clay. Venus Portesiana D'Orb., Corbula biradiata Sow.
100.50—101.40	quartz-sand
101.40—113.60	very fine quartz-sand
113.60—115.00	quartz-sand
115.00—120.00	fine quartz-sand containing remnants of decayed wood
122.00—125.20	very fine quartz-sand
127.30—129.00	coarse quartz-sand containing traces of lignite
129.00—140.00	coarse, sharp quartz-sand
140.00—147.60	sharp quartz-sand containing fragments of decayed wood
147.60—148.32	sandy clay containing fine quartz-sand
148.50—149.20	very coarse quartz-sand containing traces of lignite
149.20—156.20	sandy clay containing coarse, sharp quartz-sand
156.20—167.00	coarse, sharp quartz-sand
167.00—171.48	sandy clay containing some quartz-pebbles
171.48—177.50	coarse quartz-sand containing some fragments of lignite
177.50—178.50	quartz-sand
178.50—179.50	sandy clay (kaolin)
179.50—182.00	sharp quartz-sand containing some fragments of lignite
182.00—184.60	sandy clay containing fine and coarse quartz-sand
184.60—187.00	sharp quartz-sand
187.00—191.00	coarse, sharp quartz-sand
191.00—193.00	coarse, sharp quartz-sand containing fragments of lignite
193.00—201.10	sandy clay containing some coarse quartz-grains
201.10—202.00	sandy clay
202.90—204.20	coarse quartz-sand
204.20—205.00	lignite
205.00—212.50	sandy clay containing some coarse quartz-grains
212.50—219.00	coarse, sharp quartz-sand
219.00—225.00	clay containing coarse quartz-sand
225.00—231.00	sandy clay containing coarse, sharp quartz-sand and some fragments of lignite
231.00—233.72	clay, rich in pyrite
233.72—251.00	coarse, sharp quartz-sand, rich in fragments of lignite
251.00—256.00	sandy clay containing very fine quartz-sand and some coarse quartz-grains
256.00—278.00	coarse, sharp quartz-sand containing fragments of clay shale and of lignite
278.00—280.50	sandy clay containing coarse quartz-sand
280.50—282.90	clay and clay shale fragments
282.90—283.20	sandy clay containing coarse quartz-grains
283.20—289.00	coarse, sharp quartz-sand and fragments of clay shale
289.00—291.50	sandy clay
291.50—296.40	sandy clay containing coarse, sharp quartz-sand and gravel
296.40—296.90	lignite
296.90—302.00	clay containing some coarse quartz-grains

[1]) It will be observed that the profile is not quite complete; not all the samples have been handed in for research.

Plate 6.



Section of latest deposits along Colonial railway Paramaribo Zanderij I, after borings. Vertical scale 1 : 2000.
(The starting-point of some of the borings in relation to the sea level needs some correction, according to data received afterwards).

the greater part is based on data obtained these last few years from the already mentioned borings carried out by the Paramaribo water-works, and from the oil-boring at Nickerie. The sections of both regions will be discussed separately. The first group of borings has been made along the Colonial railway and extends to rather more than 40 km. south of Paramaribo, while in the neighbourhood of Republiek (Colonial railway km. 41.2) a large number of borings have been made. The sections of a few of these borings are given here (see table 2—4). For the place where the borings have been made, see Pl. 6. It appears that the continental and fluvio-marine deposits in these sections show distinct points of difference.

The clays of the continental alluvia are very rich in kaolin; they change from pure kaolin to clays which in habitus cannot be distinguished from the marine ones. Their large percentage of kaolin and slight percentage of bases, stamp them as unfertile. The quartz-sands of the fluvio-marine deposits are fine-grained, mostly very fine ($<$ 0.15 mm.), being of an even size in the same sample and highly waterworn, unlike the continental sands which are very often coarse (1—2 mm.) and vary in size in the same sample, are sharp and therefore little waterworn. The quartz-sands in the sandy clays of the fluvio-marine deposits have the same features as those of the fluvio-marine sands, which is also true of the continental alluvia.

Marine shells appear both in the clays and in the sands or are entirely wanting. Some layers are so rich in shells that we are concerned with a "Lesedecke".

Another point of difference is the frequent occurrence of decayed vegetable matter and the accompanying pyrite in the continental alluvia in contradistinction to the fluvio-marine deposits. The latter difference does not, of course, finally settle to which of the two groups of deposits a sample belongs, for some pyrite occurs in the fluvio-marine ones too.

Remarkable differences exist between the combination of the heavy minerals in both groups of deposits. Table 1 gives the percentages of the components in the fluvio-marine and in the continental alluvia.

The percentage of ore was ascertained separately by counting the number of ore grains, which occur in 200 grains. Then the percentage of the other heavy minerals was ascertained again by counting to 200, and reducing the grains in either case to 100. Those minerals which are only met with once in two-hundred grains or are very scarce in the preparation are mentioned as "rare". In order to get rid of the pyrite, the samples have been treated with nitric acid, by which any apatite that might be present is lost too.

The clays of the fluvio-marine deposits appear to contain a comparatively large quantity of heavy minerals so that it is possible to count the grains. The case is different with the clays of the continental alluvia. Many of them are so pure that they yield no heavy elements. The sandy clays, however, possess them in abundance, consequently these have been selected for study. The quantity in the continental sands varies, the coarse quartz-sands being particularly poor.

Let us now look into the mineral-combination of the fluvio-marine deposits (table 1). It appears that the combination in the sands does not differ from that in the clays and locally the modifications are but slight. The percentage of ore is high. Zircon is invariably present in considerable quantities, and the quantity of staurolite is strikingly large. Other minerals from metamorphic sedimentary schists, kyanite, andalusite, and tourmaline are present in varying quantities. In places andalusite is of very frequent occurrence. (Combé boring). Hornblende and epidote invariably occur.

In the continental alluvia we also find a large percentage of ore and staurolite. The other minerals are also represented again, with the exception of hornblende and epidote which are wanting here. The continental alluvia are characterized by the variability of the mineral-combination, which occurs not only with regard to different locality, but even in the same section within a few m. vertical distance. The percentage of staurolite is generally high, sometimes even abnormally so (Republiek III, 21,00 and 18,50 m.). The latter sample has moreover a strikingly large percentage of andalusite. Remarkable is also the variability of the zircon percentage: now an abnormally large quantity (Savannah boring 1,80 m.), now wanting (Onverwacht 38,50 m.; Republiek III 18,50 m.; Savannah 21,60 m.) etc. Where coarse tourmaline is present, the percentage of ore is given in brackets, because the almost opaque tourmaline may cause us to overlook the sparse ore. The investigations into the heavy elements of the other borings yield similar results and are not given therefore.

In view of these differences the distribution of the fluvio-marine deposits and the continental alluvia may be schematically shown in the sections. Both borings at Paramaribo ("Combé" and "Vaillant plein") have been drilled through fluvio-marine deposits only. The Lelydorp-bore shows fluvio-marine deposits up to 11 m. in depth: very fine, evenly-grained, and highly waterworn and also ferruginous sands of the types which are characteristic of fluvio-marine deposits are present, while weathered fragments of shells appear at a depth of 11 m., among which a Corbula biradiata was found, which is a marine species. Whether the greenish clay adjoining it underneath is fluvio-marine or continental is difficult to make out. Below this, however, follow typical continental deposits, viz: the coarse sharp quartz-sands, sometimes accompanied by decayed vegetable matter. Although bearing no fossils, the very fine highly-worn clayey quartz-sand in the boring of the Colonial railway km. 23. must probably also be looked upon as a fluvio-marine deposit, judging from its habitus (the average size of the water worn quartz-sand was fixed at 0.12—0.15 mm.) and from its heavy mineral components. The first profile of fluvio-marine sediments only, was found in the boring at Onverwacht.

It is evident from these borings that the fluvio-marine deposits rest on continental alluvia.

In the borings made farther south, continental alluvia exclusively occur. Some clays are pure kaolin of a few m. in thickness. The sandlayers, too, may attain to a considerable thickness: often to as much as 5 m., the greatest thickness being 14½ m. (Onverwacht).

While some drillings show a frequent alternation of layers of different material (e.g. the boring at Lelydorp) the thicker layers in the borings around Republiek may extend over some hundreds of m. It must be emphasized that on the surface the same quartz sands, clays and sandy clays are found in the area under consideration. The composition of the soil changes at about every couple of hundred metres. This alternation both in vertical and horizontal direction points to the fact that *the sands, clays etc. of the continental alluvia occur in lens-shaped layers*, and not as layers which continue uninterrupted over large distances. It may be safely assumed that all these layers lie nearly horizontal.

These drillings teach us at the same time that the continental alluvia have a considerable thickness far inland. In the Lelydorp boring (74½ m.), and the borings around Republiek which may attain to a depth of 31 m. the bedrock has not been reached. The mixture of clay, red microcline and mica constituting the deepest samples from the Onverwacht boring seems to be the weathered bedrock of pegmatitic granite. The very sandy clay, rich in sharp quartz and mica, from a boring on the trail of Republiek-Matta, at a depth of 21.00 m., probably also belongs to a weathered granite-bedrock. In other borings, however, the same material is found with water-worn quartz pebbles in it, so that we must still be concerned with removed material there.

Let us now have a look at the boringsection near Nickerie, in the extreme north-west of the Colony. The starting point of the boring is approximately at sea-level. The boring has, at any rate, as far as I am aware, been continued to a good 300 m. depth without the basal complex having been reached. This section is also characterized by a continual alternation of sands, clays and sandy clays, with one single stratum of lignite (see table 5). It should be borne in mind that on the whole the samples are less reliable than in the preceding sections. The greater part of them are bailer samples, and it seems that material has fallen back. Consequently, we cannot tell with certainty which sediments are fluvio-marine and which are continental. The first dozens of metres of the section are, undoubtedly, fluvio-marine, judging from the frequency of marine molluscs. The same was seen a short time ago in a couple of shallow borings made to obtain a supply of drinkingwater ("Waldeck", and "Corantijn polder"). These first dozens of metres consist of clays, and mostly of very fine quartz-sands, generally less worn than in the sections discussed above. If we regard the fossils as the determining factor, marine deposits as deep down as 100 m. should be met with (in view of the fact that Venus Portesiana and Corbula biradiata, both marine species, occur). If this be correct, we are concerned with sediments very near to land, judging from the coarse grain, the moderately worn-down state, and the slight selection that has taken place. In some clays, coarse quartz-sand occurs irregularly distributed. It is not improbable that we have to do here with estuarian deposits.

Below 100 m., however, the majority of the deposits, possibly all of them, are of continental origin. This is indicated by the frequency of but slightly-worn, coarse sands, by the clays rich in kaolin and by the decayed vegetable matter, appearing in strata up to 1 m. in thickness, while marine molluscs are wanting. Sponge- spicules and occasionally foraminifera occur in the deeper parts of the section, but to these we can attach no value for we suppose them to have fallen back from the upper strata. The combination of the heavy minerals has been investigated all along the section. Ore and zircon are abundantly present everywhere. Mineralogically the first tens of metres of the section appear to be distinguished from the deeper parts: ore, hornblende, sillimanite, staurolite and zircon being the essential components. In the deeper parts, however, hornblende and staurolite recede considerably into the background, while sillimanite asserts itself all the more. Sillimanite attains to abnormal percentages here, sometimes to about 50 %!, not counting ore.

Leaving the upper strata out of consideration, there are two minerals showing a gradual change, to wit: staurolite and sillimanite. Fig. 6. gives the frequency expressed in percentages, obtained by counting, in which ore, leucoxene and zircon are not included. It appears that sillimanite continues to be found in abundance as far down as to approximately 200 m. and then diminishes. With staurolite it is just the reverse.

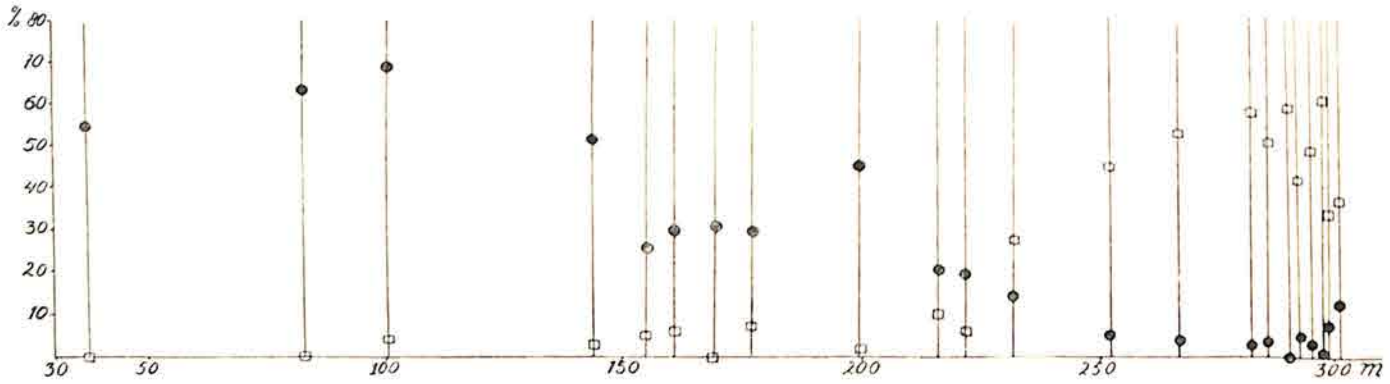


Fig 6.

● = sillimanite   □ = staurolite

For the rest, the mineral combination exhibits no gradual change. Tourmaline, garnet and andalusite may be present in considerable quantities. Kyanite, hornblende, epidote and rutile are quantitatively insignificant. Monazite, anatase, spinel, corundum and topaz are repeatedly found as accessories, while cassiterite, chloritoid, diopside, brookite, and carbonate are rarely met with.

Let us now see wheıe the material of the latest deposits has come from. For this purpose we shall turn first to the region of the Colonial railway. The combination of the heavy minerals gives us an indication here. The samples for the greater part show such a large quantity of staurolite sometimes also accompanied by copious andalusite and tourmaline that the heavy mineral combination must to a great extent be traced back to metamorphic, sedimentary schists. In this connection, the slight percentage of garnet is striking. Zircon and sometimes also monazite point to the fact that besides these, granito-diorites may have contributed also. In general, however, the combination bears a local character, which tallies with the fact that the drillings in the continental alluvia comprise but a comparatively small area, viz: the present basin of the Para creek and the divide with the Saramacca, the region around Republiek. In this area we have no exposures of solid rock, but the mineral combination renders it probable that para-schists are very frequent in the basal complex.

Now it is the question how the continental alluvia have been conveyed in the above-mentioned district. Several possibilities must be taken into consideration: conveyance by running water of rivers or creeks, settling down in stagnant water, or creeping along slopes. It seems probable that conveyance by the great rivers played a minor part. It is more likely that we are concerned with repeatedly interrupted conveyance, in which the weathering products of the basal complex, now submerged in recent sediments, moved from the insignificant divides to lower regions under the influence of washing down and also of transport by the creeks. The pure layers of clay settled in stagnant water in the flat country, a phenomenon that is common in the rainy season. Where the clayey elements were carried off, the quartz-sand remained behind as a residue and formed the layers of sand which we now find in the boring-sections and on the savannahs. It is evident that the creeks assisted in the conveyance of the material. In the rainy season they deviate from their beds, they again displace the deposits which have already been repeatedly turned over. The irregular distribution of quartz-sand in some clays is also to be ascribed to the periodical activity of the creeks. Sharp, coarse quartz-sands varying considerably in the size of the grain, form spots in the clays. These sands have probably been carried along by swiftly running water and on the latter quickly slackening its pace they have been deposited without selection as to the size. The temporary swelling of the creeks during the tropical down-pours may be held responsible for this. It is not impossible that creeping plays no insignificant part, where there were still considerable surface slopes. The vegetable matter which we so often find in the continental alluvia has been buried during the conveyance of the material. It is still possible for us to study the different displacement processes in the zone of the savannahs, where scanty vegetation presents a view over a large area. Here we see, how, on one side, clays rich in kaolin are deposited in stagnant water in the rainy season, on the other side, how sharp quartz-sands are left behind as a residue after washing. In the groves which skirt the creeks in the depressions, we may observe how trunks and branches are buried in the sands by washing, and how the sands are mixed with humus in contra-distinction to the little humus that characterizes the soil of Surinam elsewhere.

The continental alluvia from the boring at Nickerie suggest the following: The heavy minerals point to the fact that para-schists here have also greatly contributed to the material. The upper portion of the section is characterized by a very large percentage of sillimanite. Locally this mineral shows features agreeing entirely with the sillimanite-gneisses from the Upper-Nickerie region. Here too, the sillimanite shows a cloud-like dispersion of red colour, with pleochroism; it contains copious rod-shaped inclusions. We are not acquainted with such-like sillimanite anywhere else in the Colony. Besides this, spinel is common in the gneisses here, which is also true of the sediments under consideration. All this renders it likely that the said sillimanite-gneisses have contributed very materially to the composition of those sediments. It goes without saying that the Nickerie river is responsible for the transport.

The minerals in the deeper parts of the section, however, point to another origin of the sediments. Here the staurolite has by far the upper hand of the sillimanite. We are nowhere acquainted with staurolite-schists in the Upper Nickerie region. On the one hand it is possible that the staurolite had its origin in higher parts of the schist-formation of the Nickerie area which have now been completely destroyed by erosion. On the other hand the material may just as well have been conveyed from other regions. It should not be lost sight of that zircon constitutes a very large percentage of the heavy minerals which points to the fact that granitodiorites have also contributed in no small measure.

In what manner the continental alluvia in this section have come to be where they are, is not to be traced in detail. The frequency of the coarse-grained, sharp, and therefore but slightly waterworn sands points to the fact that here, too, the material cannot have been conveyed very far.

Before discussing the origin of the fluvio-marine deposits we might insert a few remarks concerning the continental alluvia in the interior of which there are but few data available. In the broad river-valleys and along the creeks we find recent deposits formed in the same way as outside Surinam. They show a repeated alternation of clays and sands, and a mixture of them in the sections. Kaolin, too has a wide distribution here, which cannot but strike everyone who sees the bank-sections along the rivers. It should be borne in mind that presumably the same conditions of sedimentation prevail in the but slightly undulating areas (which, as we have seen, occur far in the interior) as in the Para-region; so there, the large rivers have not played any part either in the building-up of the latest deposits.

On p. 38 we have already discussed quartz-sands, gravels and pebbles which are cemented together into loose sandstones and conglomerates of a variable habitus. These formations rest either directly on the solid rock, or are separated from it by loose deposits; the former case seems to be the commonest, as is seen at low water, when a section of the river banks is exposed. Elsewhere they cover the dried-up river bed. They seem only to have been observed in river-beds, and it is questionable whether they also appear beyond them. In the river-beds they are seen at quite a number of places: along the Suriname river upstream to near Goddo they rest directly on the solid rock; at low water during our expedition the pudding-stones even attracted the attention of the non-geologists. Here we often see very large pebbles in the conglomerates, both of quartz and of other rocks, covered with heavy weathering-crusts, consisting of a ferruginous substance which is only formed on submerged rocks. The conglomerates on the Marowyne river in the neighbourhood of Langa Tabbetje are also peculiar. Here we observe smooth waterworn pebbles of the size of a walnut in a clayey and ferruginous cement, covering the bottom of the river. Sandstone-like formations exposed in the banks occur at quite a number of other places: along the Suriname river; along the Gran-rio; here and there along the Lucie river; and along the Curuni river. With regard to the Nickerie river they have been mentioned by Van Cappelle.

From the literature on the subject we get the impression that these sandstones and conglomerates must have been deposited in a period during which the basal complex "as a whole" was involved in a stage of intenser erosion, because the rivers possessed a stronger power of conveyance. Even now at very low water we may locally observe pebble-deposits on the bottom of the rivers in their middle-course. These pebbles are sometimes loose, sometimes even now they are cemented together by ferruginous material, which forms a black crust on all submerged rocks. Although these deposits are, in parts, comparatively old, judging from the position at the base of the loose sediments, they are still being formed. As we have said, moreover, the cemented sands may be separated by loose material from the bed rock. It must be a local formation of relatively recent age which because of its firmness may be mistaken for an old one.

The heavy minerals of a number of river-sands have been concentrated and investigated in the usual way: the combination is usually poor in species. The sands which were collected on the surfaces of the sand-banks, have but a slight heavy portion. Where the rivers flow over the granitodiorites, hornblende, epidote, zircon and ore are present in abundance; biotite, however, is very scarce. The latter is the case in all Surinam deposits, and in contradistinction to the percentage of biotite in the rocks. Therefore, biotite must have very little resistance under tropical weathering-conditions.

The "kruit-zand" (gunpowder sand), mentioned on p. 38, which is a natural concentration, is chiefly composed of ore. Other heavy components occur in it, of course, varying according to the locality, e.g. zircon, some monazite, and in a sample from Françoiskondre on the Lower Marowyne, copious staurolite (V. 3527).

We should bear in mind that monazite only occurs in very slight quantities in the continental deposits and in the river-sands, [1]) so that there is no question of its being exploited.

The occurrence of tinstone in the Surinam alluvia was also unknown. In the boring at Onverwacht it is found at a depth of approximately 60 m. The samples from the boring at this depth consist of a coarse mixture of microcline, quartz and muscovite, together with a clayey cement. This mixture is, probably a bed-rock weathered in situ. The heavy minerals are chiefly tourmaline; with no insignificant percentage of tinstone, and some monazite. It is the yellowish tinstone variety. The tourmaline belongs to a single colour-type, and this fact also argues for little removed material. Moreover tinstone is found in the samples of the oil-boring at Nickerie, at a considerable depth.

Let us now see where the material of the fluvio-marine deposits came from. The rivers, especially in the rainy season, carry colloidal matter down to the sea. Where the fresh and salt water mix, the colloids flocculate and may be deposited (clay). The sands are also carried seaward by the rivers, rolling and sliding along the bottom, where the current is strongest. The heavy mineral combination of the fluvio-marine deposits in the neighbourhood of Paramaribo, and also near Nickerie, points to the fact that the continental alluvia have materially contributed. Near Paramaribo we find a considerable percentage of staurolite, near Nickerie, however, we find more sillimanite just as in the continental sediments in the hinterland.

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[1]) E. Middelberg. **67**. p. 6, however, gives a negative result of the research for monazite.

Again and again in literature we find Lyell's view, [1]) that the material which builds up the coastal-zone and sea-bottom along the Guianas is carried seaward by the Amazone and is conveyed in a NW. and W. direction by the equatorial current. This opinion is certainly a correct one, but it has been wrongly interpreted by Lyell's followers. Lyell's opinion must be correct in so far as it refers to substance suspended in the sea-water. The sands of the Guiana coastal region may just as well for the greater part be of local origin. The Amazone carries enormous quantities of material down to the sea. [2])

PERCENTAGE OF SOLID SUBSTANCE IN MILLIGRAMS A LITRE.

	August 1907		September 1907		October 1907		November 1907		December 1907		January 1908	
	high tide	low tide	high tide	low tide	high tide	low tide	high tide	low tide	high tide	low tide	high tide	low tide
Susanna'sdaal Suriname river												
residue	11460	3030	17720	7620	19050	11160	32200	23110	34590	26870	33200	5780
chlorine	5838	1519	8761.4	3805.6	9336.5	5559.3	15932.4	11267.7	16905.1	13163.4	15705.2	2811.6
Accaribo Suriname river												
residue	70	70	60	60	50	50	2410	800	3190	3010	470	330
chlorine	7.1	7.1	3	3	7.1	7.1	1178.6	326.6	1569.1	1469.7	85.2	57.5
Groningen Saramacca river												
residue	60	60	70	70	11680	8060	11510	5180	11660	7250	150	140
chlorine	7.1	7.1	7.1	7.1	6304.8	397.6	5818.4	2122.9	5594.8	3550	7.1	7.1

	February 1908		March 1908		April 1908		May 1908		June 1908		July 1908	
	high tide	low tide	high tide	low tide	high tide	low tide	high tide	low tide	high tide	low tide	high tide	low tide
Susanna'sdaal Suriname river												
residue	25150	4620	19960	1120	15770	850	—	—	3600	140	10840	620
chlorine	11594.3	2243.6	9315.2	497	8037.2	340.8	—	—	1732.4	28.4	5339.2	273.4
Accaribo Suriname river												
residue	150	70	80	80	70	70	80	80	40	40	100	100
chlorine	7.1	7.1	3	3	3	3	5	5	3	3	3.9	3.9
Groningen Saramacca river												
residue	90	90	90	90	90	90	70	70	70	70	90	70
chlorine	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	6	6	6	6

TABLE 6.

[1]) Lyell, Principles of Geology, second edition, 1832, p. 353—354. As early as in 1822 Gutsmuths came to the same conclusion in a detailed account of the origin of the Guiana coastland (I. E. F. Gutsmuths. **1**. p. 381—393).

[2]) Katzer estimates the dissolved and suspended substance transported by the Amazon near its mouth, at 1000 million tons a year. (Fr. Katzer, Das Wasser des Unteren Amazonas, Sitzungsber. k. böhm. Gesellsch. Wissensch. 1897. p. 1—38).

but the other rivers contribute equally. Together they supply the material forming the muddy bottom of the sea. Up to a great distance from the coast, the ocean has a dark tint; nearer to the land the water is laden with suspended matters moving westward under the influence of the equatorial current. On the one hand the as yet undeposited ooze, on the other the material loosened by the tides is displaced again and again. Whilst the material carried by the rivers is accumulated on the bottom of the sea, the coast itself is built up by the tides. They flood the low-lands and tidal-woods and deposit ooze. As we have already seen, the running of the tides is affected by the varying quantity of water conveyed from the interior. Sack [1]) has made an inquiry into the quantity of solid matter dissolved and suspended in the water of the lower-rivers and also into the percentage of salt a few of which results we may state here. The samples were taken on the first of every month at high and low water. See table 6.

It turned out that the water at the plantation of Suzanna's daal on the Suriname river is salt, both at high and low tide and in all seasons. At the plantation of Accaribo (on the Suriname river) and the settlement at Groningen (on the Saramacca) we observe, how the water is periodically salt, viz. in the months of October to December. The latter months are those of minimum rainfall (August-November), during which time the quantity of river-water from the interior is smallest, consequently the sea-water may penetrate further inland. If we calculate the quantity of Cl as Na Cl (by multiplying Cl with $\frac{50.5}{35.5}$ and if we substract this product from the total residue we get an impression of the quantity of other substances in the sea-water that enter the river mouths. This quantity is much larger than the quantity of solid substance in the pure riverwater. Hence the sea-water may, during part of the year convey a considerable quantity of material landward and deposit it on the flooded banks, but we should bear in mind that part of the material is carried back at ebb-tide. This is also illustrated by the fact that often, when the lock-gates of the plantations are opened at the close of the dry season, a considerable quantity of clayey mud has first to be removed from outside these gates. While the clayey components of the fluvio-marine deposits are partly conveyed from the interior by the rivers, partly also by the tides from elsewhere, the heavy mineral combination indicates that probably also an important part of the material comes direct from the continental alluvia inland.

Let us now turn to the question, as to how the coastal landscape has developed. At one time the sea extended farther inland as is indicated by the distribution of the fluvio-marine deposits. As the fluvio-marine deposits rest on continental alluvia the sea must once have made an ingression on the former coastland. It is probable that the few hills which are at present situated in the coastland and which seem to have a rocky core projected from the sea during the period of transgression, in the same way as the rocky islands along the coast of French Guiana do now.

Other smaller hills were probably buried under the fluvio-marine deposits.

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[1]) J. Sack. **70**.

This transgression must have been the result of a subsidence of the land, or of a rising of the sea-level.

The transgression was followed by the settling down of the fluvio-marine deposits; on account of the increase of the land, the coast-line has been shifted northward. The shell reefs indicate that there have been complications. The shell reefs, which, as we have said, extend far inland at present, rise several metres above the surrounding country. These reefs point to the fact that the coastland must have undergone a relative elevation in view of the present sea-level, whether by an uplift of the land or by a subsidence of the former; this relative elevation need only have been a few m. Which of these two causes has been active must remain undecided. If we are concerned with a subsidence of the land it goes without saying that the phenomenon must have taken place on an extensive scale, since we also find the same state of things along the coast of British Guiana.

It is a known fact that sand- and shell reefs are formed on coasts which very gradually shelve into the sea. The formation of the reefs is probably entirely due to the upbuilding action of the surf. The surf may throw sand and shells on to the coast, or form reefs in the shallow water, which, in the case of vertical incidence of the waves, will run parallel to the coast and be broken in places by channels thus providing an outlet for the water at ebb and flow, and also affording to the river-water an opportunity of flowing in and out. In this way bays [1]) are formed. It is evident that the shallowness of the sea along great distances is pre-eminently favourable to the formation of reefs of great length along the Surinam coast. It is likely, therefore, that the land has increased in this way, whilst, as we have said, a comparatively slight simultaneous uplift is probable.

It may be remarked, however, that this course of events does not agree with what is taking place at present on the coast of the Guianas. The formation of bays by reefs is seen nowhere. Consequently conditions must have been modified in later times, on account of which the increase of land on a large scale has come to a standstill. There are, indeed, indications that the reverse is taking place: some shrinking of the coast is probable, contrary to what is often stated in publications on the subject.

The Nickerie settlement has been removed considerably inland. A sketch on Cateau Van Rosevelt's map [2]) gives the position of the present "New" Nickerie, south of the Nickerie river, while the former, has been superseded by a mud-bank along the coast. In twenty or thirty years' time the coast there will have receded about ten km. inland.

A second point, where considerable loss is known, is to be found at the Coroni settlemente (approximately halfway between the Courantyne- and Coppename river). The first settlement here dates from 1808 and cotton plantations flourished here. The plantation grounds were bordered by dykes on the sea-side. At the back there was a shell reef running parallel to the coast, on the top of which there was a road. The land has now been washed away as far as the latter. At the same time when the land was being washed away, mud-banks began to form along the coast, hampering navigation.

Near Braamspunt at the mouth of the Suriname river, there used to be a sandy beach, which took at least half an hour to walk along. This has been washed away during the last decade.

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[1]) "Haffs" in German.

[2]) J. F. A. Cateau van Rosevelt. **18.**

In several places the mangrove woods along the coast have been forced back and the roots which became exposed have accumulated on the shore.

At the mouth of the Warappa creek (connecting the Commewyne river with the sea) there must have been three plantations, besides a military station in the early part of the previous century, which have now been washed away.

In connection with this recent shrinking of the coast we want to state here that earthquakes are felt, time and again in the coast-land. Though the epicentres are unknown, it is probable that the continental border is unstable at present.

Summing up we may say that the following development of the coastal landscape is probable:

1) Transgression of the sea over continental alluvia to the boundary of the fluvio-marine deposits. The cause of the transgression is undecided.
2) Regression of the sea and increase of land, during which a slight uplift of the coastal area probably took place (judging from the present high position of the reefs). The regression possibly extended farther than the present coast-line.
3) Cessation of the formation of bays and of increase of land; some loss of land in the present time.

From the preceding it will be clear that most of the fluvio-marine and continental alluvia are of a very recent date. We ascribe them to the Pleistocene and the Holocene. In one of the shell reefs near Paramaribo even shards of Indian earthenware have been found. [1])

Now we may ask ourselves what the thickness of the latest deposits in the coastal regions amounts to, of what age the deeper parts are, and what there is to be known about the tectonics. The crystalline basal complex, which disappears under the latest deposits, crops out in the East of the Colony, on the Marowyne, at approximately 30 km. from the coast, in the West, on the Courantyne, at approximately 100 km. from the ocean, and in the intervening rivers at proportional distances as we go from East to West. Hence most space is left for the latest deposits in the West, and owing to this it is also probable that they are thickest in the West. There are indications of the basal complex having an irregular surface. Some hills, such as those of Topibo and Portorico, lie forward rather far into the latest deposits, and their laterite-covering leads us to suppose that they have a crystalline core. But also farther Northwards, buried under more recent deposits, the solid rock of the basal complex is said to have been met with; according to Essed [2]) the solid rock occurs at 14′ depth at the mouth of the Boekoe creek on the Cottica river; igneous rocks are said to form the basis of the shell reef on which Groningen (on the Saramacca) has been built. Other data point to the fact, however, that the most recent deposits may attain to a great thickness. The bed-rock near Onverwacht on the Colonial railway has been reached at a depth of abt. 60 m.; a boring at Paramaribo has penetrated 180 m. [3]) into loose sediments and come to an end in a "woodlayer" (probably lignite)

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[1]) According to Voltz; see K. Martin. **26**. p. 202.
[2]) E. Essed. **105**. p. 331.
[3]) In accordance with verbal information obtained at Paramaribo. It is a great pity that no further data concerning the sediments met with, have been preserved.

without reaching the basal complex. The oil-boring at Nickerie has been deepened by more than 300 m. without the basal complex having been reached.

We must point out emphatically that the deposits in the coastal regions, in as far as is known to us, must be regarded as very late formations. This not only applies to the fluvio-marine deposits, the upper portions of the section, whose fossil-contents prove its age, but it may also be assumed for the deeper portions of the Nickerie boring. The sediments have exactly the same habitus as that of the Holocene. Some clays in the deepest parts of the section are compact and approach the clay-shales in habitus. The compact structure is probably the result of the pressure of the sediments above them. The whole section may safely be regarded as not being older than Diluvial. Whether an older formation possibly Tertiary, occurs in the deepest parts of the coastal regions, is quite uncertain, and can only be ascertained by the continuation of deep borings.

In connection with our view concerning the structure of the coastal region, it is desirable to inquire into what is known in the adjoining country of British Guiana. The knowledge of the deeper parts of the coastland is much greater there than with us. During the last decennium, borings have been carried out by the Government and by private owners in search of oil or artesian water. These borings have been made under the supervision of Sir John Harrison, Government Geologist. From Harrison's summary the following salient points have been taken. [1]) Most important to us are the borings carried out between the mouths of the Courantyne and the Essequibo rivers, near the coast. The subjoined table shows the results.

SCHEMATIC PROFILE OF THE COUNTIES OF ESSEQUIBO, DEMERARA AND BERBICE, IN A NW.—SE. DIRECTION, NEAR THE COAST.

	NW. (County Essequibo and Demerara)	SE. (County Berbice)
fluvio-marine deposits	0—119 ft.	0—176 ft.
dune-sands	119—191	176—462
sandy clay	—191/250/270/308 [1])	—462/718/904 [1])
	stratum of lignitic sandy silts.	
shaly calcareous or ferruginous clay, fairly compact shales, silts, sands	—368/608/abt. 700/856 [1])	—978/1084/1479 [1])
	bedrock attained	bedrock not attained

[1]) records from several borings.

TABLE 7.

On the surface along the coast we find fluvio-marine, and inland continental alluvia. The fluvio-marine in the South-East is thicker than in the North-West; locally attaining to a thickness of 256 ft. The thickness decreases going inland. The fluvio-marine deposits rest on dune-sands. The thickness of those dune-sands is on an average 182 ft. The surface is marked by some elevations and depressions. The base, and this is important, lies higher in the North-West than in the South-East. The thickness of the dune-sand diminishes inland. As has

[1]) J. B. Harrison. **103.**

been proved by the borings the dunes have been piled upon a sandy clay, the lower parts of which are marked by a persistent bed of black lignitic sandy silt. This belt has been traced in the majority of the borings from Parika in the West on the Eastern bank of the estuary of the Essequibo river to New Amsterdam in the South-East. In the vicinity of Georgetown the lignitic stratum occurs at a depth of 250—276 ft. whilst at Lichfield and at New Amsterdam it was traversed by the borer at 718 and at 904 ft. respectively. The characteristics of the strata below the horizon of the lignite differ very greatly from those above it. The lower strata are shaly, calcareous or ferruginous clays, soft to fairly compact shales, silts and estuarian marine sands. The clays commonly contain nodules of argillaceous limestone, or of clay ironstone, while some of them contain casts and fragments of globular foraminifera. It is this series of beds, non existent or not recognizable in well-borings situated to the West of the Essequibo river, which is regarded by Harrison as possibly being of Tertiary origin. They are of another types than the unconsolidated recent alluvial deposits which occur above the horizon of the dune-sand.

The basal complex dips from NW. tot SE. It was reached at 308 ft. at the estuary of the Essequibo (Parika boring); at 608 ft. more to the East near Leonora; at abt. 700 ft. near Georgetown; at 856 ft. at Nabaclis; more to the East, between the mouth of the Essequibo and of the Courantyne, however, the basal-complex has not been reached; the boring at Lichfield has been continued to 900 ft.; that of New Amsterdam to 1479 ft.; that S.S. West of N. Amsterdam, near Friends to 1084 ft. Hence the sediments are decidedly thickest in the SE.; the recession of the basal complex far inland on the Courantyne is, as we have seen, in agreement with it.

The section in NE. of British Guiana, therefore, shows fluvio-marine deposits, which to the depth, make room for dune-sands with clays and a lignite-bearing stratum at the base, which must have been formed at a period of regression of the sea, while all of them together may be reckoned among the latest deposits. Under these come strata of different lithological composition, which may be Tertiary, but let it be expressly understood, that this has been regarded by Harrison as an open question. [1]) That this modification in facies means an important change in the conditions of sedimentation, is clear; the sediments are marine- and estuarian deposits; except the remnants of foraminifera which do not allow of closer identification no fossils, which would enable us to ascertain the age, have been found. Nor is it to be ascertained from a theoretical standpoint, to what interval of time the change in the facies corresponds.

Apart from the gradual dip of the sediments from NW. to SE. and in the direction of the ocean, Harrison has brought forward no conclusive arguments which point to the fact that the older parts of sedimentary deposits show tectonic disturbances. The only sediments that might be considered as disturbed are regarded as being possibly false-bedded: "The lower sections of the borings at Pln. Friends where through highly-disturbed and inclined strata, possibly false-bedded . . ." [2]).

Let us now see what these experiences in Br. Guiana show in connection with Surinam. There are many points of similarity, but also points of difference. We did not come across the dune-sand formation, nor are we acquainted with the clay shales etc., found in the deeper parts. When we regard the coast-land of Surinam tectonically, the following is probable. The

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[1]) In an older publication Harrison (**68.** p. 19) suggested that the deeper parts of the latest deposits might be compared, as to their age, with the Moruga sands of Trinidad which are of Tertiary age. This supposition dates from before the time when the deep borings were carried out, and apparently Harrison himself has afterwards abandoned it.

[2]) J. B. Harrison. **103.** p. 10.

basal complex in the east lies close to the surface (Marowyne). In the West it lies deeper (the Paramaribo and Nickerie borings). The deepest probably it lies in the county of Berbice (bed-rock not reached). Still more to the west, we find the reverse, in the counties of Demerara and Essequibo, the bed-rock gradually approaches the surface more and more, as we go westwards. The bedrock nearest to the surface has been met with at 368 ft. In agreement with this, the exposures of bed-rock recede farthest inland in the Courantyne basin.

It is probable that this position of the basal complex is a result of tectonical movements in the complex. It must have subsided comparatively most in the Courantyne region. In this connection it is not impossible that the deeper parts of the latest deposits in Surinam do not lie strictly horizontal, but viewed over great distances show some dip agreeing with that of the basal complex just mentioned, consequently in the same way as Harrison has demonstrated for his dune-sand-formation in British Guiana.

F. *On the origin of the Savannahs.*

As we have seen, the savannahs are found particularly in the zone of continental alluvia adjoining the fluvio-marine deposits inland. They form a gently rolling landscape. Although the savannahs may cover areas of many km^2. they constitute no more than local breaks in the extensive primeval forest. We meet with vegetation along the streamlets which rise in the savannahs. The transition to the primeval forest is not clearly marked. The sharp and coarse quartz-sand found on the surface is typical of the savannahs; by the side of this sand, sandy clays occupy no insignificant part and both may occur in the same savannah.

Let it be borne in mind in the first place that the savannahs do not owe their origin to lack of rain during a great part of the year; the rainfall is not less than that in the surrounding country. The cause of the absence of forest-vegetation must be looked for in the barrenness of the soil, the origin of the Surinam savannahs is to be attributed to edaphic factors.

It should be expressly pointed out that the profile of the subsoil in the savannahs, shows no difference from that which characterizes the continental alluvia elsewhere; borings made in the savannahs and in the neighbouring forest indicate this clearly (cf. Zandery I boring and Savannah boring path Matta-Republiek, with the others, Table 3, 4 and 5). The same sands that characterize the surface of the savannahs also occur beneath them, alternating with sands and clays.

It seems that the savannahs, in as far as the data allow us to judge, are on the whole, situated in those areas where the gently rolling ground about reaches its greatest height, belonging partly to the flat watersheds. The savannahs of Pl. 8 fig. 1 belong to the watershed between the Saramacca river and the Para creek, the Coropina creek and the Saramacca creek flowing down to the latter. Pl. 8 fig. 2 which gives an outline of several savannah-complexes also shows that the savannahs lie higher than the surrounding country.

Plate 7.

Grass-savannah near the Coesewijne river.
Inset: group of Mauritia-palms (Mauritia flexuosa).

It is the position of the savannahs that accounts for their barrenness. The rain-water penetrates into the ground, and the groundwater partly flows away to the somewhat lower-lying ground in the vicinity partly into the brooklets that occur in the savannahs. Although the level of the savannahs is but slightly above that of the surrounding country, leaching of the soil takes place year in and year out. The sands already poor in themselves, and the clays rich in kaolin, will loose what they still contain in alkalies. The result is an extremely barren soil on which nothing will grow. The groundwater, however, draining the deeper strata of the higher-lying parts of the savannahs, which strata have been leached to a smaller extent than the surface, carries dissolved matter with it and renders vegetation along the brooklets that arise in the savannahs, possible. Parts that seem destined later on to give rise to savannahs may also be met with in the forests. The soil there has the same character as in the savannahs, and the trees, among which there are many Euphorbiaceae, are greatly stunted in growth. Such-like forests are known in Surinam under the name of "Moeri-moeri-bosch", and, in as far as they are not caused by solid rock lying close to the surface, they are produced by the same factor as the savannahs.

In works on Surinam the opinion is sometimes expressed that the savannahs are in a period of diminution, and that the forests gain ground. We may assume, however, that the leaching-process is steadily extending not only in a vertical but also in a horizontal direction, which cannot but result in an extension of the savannahs. There are, however, two factors which may act in a contrary sense: viz. the rising of the groundwater level, which will certainly follow a possible subsidence of the soil and the denudation of the surface of the savannah complexes.

G. *The Laterites.*

Before describing the Surinam laterites, it is desirable to give a short outline of the current ideas about the chemical weathering process.

General data about chemical weathering.

In chemical weathering H_2O, CO_2 and O_2 must be considered as agents. The effect of the water may be divided into:

1) Dissolution, in our case of less importance, in view of the little dissoluble components of the Surinam rocks.
2) Hydrolysis. Hydrolysis causes the formation of free silicic acid and bases from the silicates. The quantitatively important aluminium silicates however, furnish colloids of aluminium silicate; in the purest form this is kaolin ($H_4\,Al_2\,Si_2\,O_9$) which is one of the most important components of clay. These colloids, just like the hydrates which arise out of the oxides of iron and manganese and partly also out of the titanium oxides, occur as gels.

   So we have to do with a division into a movable and an immovable group; the latter (Al, Fe, Ti, Si) is concentrated in weathering residues, the former (Ca, Mg, Na, K) is carried away.

CO_2 forms with the movable bases and with some Fe and Mn dissoluble carbonates. The effect of the CO_2 on the silicates seems to be of secondary importance in comparison with that of the hydrolysis. [1])

The oxidizing effect of O_2 may here remain unconsidered. Herewith the course of weathering is very schematically represented for the silicates and oxides, but not for quartz. Free quartz is little soluble, and consequently remains, in as far as primarily present, in the unmoved weathering residue.

In the temperate zones the kaolinic weathering silicates seem to be constant, in the tropics, however, as a result of stronger weathering, the ratio $Si\ O_2$: $Al_2\ O_3$ may approach to zero, in which case we have to do with laterites. Besides the laterites, however, we just as well know in the tropics weathering products such as arise in temperate climates, e.g. kaolin, which is widely spread in Surinam. Besides we often find brown, red-brown, or red soils which occur in the tropics, referred to simply as "laterite", which has partly been proved to be wrong, at least in this sense that not all red and brown soils appear to contain free hydrated aluminium oxide, and consequently cannot be called laterite in a stricter sense. Among these variegated non-lateritic soils we may distinguish two groups. The soils of the first group contain a considerable percentage silicic acid, so that the $Al_2\ O_3$ is bound as aluminium hydrosilicate. These soils are rich in gels, they easily absorb water and are plastic. On drying they crumble. Through the percentage of gels they absorb bases. Free quartz may be admixed in varying degree. This type does not differ essentially from such soils as occur in sub-tropical areas. We find this type treated in the literature on the subject under various names. Shantz and Marbut use the term "Red Loams", [2]) Bennett and Allison "Plastic soils", [3]) Vageler "Silicatische Rot- und Braunerden", [4]) Harrassowitz "Braun und Rotlehme". [5])

The second type is poorer in $Si\ O_2$, contains free hydrated aluminium oxide, is poor in colloids, is much permeable, is not plastic, retains little bases. Quartz may also be found admixed here in variable percentages. This type occurs only in the tropics. It is indicated by Shantz and Marbut as "Lateritic Red Loams", by Bennett and Allison as "friable soils" (indicating the physical character) by Vageler as "lateritische Braun- und Roterden", by Harrassowitz as "allitischer Rotlehm".

Both types may occur in the same areas, the first as the initial stage of the second; the first however, especially in areas with an uninterruptedly humid climate, the second where change of monsoon takes place (i.e. according to the cited literature). The de-silification in the formation of laterite may

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1) E. Ramann. Kohlensäure und Hydrolyse bei der Verwitterung. Centralblatt f. Miner. etc. 1921. p. 233.
2) H. L. Shantz and C. F. Marbut. The Vegetation and Soils of Africa. New York. 1923.
3) H. H. Bennett and R. V. Allison. The soils of Cuba. 1928.
4) P. W. E. Vageler. Arch. Theecultuur Nederl.-Indië. Batavia. 1926. Nr. 2.
5) H. Harrassowitz. Laterit; in E. Blanck. Handbuch der Bodenlehre III. Berlin. 1930.

Plate 8.

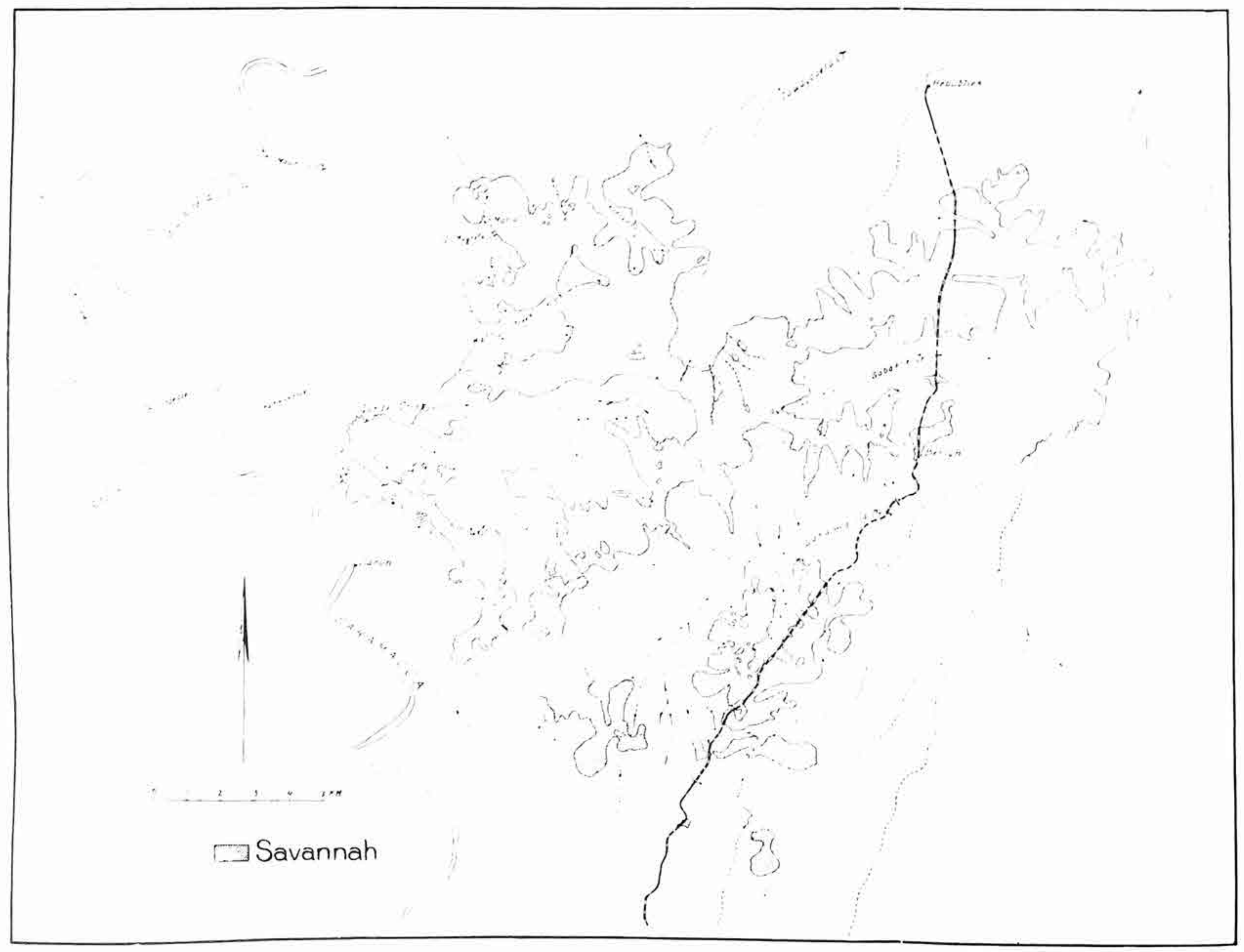

Fig. 1. Sketch-map of savannah near Republiek (Colonial railway).

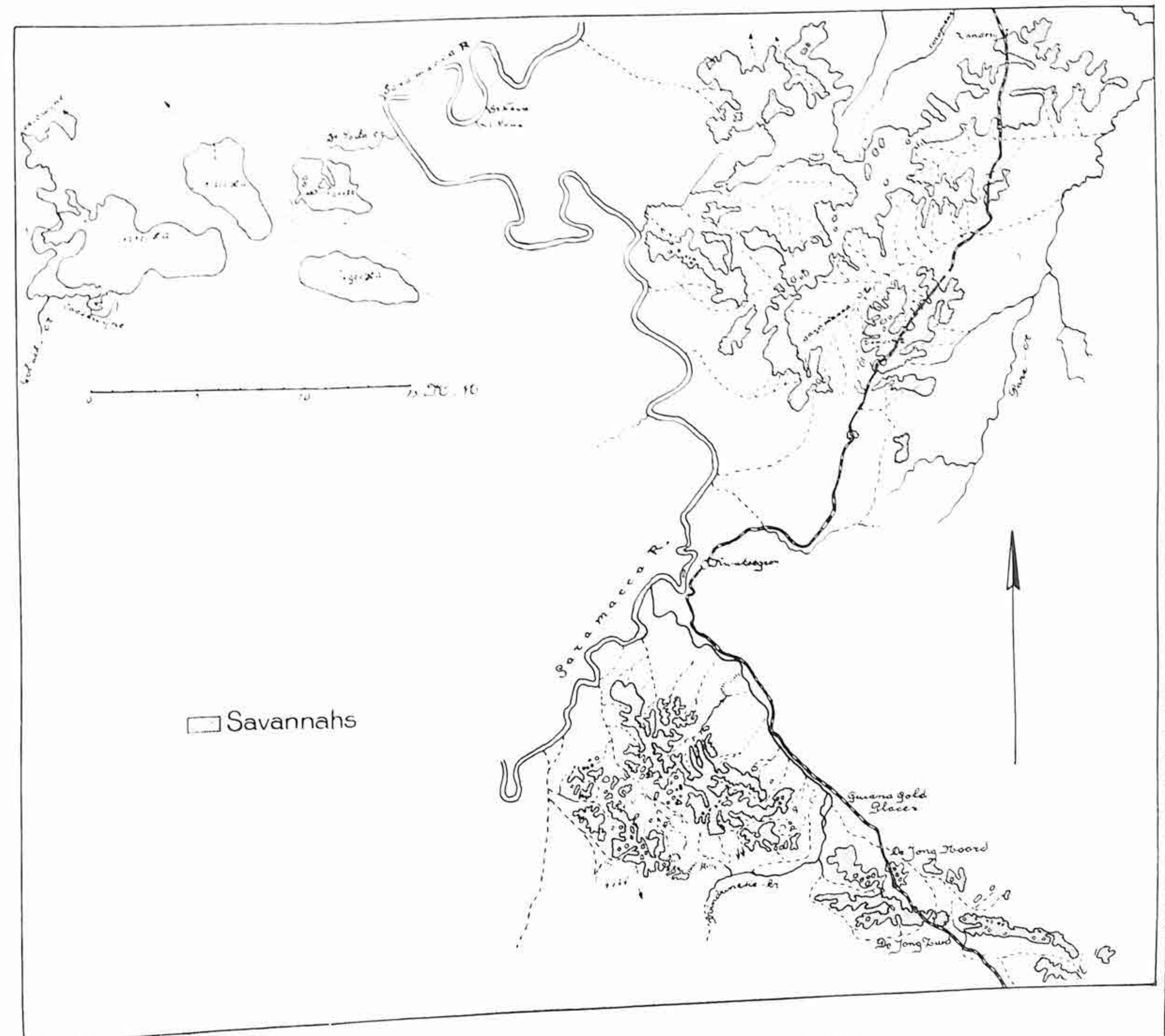

Fig. 2. Sketch-map of savannahs along Colonial railway and between Saramacca and Coppename rivers.

go so far that there result products very rich in free hydrated aluminium oxide, which have in their purest form the composition of bauxite, the latter being of the greatest importance for Surinam.

The concentration of hydrated iron oxide may produce lateritic iron ores, which are also widely spread in Surinam. Bauxite and iron ore are found mostly at the surface of the laterite profiles. It is supposed that these concentrates are not only the result of weathering in situ, but that also migration of products in an upward direction has taken place. An argument in favour of the latter opinion is the absence of free primary quartz in bauxite which has been derived from acid rocks, for it is assumed that quartz in the process of lateritization is little affected. For the formation of laterites generally and for that of bauxite in particular, the reader may be referred to the subjoined literature. [1])

The Surinam Laterites.

After Bauer in 1898 [2]) had recognized the chemical nature of the laterites, we find among the long series of publications, treating of laterite and its formation, writings, in which Surinam material formed part of the investigations. These are the publications of Du Bois [2]) and of Van Bemmelen. [3])

Du Bois considered the problem from various points of view, Van Bemmelen especially from the chemical one.

Van Bemmelen emphasizes the differences between the products of lateritic and kaolinic weathering, by means of extractions with hydrochloric- and sulphuric acid, instead of the previously universal method of total analysis.

Du Bois in his well-known publication discusses the Surinam laterites at great length: many of his data have been taken over in later publications. Du Bois expressed his opinion about the cause of laterite formation (l.c. p. 29—30). He assumes that sulphuric acid, formed by oxidation of pyrite, causes the lateritization; besides, sulphuric acid formed from vegetable matter may likewise be active. Pyrite as such cannot have a primary influence, numerous rocks, containing no pyrite, weathering into laterites. Besides, the oxidation of pyrite above the ground-water level, where moreover the formation of laterite chiefly takes place, is very soon accomplished, and it is not clear whence the sulphuric acid, necessary for the continuation of the lateritization, should proceed.

It stands to reason that we must look for the initial phase of lateritization, where the solid rock undergoes the first changes. As elsewhere, the lateritic weathering appears to penetrate to a considerable depth. Here and there natural or artificial exposures show how deep the weathering-process goes.

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[1]) H. Harrassowitz. Laterit. Fortsch. d. Geol. u. Palaeont. IV. 1926. p. 1.
C.S. Fox. Bauxite. 1927.
C.S. Fox. The Bauxite and Aluminous Laterite occurrences of India. Mem. Geol. Survey India XLIX. 1928. p. 1.

[2]) M. Bauer. Beiträge zur Geologie der Seyschellen, insbesondere zur Kenntnis des Laterits. Neues Jahrb. Miner. 1898. II. p. 163.

[3]) G. C. Du Bois. **46**.

[4]) J. M. van Bemmelen. **48**, **52** and **74**.

Near the Suriname river, and the Curuni river above "Point right about" and probably in many other places, the rivers cut through the hills and show that the weathered covering reaches a thickness of at least 20 metres. Exposures in the gold-mines show the same. In a shaft on the "Old Lionarons placer" near Boschland (Suriname river) no change in laterite was observed, according to Du Bois, down to at least 22 metres; the last metres, however, were more compact and difficult to pierce.

It is a well-known phenomenon in Guiana as well as elsewhere, that the structure of the starting material may long be preserved in the lateritization, the weathered mass being rich in pseudomorphs. Du Bois records this for Surinam: [1]) Duparc for laterites in Venezuela near El Callao [2]). The same phenomenon we often see with blocks included in laterite still containing a core of entirely unweathered rock.

The chemical composition of the laterites in the initial stage has been investigated for Surinam in a few cases only. The following table gives the composition in comparison with the unweathered starting material, viz.: a diabase poor in quartz (acc. to Du Bois p. 24).

	Initial laterite	Diabase
SiO_2	43.64	46.20
TiO_2	traces	3.10
Al_2O_3	19.32	12.23
Fe_2O_3	27.57 (with FeO)	9.25
FeO		8.95
Mn O	0.72	1.10
CaO	—	8.50
MgO	traces	4.93
$Na_2O + K_2O$	—	3.91
H_2O	8.71	1.72
	99.96	99.89

TABLE 8.

In this laterite there appears to be present 2½ % of free quartz. There is no question as yet of a typical laterite. Nevertheless it is remarkable that the alkalis and alkaline earths have almost disappeared.

Figures representing the concentration of iron and the decrease of silicium oxide in a Surinam laterite profile, we find in the following table 9, derived from a laterite profile 15 m. deep, of the Maäbo hill on the Colonial railway. [3]) The primary rock is unknown.

Little is known about the chemical composition of the variegated, red-brown or yellow-brown "laterites", which are widely spread in the interior. They cover the hills, the mountains and even steep mountain-ridges. It is doubtful whether these soils are real laterites in the narrower sense, so whether they bear $Al_2 O_3$ that is no longer combined with silicium oxide. For we have

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[1]) G. C. Du Bois. **46**. p. 21.
[2]) L. Duparc. **100**. p. 35.
[3]) According to E. Middelberg. **67**. p. 6.

depth	iron	silicic acid.
0.20 M.	21.91 %	22 %
1 ,,	32.49 ,,	18.5 ,,
2 ,,	31.47 ,,	19 ,,
3 ,,	18.94 ,,	28.5 ,,
4.5 ,,	17.31 ,,	35.5 ,,
6 ,,	18.12 ,,	38 ,,
7 ,,	16.36 ,,	39.5 ,,
8 ,,	16.20 ,,	42 ,,
9 ,,	16.00 ,,	47 ,,
10 ,,	16.20 ,,	45 ,,
11 ,,	15.40 ,,	44.5 ,,
12 ,,	14.10 ,,	46.5 ,,
13 ,,	13.18 ,,	48 ,,
14 ,,	12.55 ,,	49 ,,
15 ,,	11.26 ,,	49.5 ,,

TABLE 9.

already expounded that variegated weathering soils formed in the tropics, not always fall under the idea of laterite, and that among them we can distinguish two types differing in chemical and also in physical properties. Which of these two types preponderates in Surinam we know by no means. That the first, plastic type (see p. 64) is considerably spread, becomes probable if we remember that on the steep slopes there generally occur variegated weathering-soils, which must necessarily be plastic. Neither among the analyses of Du Bois, nor among those of Van Bemmelen do we meet with any of these soils. These analyses refer to typical laterites. The analyses of Van Bemmelen point to the considerable variation of the percentage of iron and free hydrated aluminium oxide of the Surinam laterites (see Van Bemmelen 1904. p. 308—310 Table XIV—XVIII.)

The Ferrous Laterite Concentrates.

The iron laterite concentrates appear in the laterite on the surface as scoriaceous, porous, red-brown masses or as shot- and bean-ore; the loose pieces mostly coalesce to crusts covering the soil, and are known in the Colony as Kakkerlakiston (French: Roche à ravets; Venezuela: Moco de hierro). These crusts of iron ore, which extend over a large area in Surinam, greatly draw the attention. They occur on hill-slopes as well as on the tops, and may cover them with a compact crust. They are overgrown with primeval forests. Here we often see the crusts, cut through by erosion, fall asunder into blocks, the respectable thickness which these rocks may attain to becoming visible. Du Bois mentions a thickness of 5 m. [1]) I have observed the

[1]) G. C. Du Bois. 46. p. 18.

same thickness of crusts on the watershed between Mindrineti creek and Suriname river. They are said to reach even larger dimensions on the Guiana Gold placer, near the Donderbari mountain, where, according to Voit, [1]) their thickness amounts to 15 m., and where they occupy an area of several km.^{2}

The crusts consist of a porous mass, penetrated by channels and caverns, in which sometimes haematite is visible. Usually however they are coated or filled with lighter coloured material: kaolin and sometimes also crystalline hydrargillite.

Chemically they exist chiefly of hydrated iron oxide with a variable quantity of hydrated aluminium oxide, silicium and titanium oxides. According to Voit, the bean-ores of the Guiana Gold placer are often provided with an outward shell of magnetite.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Fe_2O_3	62.08	55.94	62.2	65.5	65.0	70.4	85.7	75.6	69.4	67.15	83.4	86.9
SiO_2	7.50	14.89	3.6	5.0	4.5	9.2	2.2	8.6	10.4	10.08	7.0	3.1
Al_2O_3	0.14	17.97	18.2	14.2	15.0	11.8	0.2	10.0	11.4	13.45	5.0	4.0
TiO_2	14.08	—	2.0	2.0	2.0	0.75	0.3	0.8	1.0	1.0	—	—
MnO	0.09	—	—	—	—	—	—	—	—	—		—
P_2O_5	0.07	—	—	—	—	—	—	—				—
CaO	0.02	traces	—	—	—	—	—	—	—	—	1.0	1.0
MgO	—	traces	—	—	—	—	—	—	—	—		
NiO	0.004	—	—	—	—	—	—	—	—	—	—	—
H_2O+	15.60 (H₂O+ and H₂O−)	11.03	12.1	12.0	12.4	6.63	11.0	3.7	6.7	6.72	4.0 (H₂O+ and H₂O−)	5.4
H_2O-			1.9	1.3	1.1	1.22	0.6	1.3	1.1	1.6		
	99.584	99.83	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.4	100.4

Of I, II, XI, XII the findspot is unknown, III—X refers to rocks of the Donderbari mountain.

TABLE 10.

The table above represents the composition of these porous laterite crusts, column I and II according to Du Bois; [2]) column III—X according to Voit; [3]) X gives the average composition of a great number of samples.

In the porous ores there may locally occur concentric structure. With other types this structure becomes clearer and clearer, and we see a sharp boundary between concretions and cementing material; the latter has a lighter colour and is apparently less ferrous than the concretions; in the extreme case, the concretions are purely rounded off and so numerous that the whole has oolitic structure. [4]) If a clayey cement appears between the separate concretions, the last type passes into shot-ore, from which the loose concretions which are again purely round, may be easily isolated. [5]) Analysis XI refers to a type with oolitic structure and ferruginous cement, analysis XII to loose concretions of more irregular form, according to Du Bois. [6]) The Donderbari ores according to Voit, contain no phosphorus at all or a percentage that can hardly be ascertained.

[1]) F. W. Voit. **101.** p. 20.
[2]) G. C. Du Bois. **46.** p. 19.
[3]) l.c. p. 21.
[4]) V. 148, 784, 785, 1540, 1605, 1717, 1718, 2218, 2411, 2414, 2415, 2416, 3614, 3615.
[5]) e.g. V. 1669, 1719.
[6]) l.c. p. 33.

Remarkable is the large percentage of $Ti O_2$ in one of Du Bois's samples, which is so large that it will seldom be found mentioned for laterites, and the question arises in which form it is present, either as ilmenite or as hydrated titanium oxide.

The original material of these iron laterites is furnished by basic rocks, to all appearances especially diabases, gabbros and epidiorites derived from them, while probably also amphibolites come into account. On epidiorites I have seen them near the above-mentioned watershed; on gabbro in the Wilhelmina mountains; for diabases they are recorded by Du Bois; in Demerara they occur on the same rocks.

According to Voit similar ores occur in the Guiana Gold placer on schists that are rich in hornblende, but the original material of the most important ones, i.e. those of the Donderbari mountain, is unknown; I expect it will not be a peridotite, as Voit supposes, in view of the fact that this rock has as yet been unknown in Surinam.

About the nature of the laterite profile that forms the basis of these concentrates, we possess no data.

Extensive prospects [1]) have shown that at present there is no sense in the exploitation of these iron ores.

Two types of iron ore concretions, which have been formed under different circumstances from the previously discussed lateritic iron ores deserve separate mention, because they are not formed from the weathering products of basic rocks, nor do they grow together into covering masses. In the motley weathering products covering granites and acid diorites iron ore concretions often occur in profusion. They are found at some decimeters' depth already, so that they often come to the surface through the washing away of the soil. It is not known whether the soils in which they occur contain free hydrated aluminium oxide and consequently are laterites in a stricter sense. The rock from which the weathering-soils are derived need only contain a small percentage of ferrous material, for in the Wilhelmina mountains for instance, the concretions were found in soils that were derived from granite poor in biotite, even almost aplitic. The concretions show a smooth or knobby surface; they may be as big as a fist, but are usually smaller. The bigger ones are more or less potato-shaped, the smaller ones are rounded off and the smallest are often purely globular. The smaller concretions appear to be homogeneous, apart from some indication of zonary structure. The concretions can not be distinguished from those which occur together with the afore mentioned crusts of lateritic iron ore.

The larger ones, however, include a varying percentage of sharp grains of quartz, which are present in the weathering-soils in a large quantity. The following analyses represent the composition of such concretions, viz.: of the quartz-free form (I) and the quartz-bearing one (II), the first according to Du Bois [2]) and the second according to a new analysis.

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1) by Prof. Dr. J. A. Grutterink, in 1920.
2) G. C. Du Bois. **46.** p. 33. Nr. IX.

	I	II	III
Fe_2O_3	81.28	32.93	64.05
MnO	0.06	0.01	0.31
P_2O_5	1.88	0.11	0.03
SiO_2	1.17	41.97	13.62
TiO_2	0.04	0.41	0.21
Al_2O_3	6.25	14.14	8.83
NiO	0.004	—	—
CaO	0.03	—	—
H_2O+	9.02	9.32	11.12
H_2O-		1.40	1.66
	99.734	100.29	99.78
Anal.	Dr. Heffelman Dresden	Dr. Spoelstra Colonial Institute Amsterdam	Dr. Spoelstra Colonial Institute Amsterdam

TABLE 11.

The first concretion certainly possessed some free hydrated aluminium oxide. In the second analysis a considerable percentage of free quartz must be taken into account. The exact percentage is unknown, as the percentage of quartz in the concretions is subject to great variations. In one concretion the percentage was fixed at 15 %, but the analysis suggests a much larger percentage. This analysis represents the composition of a concretion, appearing in a yellow-brown weathering-soil on biotite granite near the Bush-negro village of Semoisi on the Suriname river (Y. 64).

The concretions that may be met with on the savannahs must have been formed under different circumstances again. For here we see dark, strongly flattened concretions, with a rough, partly knobby surface. On the cross-fraction they are homogeneous or finely porous. Their shape and position point to their having originated on the surface of the savannahs. Column III gives the composition of one of the concretions, collected on a savannah near the station of Gros placer on the Colonial railway (Y. 375). Here, too, a certain percentage of free quartz must be taken into account. It is very probable that the occurrence of these concretions on the surface of the savannahs is owing to alternating heavy rainfall and drought, consequently to periodically rising ground-water.

The Aluminous Laterite Concentrates (Bauxites).

Pure bauxite is chiefly composed of hydrated aluminium oxide. The question in what relation H_2O is combined to Al_2O_3, must be considered as not yet solved. In the latest publications it is defended that it is chiefly monohydrate ($Al_2O_3 . H_2O$),[1]) then again that it is bihydrate ($Al_2O_3 . 2 H_2O$).[2]) Very often, however, trihydrate in crystalline form (hydrargillite or gibbsite) occurs in bauxite in a smaller percentage, as a secondary product. The other hydrates are always amorphic.

[1]) H. Harrassowitz, Naturwissenschaften 17, 1928, p. 928.
[2]) T. V. M. Rao, A study of bauxite. Miner. Magaz. XXI. 1928. p. 407.

In a smaller percentage other laterite components have been admixed, ferric hydro-oxide, silicium oxide and titanium oxide. Silicium may be present in an indissoluble condition (quartz) but just as well as hydrous alumino silicate.

	I	II	III	IV	V	VI	VII	VIII
	Moengo Upper Cottica river	do	do	Plantage Acca-ribo Suriname river	loco non dato	do	do	Moengo Upper Cottica river
SiO_2, free	1.78	2.36	0.3	0.87	7.0[1]	14.5[1]	3.1[1]	0.47
SiO_2, combined			1.2					
TiO_2	0.85	0.90	0.9	3.61	—	—	—	1.78
Al_2O_3	64.02	63.51	64.6	57.8	63.3	48.5	52.5	33.56
Fe_2O_3	0.49	0.32	1.2	6.6	10.5	21.6	14.4	44.26
H_2O+ (105°)	32.22	32.64	31.8	31.0	17.6	14.0	27.6	19.64
H_2O-	0.41	0.23						0.41
MnO	traces	—	—	—	—	—	—	—
MgO	0.03	—	—	—	—	—	—	—
CaO	0.05	—	—	—	—	—	traces	—
Na_2O	0.02	—	—	—	—	—	—	—
K_2O	0.12	—	—	—	1.0	1.0	1.5	—
SO_3	0.03	—	—	—	—	—	—	—
P_2O_5	0.03	—	—	—	—	—	—	—
Cr_2O_3	0.06	—	—	—	—	—	—	—
V_2O_5	0.007	—	—	—	—	—	—	—
	100.117	99.96	100.00	99.95	99.4	99.6	99.1	100.12
Anal.	Dr. Möser Gieszen	Dr. Spoelstra Col. Inst. Amsterdam	do	Prof. S. J. Vermaes Delft	1) As secondary chalcedony	1) do	1) do	Dr. Spoelstra Col. Inst. Amsterdam

I ex. H. Harrassowitz. Laterit. in E. Blanck, Handbuch der Bodenlehre III. 1930, p. 422.
II, III and VIII ex. D. Ouwehand. **109**.
IV ex. J. A. Grutterink. **93**.
V—VII ex. G. C. Du Bois. **46**. p. 37.

TABLE 12.

The composition of highly-concentrated bauxites is given in columns I—IV of the above table. A full analysis has been published by Harrassowitz (I); the other analyses have been gathered from diverse publications; the analyses V—VII refer to oölithic bauxites. For technical purposes these bauxites are among the best in the world, except the oölithic forms mentioned here.

The highly concentrated bauxites have a very variable habitus judging from the material in the Delft Polytechnic. Macroscopically the structure is finely granular, dense, or porous, with small irregularly distributed cavities. Besides we also find samples with oölithic structure. The colour varies from pink, pinkish cream, greyish white, bluish grey, to light or reddish brown. The light-coloured types without porous structure and softer than usual, may be easily confused in the sample with kaolinic clay. [2])

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[1]) A fine collection which contains all Surinam bauxite types was gathered by the Eng. E. A. Douglas, in his prospects of the deposit at Rorac, Suriname river. This collection is in the Delft Polytechnic.
[2]) V. 2491, 2925.

In the oölitic varieties we see oölites of a size varying from some millimetres to some centimetres, lying in a groundmass mostly of a lighter colour. [1]) Just as elsewhere, besides pure bauxite, types bearing a varying percentage of hydroxides of ferric iron occur on a large scale, so that all transitions between bauxites and lateritic iron ore are present: the types are closely related as to genesis. Colum VIII gives the composition of a ferric "bauxite", which however may just as well be entitled aluminous iron ore, if we fix the limit at 50 % hydrated ferric oxide or 43.75 % Fe_2O_3. The ferric bauxite has a rougher habitus in the sample than the pure bauxite; the former may be very porous, with larger cavities, and occasionally tortuous tubes. The colour is brown in different shades, to redbrown or mottled with white, grey or light brown spots. The light spots are considerably richer in aluminium than the rest and poor in iron; in some samples these spots on macroscopic examination already show crystalline hydrargillite (gibbsite). The cavities may be coated with hematite. [2])

A number of samples of these transition rocks again show oölitic structure, and often we are in doubt as to whether we must classify them with bauxite or with the previously discussed oölitic iron ores.

Microscopically the bauxites are little transparant, except for spots containing crystalline hydrargillite. The latter mineral may sometimes form the cement of the oolites. A special type is a sample of Rorac which microscopically appears to consist entirely of hydrargillite. Macroscopically it shows a porous structure, brick-red colour, and betrays its crystalline habitus by sparkling, especially in lamp-light. In the slide an aggregate of crystals, chiefly twinned polysynthetically according to the base is seen. Some crystals, freely grown into cavities, are flattened towards the base; besides (100) and (101) are developed. Dispersion strong.

In dissolving bauxites in concentrated sulphuric acid a residue of accessory minerals appears to be present, astonishing both as to quantity and species. As is shown by table 13 the residue as a rule contains abundant zircon and leucoxene, whilst ore, staurolite, tourmaline and quartz are in variable quantities present, and rutile, muscovite, chloritoid, titanite and kyanite were seldom found. In the thin sections the same accessories may be met with.

About the geology and genesis of the bauxites, only data of a general nature can be procured. According to their topographical situation, two types may be distinguished in Surinam.

The first is the lowland-type. This forms flat-topped low hills, whose greatest height is 35 m. The base of these hills lies a few metres above sea-level. Their area is at most some tens of acres. To these deposits in the lowland belong those of Moengo and its surroundings (Upper Cottica river), Rorac, Accaribo and Marechals creek (Suriname river), Ongelijk, Onverwacht, Onoribo, Portorico, all of them in the basin of the Para creek etc.

The second type is found on the Brownsberg, about 140 m. above sea-

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[1]) e.g. V. 2479-80-81-82-84.
[2]) V. 2667, 2672.

	Moengo —	Rorac — 3 m. (I 3)	Rorac — 1 m. (D 5)	Rorac — 1½ m. (E3)	Rorac — 4½ m. (F5)	Rorac — 2 m. (D 5)
Original material	abt. 2 kg. cream-coloured, compact bauxite	230 gr. cream-coloured, soft bauxite	230 gr. light-coloured, variegated, porous bauxite	250 gr. red-brown bauxite, porous, rich in iron, showing haematite in the sample	315 gr. light-coloured, variegated, porous bauxite	205 gr. brick-red, porous, hydrargillite aggregate
Residue	3370 mgr.	40 mgr.	95 mgr.	745 mgr.	105 mgr.	555 mgr.
Ore	1 %[1]	———	———	———	———	———
Leucoxene	32 „	———		═══	═══	═══
Zircon	53 „	═══	———	═══	═══	═══
Staurolite	10 „	———	———	———	———	———
Tourmaline	4 „	———	———	———	———	———
Quartz	—	———				———

Rutile, Muscovite, Chloritoid, Titanite, Kyanite are rare.
[1]) Percentage of grains ascertained by counting.

═══ = ultradominant ——— = scarce

TABLE 13.

level. The same type seems to occur in the Nassau mountains. The appearance on the Brownsberg agrees in all respects with the situation that is typical for the appearance of bauxite in the tropics, forming part of the surface of a plateau, where conditions of prolonged atmospheric weathering are prevalent, while mechanical weathering is excluded.

The other deposits are situated less high, but the fact that they lie on flat topped hills, points to similar genesis.

Schematically the profiles have the following composition.

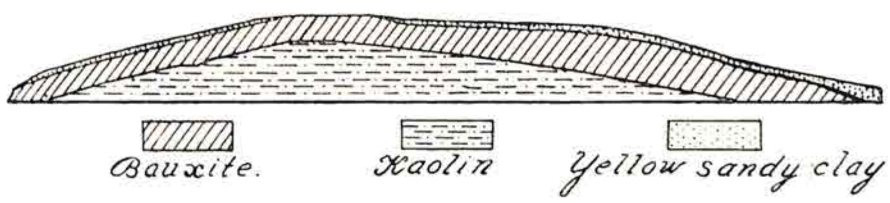

Fig. 7
Section of a Surinam Bauxite-hill. (After E. A. Douglas. Eng.)

The surface of the deposits is generally rough while lumps of bauxite protrude here and there from a clayey soil. Locally this bauxite may be pure, usually however it is a ferric variety. In other places it passes into lateritic iron ore which in that case may form a cap of 2—3 m. thickness on the purer bauxite. This capping is very tenacious and is hardly workable with a pickaxe. In the deeper parts of the deposits, the bauxite may likewise be superseded locally by ferric groups. The oölitic bauxite variety is restricted to the upper parts of the bauxite mass. The thickness of the bauxite complex does not exceed 8 m. It is of importance that the bauxite generally rests on kaolin. The demarcation-line between bauxite and kaolin is sharp. At Rorac small layers of bauxite (of some cm. in thickness) occur in the kaolin below the main bauxite mass. In the demarcation-line there are sometimes found bauxite concretions, showing concentric shells, the cavities between them are partly filled with kaolin.

The important question from what rock the bauxites are derived, can not be answered with certainty. For Moengo weathered granite is recorded: whether this is correct, I am not in a position to decide. The percentage of combined water seems to indicate that the original material of the Surinam bauxites is rich in aluminium, in contradistinction to the bauxites that originate especially in the subtropical or temperate zones from rocks rich in carbonate. Experience shows namely that the first group contains combined water more than 20 %, the second less than 20 %.

We do not know whether the Surinam bauxites are derived from acid or basic igneous rocks, or from crystalline schists; elsewhere, however, very different rocks may have furnished the original material. The intimate connection existing between bauxite and the lateritic iron ores, added to the fact that the latter seem to be principally derived from basic or metamorphic basic rocks, render it not improbable that the bauxites in Surinam should also by derived from these rocks.

The accessory components mentioned above, amounting to more than one percentage of the whole, plead partly against igneous rocks being the original material: all the samples contain some staurolite, which may amount to 10 % in one of them. The other components, except those which were rarely found, are not decisive, as they occur in igneous rocks as well as in metamorphic sedimentary rocks. The grains are always fine and show no excessive differences in size. Whilst zircon, tourmaline and staurolite are not worn, the quartz shows partly highly rounded-off crystals. It may be that during the process of bauxite-formation, mineral grains from elsewhere, were added, either aeolian, or washed in. This however is improbable, considering the high position of the bauxites in the field, and the forest vegetation which covers them. Secondly it may be that the bauxites were once covered by sedimentary deposits, and that the accessories now found in the bauxites are derived from the latter, and enclosed into the weathering mass. Thirdly it is not impossible that the bauxites were derived from material in a secondary position, in which case many kinds of sediments come into consideration. Whatever the original material may be, this simple method of research should also be applied to other bauxites with known origin.

The chemical analyses can furnish no clue. The percentage of titanium is neither high nor low, [1]) besides it may be present as hydrated oxide; in the latter case it may have been mobile.

Harrison [2]) has proved for British Guiana that the bauxites there are derived from diabases, metamorphic diabases and hornblende rocks.

There remains the question of what age the Surinam lateritic iron ores and bauxites are. It is clear that also nowadays the formation proceeds, but

[1]) In literature 3 % is given as the average percentage of TiO_2 of the Surinam bauxites (see F. Oudschans Dentz. **95**. p. 499).

[2]) J. B. Harrison. **91**.

the question is at what time the formation of the mighty deposits began. It is not improbable that the formation of the bauxites began before the sedimentation of the continental alluvia which we supposed to be Pleistocene and Holocene. A glance at the map informs us that the Rorac bauxite probably lies within the domain of the fluvio-marine deposits. Do the latter cover the bauxites at the foot of the bauxite hills there? If so, the formation of bauxite must have been in progress already when the marine transgression had reached it greatest extent. Do the bauxites there at present lie partly under the level of the groundwater? These are all questions which, owing to lack of data. must remain unanswered.

Manganese ores.

In the collections there are some samples of manganese ore (V. 3, 2246). It is psilomelane. About the geological occurrence of these ores we know nothing. They may probably have originated together with laterites; their habitus agrees with this supposition.

"Imported" rocks.

Attention should be paid to the "imported" rocks, which may cause errors. Among the imported rocks must be classed samples of coral limestone from Blakkawatra savannah (Cassipora creek, V. 2477) and from Joden Savannah (Suriname river); and also marly limestone from Andresa (Coppename Y. 393, and from Sewironi Tibiti V. 3002). It is not improbable that also the limestone boulder recorded by Martin [1]) from Carolina (Suriname river) and considered by him as an argument for Cretaceous rocks in Surinam, comes from outside the Colony.

The coral limestone is totaly recrystallized or shows in part the original coral structure. The marly limestones are crowded whith Globigerina and show shell-fragments.

These rocks all occur in the neighbourhood of former or present settlements. They are only known as boulders, and it is clear that they were imported in former days, possibly as ballast of ships, or as raw material for mortar. The aboriginal Indians sometimes use them as polishing stones, and further the distribution once more, but they do not know a single outcrop of the solid rock.

These rocks have been erroneously looked upon as indications for later formations in the coastland; they have even been regarded as favourable indications for the occurrence of oil in Surinam.

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[1]) K. Martin. 26. p. 174—175 and 211.

THE RORAIMA FORMATION.

History of the Discovery.

In the Surinam literature emphasis is repeatedly laid upon the similar geological construction of the three Guianas. Some authors express their surprise about the almost entire lack in Surinam [1]) of the Roraima or Kaieteur formation, by which is meant a formation chiefly consisting of nearly horizontal sandstones and conglomerates, which rest upon the basal complex. About the whole of the Pakaraima mountains consists of these sediments, here and there crowned with typical table mountains, of which the Roraima plateau is the best known.

Before the departure of our expedition there were known but of a few very local sandstone outcrops in the W. of Surinam, on the Courantyne, which, in imitation of Barrington Brown and Martin, have occasionally been compared with the Roraima formation. The formation was, however, not known as one forming mountains.

During the exploration of the Wilhelmina mountains our expedition discovered important remains of the formation. Annexed sketch shows a pano-

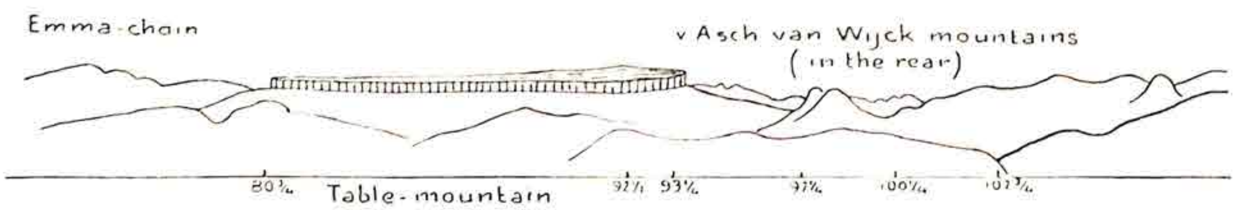

Fig. 8.

rama as seen from top 1065 in that mountain range, viewed towards the East. More in the foreground there are undulating ridges and a few rounded domes, the typical granite landscape of Central Surinam. Sharply contrasting with the rest is a plateau-mountain, which, on account of its shape, does not fit into the landscape. It was called the "Table Mountain". An escarpment surrounds it on the side which is turned to us, and by means of field-glasses, when the light was favourable, bare patches of rock could be here and there discerned on that mountain side, although the mountain lay at a distance of about 40 km. away from us. Viewed from the West, South-West and South one gets the impression as if the table gently declines towards the North-West; while a very faintly marked top rises from the plateau in the South-Eastern corner. This typical mountain must also have been seen from

[1]) H. van Cappelle. **62.** p. 45; do. **84.** p. 11—12.

some other point by an earlier expedition, for in the account of the Saramacca expedition [1]) we read:

"Wij zijn hier slechts een tiental km. verwijderd van het zuidelijk uiteinde van de Emma-keten en de lange zonderlinge rotswand of de uitgebreide hoogvlakte, wat het wezen moge, die deze keten besluit en zich, van waar ook gezien, als een naar alle zijden door loodrechte lijnen begrensde rotsmassa voordoet, rijst in het noord-westen majestueus als een naakte muur van ruw behouwen graniet, verweerd, gegroefd en gekloofd, naar de wolken op."

Van Stockum saw the mountain from the South-East (De Kock-berg), North-East (Ebba-top) and North (Hendrik-top) as an escarpment, we ourselves observed it from the South-West and West, so that the plateau must be on all sides surrounded by an escarpment.

It is not impossible that part of the escarpment was already seen by the Coppename Expedition in 1901, for East of the extreme upper-course of the right hand Coppename river, a "rockwall" is marked upon the map, as occupying a length of several kilometres, having a height of 800—890 m. Probably this corresponds with the NW. edge of the Table mountain.

Expedition to the Table mountain and exposures along the trail.

It is clear that such a plateau is bound to be of another composition than the granite landscape in the neighbourhood; and so we set out on an expedition to reach the plateau. To start with we went up the East river, a small tributary of the Lucie river (see Map V). Then we travelled on in a North-Easterly direction, across alternately gently undulating or steeper, but always low hill-country. The land is uniformly covered with virgin forest, locally broken by small swamps between the hills, and rare bamboo fields along the creeks. Cutting our way we advanced on an average about 4 km. a day. Only from a steep and somewhat higher top we obtained through the trees, a faint view of the Table mountain. The ground is covered with the same yellowish, sometimes more reddish loam which is to be found elsewhere in the hill-country, locally it is more sandy, and in this case covered with lower and open forest. In connection with the deep-reaching disintegration we met with but little rock exposure. While in the East-river biotite granite repeatedly crops out, we passed, on going inland, first some quartz porphyry, partly as solid rock. A little mountain here must also have a core of this rock. Further on this rock gave way to rough rounded blocks of porphyritic biotite granite. On the fourth day we passed a wide creek or small river, in which the same granite crops out. On the fifth day another streamlet showed at the place where we crossed it, nothing but loam and fine quartz-sand, while large bamboo fields skirted its banks. Now we were no longer in the drainage-area of the Lucie river, but had crossed a low watershed, for the creeks flowed towards the North-West, very probably towards the right hand Coppename. The valley of the latter creek was at the same time the lowest point we passed during this trip; it lies somewhat lower than the starting point at the East river. Soon

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[1]) A. J. van Stockum. **53.** p. 238.

after having passed this creek we arrived at another big creek which seems to come from the Table mountain. Its water had the colour of tea-water, and must originate from swamps. On the sixth day a surprise awaited us. While we still passed a granite outcrop only on the evening before, we struck quite early in the morning a sandstone formation, exposed in a rivulet. Beds of sandstone of a thickness of ½ to 1½ dm. form the bed of the creek. They lie fairly well horizontal. The creek has cut itself into them, so that its sides show part of the sandstone strata, covered with a yellowish loam. Here and there the sandstone bed of the creek shows steps, where a sandstone bed breaks off. In this case the latter is rounded off at the edges and hollowed out by the water. Small pot-holes, mostly of the size of a fist, occur in the solid rock. The quartz-gravel in this creek is extremely water-worn. That we struck a new formation so soon was a surprise, for we had not yet reached the foot of the Table mountain. We had, however, noticed earlier that the fine-grained sand in the tiny creeks showed a pale pink colour, in contrast with the coarser and grey quartz-sand, which is of granitic origin. Probably the spot, where we first crossed the margin of the sandstone formation corresponds with an insignificant rise of the area covered with low hills, while from the last "Coppename creek" we had come across noticeably flat country. Soon after we arrived at steep hills of yellowish, sandy loam, up to a height of some tens of metres, here and there strewn with weathered fragments of sandstone. It is clear, that they have a core of sandstone. A creek, containing clear water, descends over small sandstone terraces. The sandstone is locally extremely folded; sometimes with a dip of 50° in varying directions. At the end of the first day's march across the sandstone formation we camped between low hills by a rivulet, where extremely weathered sandstone, coloured red by iron, was exposed, this time with ill-defined banking. Here pot-holes of up to 2 dm. depth have been excavated in the rock of the creekbed.

The day after we travelled across gently undulating country, locally boggy. In the rainy season it is sure to be flooded. The slowly flowing creeks again contain tea-coloured water. Locally the soil is finely sandy, with little undergrowth. Yet some rock crops out here and there, for after having first discovered detached red blocks of sandstone in a gully filled with fine sand, we came across solid rock in the next creek (Pl. 9 fig. 1). Above the stagnant, teabrown water we saw just a glimpse of red, ill-bedded, horizontal sandstone. By midday we saw a sandstone rock of a height of 4 metres, exposed in a creek (Pl. 9 fig. 2), with layers of ½ to 3 dm. gently sloping and with a few joints. These disturbances and also those which were mentioned before are to be ascribed rather to weathering and creeping than to tectonic movements. The rivulet flows over numberless boulders of red and pink sandstone, and also over coarse, white quartz. From that point onwards the area is but slightly undulating, and shows a gradual rise. The forest becomes lower and lower; the soil is apparently very infertile. Locally we see blocks of sandstone, sparingly covered with soil. Further on there occur also blocks of conglomerate, the composition of which will be described later on. After having pitched our camp we set out that same night on

Plate 9.

Fig. 1. Exposure of horizontal, ill-bedded sandstone of the Roraima formation, South-West of Table mountain, Central Surinam.

Fig. 2. Thin-bedded, soft sandstone of the Roraima formation, South-West of Table mountain, Central Surinam.

an exploration in the direction of the mountain: the ground rose more and more, the blocks became more frequent and we came into a waste-covered talus of boulders still wooded, from which numerous rivulets flowed down; soon we reached the foot of the mountain. From the foregoing it is clear that in front of the Table mountain, on the side from which we were approaching it, there is a sandstone formation over a distance which by counting paces, may be judged at 6 km. The borderline of the formation seems to correspond with a slight rise. Farther on there are hills which reach a height of a couple of tens of metres and beyond these comes slightly undulating ground which finally passes into a talus of boulders. The difference in height between the spot where the talus begins and the point where the sandstone formation was first seen amounts to about 100 metres, according to barometer-observations.

Ascent of the Table mountain. Composition of the formation.

The next day we tried to ascend the mountain. A vast sloping field of blocks lies at its foot. Here and there solid rock is visible in rivulets; which is nothing but well-bedded red sandstone. The wooded talus of boulders is getting steeper and steeper, up to 45°, and then an almost perpendicular wall of rock rises from the waste. This rock wall is inaccessible. Shrubs and plants grow in the clefts of the rock. Through the shrubs, however, we saw a spot, where the waste-covered talus rises up to close under the edge of the plateau. Above it the rock-wall is less steep and covered with higher and denser forest, and ascending in that direction we succeeded in getting upon the plateau. The ascent by this way is relatively easy. During our ascent we came across nothing but brickred quartzitic sandstone in thick beds, lying practically horizontal. Sometimes these beds are a metre or even more in thickness, and compact, in contrast with the thin layers at the foot of the mountain. They show few joints, are very coherent, while here and there, on account of crumbling strata have been undermined and are sticking out, so that we could not pass by. At the edge of the plateau we found conglomerates. That these conglomerates reach a considerable thickness is shown by the fact that there are hills upon the plateau of a height of 10 to 20 m., which consist altogether of conglomerate. The plateau itself is covered with a dense vegetation, rich in Clusia, a kind of liana, which can also grow as a tree. Locally there is creeping bamboo. The following day we cut a way across this tangle, in two directions, advancing one km. The soil consists of sand, gravel and detached blocks of conglomerate. At the SW. edge of the plateau we came across an open joint of a width of 2 m., filled with detached boulders; it has apparently been opened in consequence of local subsidence. A tiny stream flows through it, containing the same tea-coloured water, which we saw at the foot of the mountain. It descends from the escarpment in stepwise falls. As the plateau, as was mentioned before, seems on the whole to decline towards the North-West, it is not improbable that more important creeks flow down towards that side, forming there, during the rainy season, considerable waterfalls, which may imitate on a small scale the type of the well-

Fig. 9. Section of the S.W. foot of the Table mountain on a proportional scale 1 : 700.000.

known Kaieteur-fall in Demerara. From the edge of the plateau we have a splendid view to the SW. Far away on the plain a pale green strip shows up in the dark virgin forest: the bamboo field along the Coppename creek, which we crossed.

From barometric observations we know that the foot of the mountain lies at about 410 m. above sea-level, and that the spot where the rocky wall rises up from the waste-covered talus, where we reached it for the first time, lies at 770 m.; while the edge of the plateau touches about 1000 m.; so that about 230 m. are left for the escarpment. The highest point of the plateau lies at about 1080 m. If one takes the practically horizontal position of the beds into consideration the difference in height between the foot of the mountain and the highest point of the plateau is equal to the thickness of the formation. This must be more than 650 m. for the possible thickness of the formation below the point where the first altimetry was carried out, has not been accounted for yet.

Sandstones and conglomerates are the chief rocks of the formation. It is true that a great deal of the talus is hidden from view on account of the mass of waste; but here and there the talus shows a break, on account of the downpouring water having exposed the solid rock. This invariably is the same brickred quartzitic sandstone, while in the waste at the foot, too, the components of sandstone and conglomerate are almost exclusively found.

Extension of the Roraima formation in as far as known owing to the expedition.

From the bearings, taken by our topographer Colonel J. Kremer, it appears that the top of the plateau is of a squarish shape with rounded angles and sides. This shape was constructed from bearings taken from three tops of the Wilhelmina mountains, combined with data drawn from Van Stockum's map. The mountain appears to be situated in the centre of Surinam, between the Van Asch van Wijck mountains and the Southern spur of the Emma chain, but nearest to the latter, West of the Saramacca, while the Toekoemoetoe, a tributary creek of the Saramacca probably drains most of the mountain. In the direction N—S the mountain must have a diameter of 10 km.; in the direction E—W a maximum of 8½ km. If, however, one takes into consideration that the sandstone formation on the South-Western side was found as far as 6 km. away from the foot proper, and if one assumes that this is the

Plate 10.

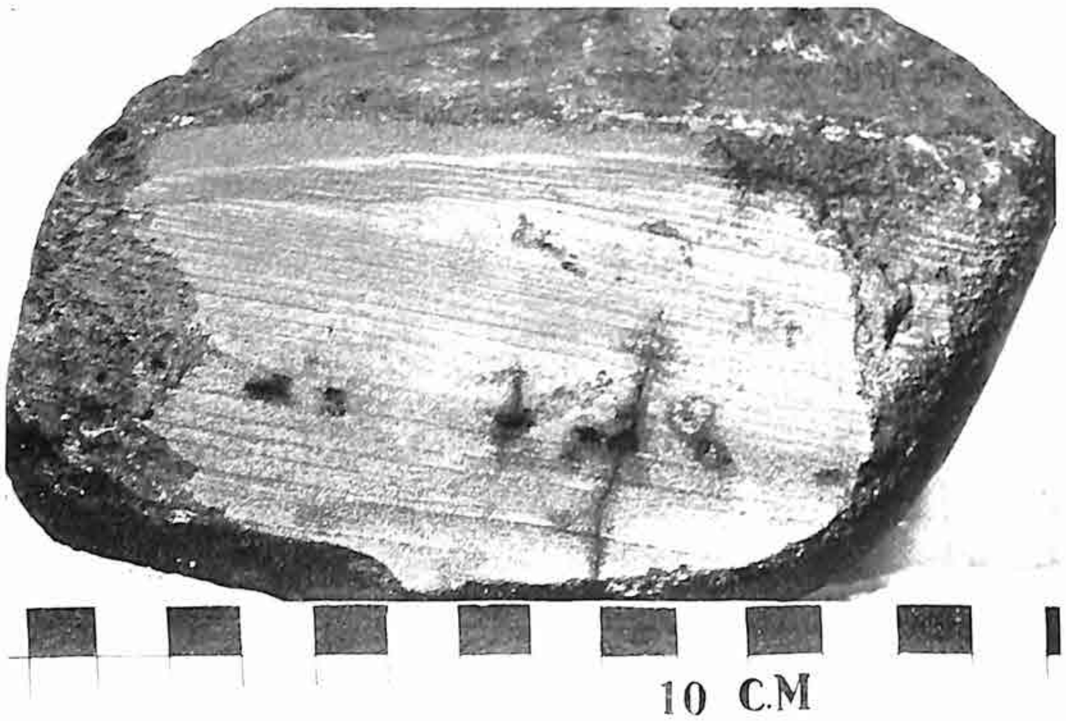


Fig. 1. Sandstone of the Roraima formation showing cross-bedding on polished face (V. 264).

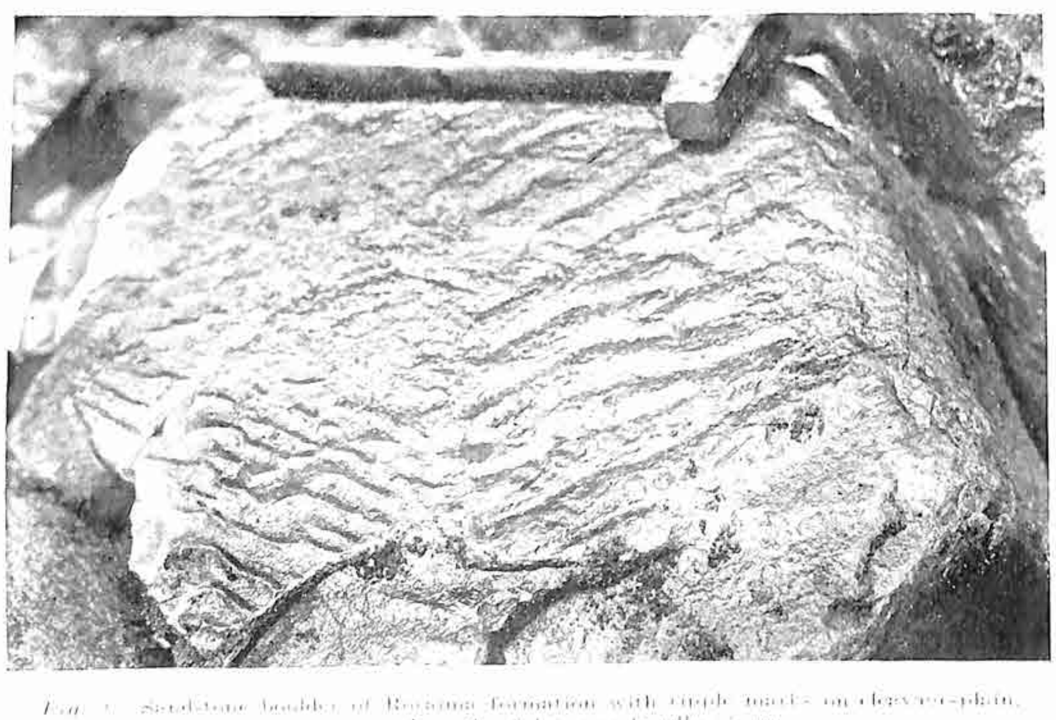


Fig. 2. Sandstone boulder of Roraima formation with ripple marks on cleavage-plain. Length of hammer-handle [illegible] cm

case on all sides of the mountain, then the base of the sandstone formation is bound to amount to abt. 22 km. in North-Southerly direction and abt. 20 km. in East-Westerly direction, so that the total area occupied by the formation must amount to abt. 400 km^2. If one leaves the outer rim out of consideration then there will be left but abt. 72 km^2. which tallies with the area occupied by the mountain itself.

The composition of the different rocks. The sandstones.

By far the larger part of the formation consists of fine-grained sandstones (granular size of 1 mm. or less). They are mostly massive or show little indication of detailed bedding (Y. 268); others, on the contrary, show fine stratification, especially visible on the weathered surfaces (Y. 263). In the brickred quartzitic sandstone the separate grains of quartz can hardly be distinguished by means of a magnifying-glass; these rocks occur especially in the upper part of the formation. When polished, this type produces beautiful ornamental stones. More distinctly visible are the grains of quartz in the pale-red sandstones, which occur more particularly at the base of the mountain and in the yellowish kind at the mountain-foot in the formation in front of it. The yellowish colour of the latter is probably the result of decolouration through weathering. In the pale-red, as well as in the yellowish rock, one often sees irregularly distributed grey spots of the same size as the rest of the grains. These spots appear to be weathered feldspar and may easily be removed by means of a needle. The sandstones of coarse grain under the edge of the plateau, which gradually pass into conglomerates, are of heterogeneous grain and more variegated. In several sandstone blocks one meets with fine cross-bedding. (Pl. 10 fig. 1). Very characteristic are the ripple marks which we discovered in some large boulders (Pl. 10 fig. 2).

Microscopically the rocks appear to consist for the greater part of quartz with varying quantities of feldspar. One of the typical features of the microscopic image is the extreme wear of the grains; most of them are strongly rounded while a smaller number are sub-angular. (Pl. 23 fig. 2 and 3). The shape of the grains is the more conspicuous on account of each grain being enveloped by limonitic substance of a redbrown or yellowish brown colour. This substance marks the outline of the grain and the latter is sharply set off against the equally crystalline cementing-material (Pl. 23 fig. 4). The red colour of the rocks may be wholly put down to limonitic substance around the grains.

Mostly the grains are subequal in size in one sample; in the finely bedded rocks however a selection according to size has taken place in the different layers. In some samples (Y 263) they considerably vary in size, but even then the diameter of the biggest is less than 1 mm. In some rocks the grains are equally arranged with their greatest length.

The quartzes may contain inclusions, especially liquid-inclusions, sometimes arranged in strings, and with vibratile bubble. Of rare occurrence are fine slightly curved filiform inclusions; both types of inclusions wholly correspond with those of the quartz in the granito-diorites. Some quartz grains show undulous extinction; a few are even crumbled within their confines. But as most of them are but little undulous, it is probable that the wavy extinction should already have been present at the time of the deposition of the grains.

At the same time water-worn grains of quartzite with typically quartzitic structure occur.

In other rocks feldspar of importance occurs beside quartz. In the afore mentioned rock (Y 268) paglioclase and microcline together form about $^1/_3$ of the whole. Some feldspars are sericitised, but most of them are strikingly fresh. The polysynthetic twinning of plagioclase is beautiful, even in the extremely water-worn grains. According to the refraction they are acid plagioclases. The microcline shows sometimes a more or less vague twinning, sometimes a distinct grating structure, and fibres of albite demixture. These feldspars, especially the microcline, show all the characteristics of the feldspars of the granites. Quantitatively other minerals are of little importance. Grains of ore were found also, mostly water-worn, sometimes octahedral; insignificant grains of zircon and a few flakes of muscovite are found.

The cementing substance is crystalline quartz. Particularly in rocks of relatively coarse grain one sees around the grains, set off against them by a covering of limonite substance, equally polarizing fields of quartz, which envelop and connect the grains. Often a field and the grain which it encloses, extinguish simultaneously, so that they must have equal orientation, as is often the case with crystallized sandstones (Pl. 23 fig. 4).

In another type of rock (Y 264) the grains are imbedded in a very fine sericitic cementing substance, which may constitute 1/3 of the whole.

The conglomerates.

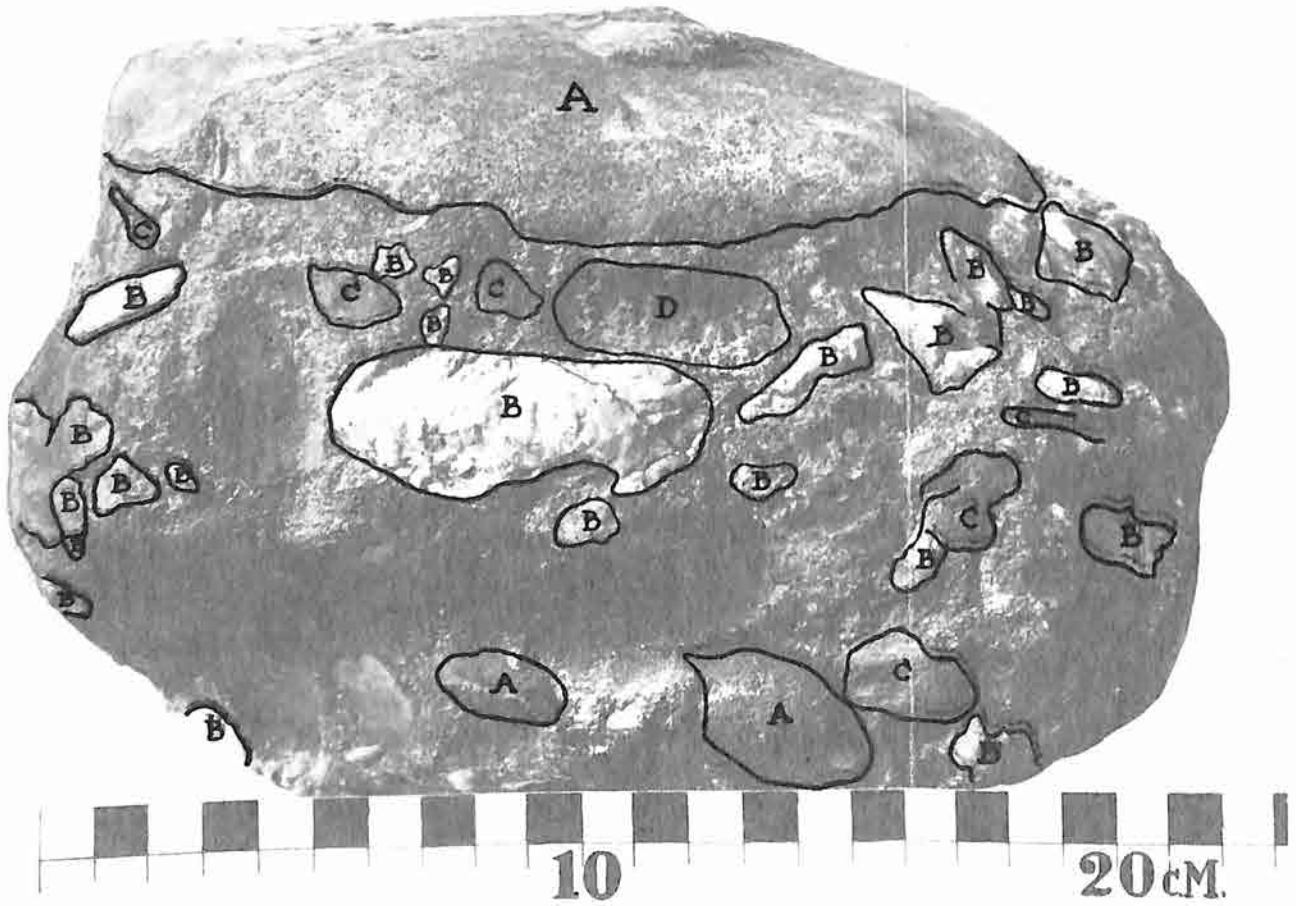
The composition varies with regard to the relation between the cementing material and the boulders, as well as to the nature of the latter. Of most frequent occurrence is a variegated type, rich in water-worn and flattened quartzite boulders, extremely water-worn white quartzes and small bits of shale in various reddish shades, also flattened or worn down; all of them embedded in a coarse, sandy cementing substance of divergent colours, often spotted grey or brownred. The quartzite boulders may attain to a length of 2 dm. Plate 11 represents a typical fragment rich in the different kinds of boulders. Besides extremely weathered fragments of igneous rocks occur, which show up as a depression in the conglomerate boulders; and also smoothly rounded fier red iron-bearing jasper.

On microscopic examination the flattened or smoothly rounded quartzite fragments appear to consist predominantly of quartz with much variation in granularity and accessoria. Of the latter, ore must be mentioned in the first place. The ore may be present in great quantity as octahedral grains together with masses of dust and irregular granular aggregates, so that originally the rock must have been richly iron-bearing sandstone, now altered into a grey or blackish quartzite. In another fragment a considerable percentage of weathered and sericitised, faintly refractive feldspar was found. The quartz partly contains liquid inclusions, sometimes with vibratile bubble, and capillary inclusions. Sometimes extremely worn crystals of quartz may be recognized, then again the quartz forms a fine-grained polyhedral mosaic, when extreme recrystallization has taken place. Some zircon and apatite also occur. The quartzite-boulders of the conglomerate, though of more varying habitus, do not show essential differences with quartzitic sandstone of the Roraima formation. The white quartz fragments do not call for a single remark. On microscopic examination the slate-like fragments appear to consist of a quantitatively predominant cementing substance, rich in sericite, coloured red by limonite matter, in which worn, angular quartz and remains of sericitised feldspar are embedded. A bright-red smoothly worn jasper with conchoidal fracture microscopically shows an extremely fine polarizing aggregate, very much soiled by a red pigment, while octahedral ore, distributed in irregular masses and strings, is present too. The jasper contains some fine angular fragments of quartz, which, though very fine, yet are set off against the cementing substance on account of their relative size; the whole is dissected by a few microscopical veins of quartz, filled with very fine quartz mosaic. A totally weathered boulder of igneous rock shows nothing but grains of granite quartz.

Porphyry-tuff.

Very remarkable are angular fragments of an extremely fine-grained, exteriorly compact rock which we discovered at the top of the waste-covered talus immediately under the escarpment. They appear to be porphyry-tuff (Y. 267). Several cleavage systems perpendicular to the bedding divide the rock into polyhedral pieces with smooth faces. The rock is of a pale colour with different shades of grey and brown, and can be scratched with steel; with the exception of a few zones which are of an absolutely close silicious habitus. Very fine detailed parallel bedding is present, with a few pale-red bands, which seem to be the result of decoloration (dark in Plate 11).

Microscopic examination shows up an extremely fine mixture of quartz and more refractive scaly substance, probably sericite. Here and there isolated acute-angled tiny fragments of



Roraima conglomerate with boulders of { quartzite (a), white quartz (b), red slate (c), weathered igneous rock (d)

Porphyry-tuff of the Roraima formation (Y. 267).

quartz occur, mostly smaller than 0.3 mm., which must be taken to be non-worn. The groundmass consists of such small quartz and sericite that even a powerful lens hardly analyzes the separate mineral grains. In some zones a number of irregularly shaped bodies can be seen, which on account of their greater transparency are set off against the richly sericite-bearing mass around them. They appear to be filled with aggregates of crystalline

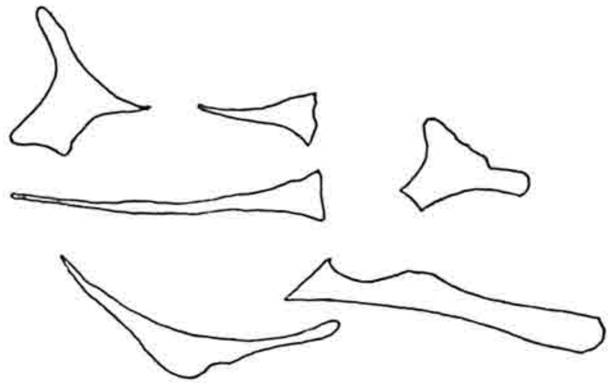


Fig. 10. abt. × 100.

grains, probably quartz, somewhat coarser than the quartz of the groundmass. The irregular shape of these small bodies (fig. 10) seems to indicate that originally they were pumice-fragments, now superseded by a crystalline mass. [1]) In some zones these bodies occur in masses; generally they are equally orientated.

Other fragments of rock are of a somewhat different composition and appearance (Y. 267 B). They are variegated owing to numerous smaller and bigger bands of grey, red, purple or brown colour, alternating with each other. The bands run strictly parallel, but they greatly vary in thickness from less than a mm. up to several cm. Often the finest bands no have constant course, but are locally interrupted to re-appear again in line and level. In some zones angular or rounded grains of quartz occur, and also sharply defined magnetite. These grains are smaller than 1 mm.

Partly these fragments of rock may be easily scratched, which microscopically finds its explanation in the presence of a great amount of sericite. In these samples the already mentioned fragments of quartz are numerous. Often they are fractured internally, allowing some sericite material to penetrate along the fractures right up to the centre. It is notable that a number of these quartzes show traces of bipyramidal form. With them it are found octahedral grains of ore (magnetite), partly, however, superseded by patches of ore substance. Redbrown substance (limonite?) abundantly occurs in zones and is the cause of the red and purple colour of the bands and bandlets.

The described rocks (Y. 267 and 267 B) appear to be transformed volcanic ashes, zonally with relics of ash structure, partly silicified, the original composition of which is not easily to be determined. Although the blocks have not been found in situ, these porphyry-tuffs are bound to occur in the upper part of the formation, as they were found at the top of the waste-covered talus, close under the escarpment. Their shape warrants that there is no question here of fragments coming from the conglomerates.

Some notes on the weathering products of the formation.

There is a striking difference between the weathering products of the Table mountain and those of the rocks of the basal complex. Especially the gravels upon the protruding foot of the sandstone formation are of a typical composition. Near the waste-covered talus the creeks still flow over a bed of sandstone and fragments of conglomerate, but closer to the edge of the for-

[1]) See O. Mügge, Untersuchungen über die Lenneporphyre in Westfalen und den angrenzenden Gebieten. Neues Jahrb. Miner. Beilage. B. VIII. 1893. p. 648.

mation the bed consists of sand and fine gravel, which rests upon weathered layers of sandstone. The gravels appear to consist of extremely worn white quartz pebbles, subangular or absolutely rounded, which are strikingly different from the acute-angled fragments of the bed-rock gravels in the granite- and gneiss region. It is clear that these waterworn gravels originate from the conglomerates, and were as much worn already when they were taken up into the conglomerates, so that in the creeks they are in a tertiary position. This is also the case with the water-worn jasper which occurs here and there. Besides water-worn fragments of the sandstone itself are found there. Locally a great many purple shale-like flakes occur which impart a variegated appearance to the gravel (Y. 260 D). It is more probable, that they once formed part of shales, enclosed in the formation than that they belong to the shale-boulders of the conglomerate. In the gravel there are also found very beautifully idiomorphic, clearly transparent quartz-crystals. These were surely deposited upon fissures in the formation and are in a secondary position in the gravel.

Sometimes the sands are very fine-grained and of a pale pink colour; in contrast to the grey and coarser sands which come from the granites. Wherever the sand of the creeks was examined, it appeared to contain fine grains of dark minerals; they have a larger size in the coarse sand and gravel. Especially in the little pot-holes, excavated in the sandstone bed of the creeks, and pre-eminently suited to retain heavier components of the gravel, we found coarser grains of these minerals. They appear to be rutile and anatase. Only a few grains the size of 5 mm. show crystal faces: viz a combination of 2 pyramids, one of the typical combinations for the mineral anatase.

A few speculations with reference to the genesis of the formation.

Let us now try to realize the conditions under which the formation was deposited. That the formation was partly formed in running water, either salt or fresh, is proved by the conglomerates. The water-worn condition of the fragments points to the normal genesis of conglomerates. Glacial till is out of question. Judging from the dimensions of the components the streams which built up the conglomerates must periodically have been of great force.

For part of the formation one may conjecture aeolic genesis, as has also been done in the case of other red sandstone formations, e. g. for the New Red Sandstone in N W. Europe. Conveyance by the wind in an arid climate may have periodically alternated with deposition in running water (conglomerates). Whether deposits of marine origin are present, too, cannot be ascertained, for lack of fossils. We did not find any trace of fossils, which is not to be wondered at, in view of the scarceness of fossils in red sandstone formations in general. But if there is question of marine genesis, then the deposits are sure to have been formed in a shallow coastal basin, probably with gradual subsidence, so that the sedimentation kept pace with the subsidence. In running water, either salt or fresh, but just as well by aeolian action, the ripple marks and the cross-bedding may have been formed. The material of the porphyry-tuffs, which take a very insignificant part in the upbuilding of the formation, may equally have been deposited on land as well as in the water. At any rate they give evidence of volcanic activity during the development of the formation. No basal conglomerate was found..

It remains a question where all the material which took part in the upbuilding of the formation comes from. This problem is closely bound up with the geological relation of the sandstone beds with regard to the granite landscape surrounding it. The top of the plateau is of the same height as many of the granite tops. In the South, for instance, there are many tops of a height varying between 900 and 1280 m.; they form part of the central Wilhelmina mountains, at 40 to 20 km. distance from the Table mountain. And as we ascertained that the sandstone complex gently slopes down towards the North-West, it is not improbable that once the Wilhelmina mountains were covered by the continuation of the formation. Nearer by there is the Emma chain. The relation between these mountains and the Table mountain itself is not clear.

In what stage of erosion did this granite landscape happen to be when the formation was deposited? Did the formation lean upon the granite mountains, and did it cover the latter's foothills? Or did the formation get into its present position as a result of local subsidence of the underlying basal complex along faults? Was this part of the Roraima formation protected against erosion by its conglomerate capping? That tectonic disturbances were active during the deposition of the sandstone formation, is made probable by the water-worn quartzite fragments, of a composition little different from the quartzite sandstones of the formation. That these fragments did form part of a complex of solid rock, before the transportation, is clear, and their displacement must surely have been the result of erosion, following upon tectonic disturbance.

The shale components and fragments of jasper point to an older formation at no great distance having been demolished by erosion; or possibly they once belonged, together with the water-worn quartzite fragments, to the deeper parts of the same formation. The quartz, and especially the microcline grains of the sandstone, had better be looked upon as components of the granites and gneisses, so that these have possibly furnished a considerable amount of material.

The question with regard to the origin of the material can also be put in general: from where do the quartz masses originate which build up the vast sediment formations which cover the Brazilian Shield to a great extent?

Age of the formation. Comparison with other formations in adjacent countries and with the Roraima formation in British Guiana etc.

As no fossils have been found, the age of the formation is unknown. We only know that it rests unconformably upon a pre-Paleozoic basal complex.

By means of comparison with formations in neighbouring countries it is, however, possible, to make a conjecture with regard to the age of the sandstone. Such a comparison must be based upon the lithologic conformity on the one side, and the geologic position on the other. The following formations, especially in Brazil, come into consideration for comparison.

In the Paleozoic deposits of the Amazon-basin in the State of Para there is a marine sandstone complex of 200 m. in thickness.[1])

The extension of another red sediment formation in the North-West of the state of Matto Grosso is very problematic[2]). There red sandstones play a considerable part in the upbuilding of Table-lands (the Parecis sandstones). The same formation is said to extend as far as the South of the State of Para in the drainage area of the Tapajos, Xingu and the Tocantins. These sandstones are by some geologists attributed to the Cretaceous period.

Soft, yellowish sandstones in a practically horizontal position form the top of the vast Crajahu plateau in the state of Maranhão. Possibly they are of Cretaceous age; they cover red sandstones with inserted layers of amygdaloidal trap which possibly belong to the Triassic period, and which, in their turn, repose upon "possibly" Permian deposits. These latter again consist of practically horizontal sediments, partly red sandstones; they are dissected by diabase dykes and contain inserted diabase sheets.

All these formations, in as far as they consist of sandstone and conglomerates, lend themselves for purposes of comparison. The last-mentioned deposit of hypothetically Permian age probably hangs together with the vast complex of sandstone and conglomerates, together with clay slate and limestone, which, now in virtue of their fossil-contents, now again in virtue of their lithologics composition, are classified as upper and lower Permian. They are distributed over a large area in Brazil, from the North-East down to the South. And they mostly form horizontal beds and tablelands.

In the same way one might also draw the sandstone deposits in Southern and South-Western Brazil (the Botucatu sandstones) into the comparison, as well as the Paleozoic sedimentary beds which occur more or less isolated in the states of Bahia and Minas Geraes, which contain important quartzites and sandstones with horizontal position or slightly folded.

Thus we see on the one hand that quartzbearing sediments are largely distributed in Brazil; they are tectonically little disturbed, for we are upon the Brazilian Shield, one of the most stable parts of the earth's crust since the the pre-Cambrium. But on the other hand it is clear that a comparison with by far the greater number of those formations will not reveal anything to us, seeing the great distance which separates them from Surinam and the great uniformity of several formations.

In British Guiana the afore mentioned Roraima formation occurs with the same composition as in Surinam, and at no very great distance from it. Geologically as well as lithologically the formations in both countries show a marked resemblance. This formation in British Guiana forms the Eastern spur of the Pacaraima-mountains, which extend Westward over hundreds of kilometres, as a watershed between the tributaries of the Orinoco and the Amazon. As far as is known the entire mountain range is chiefly formed by the Roraima formation. With regard to the Western and central parts this statement becomes probable on the strength of observations by Koch-Grünberg, along the Rio

[1]) F. Katzer. **49**.
[2]) Data on Brazil chiefly according to J. C. Branner. **88**.

Uraricuera.[1]) It is quite certain that in the region of Mount Roraima in Demerara and in large parts of Venezuelan Guiana the formation covers the basal complex.[2]) With regard to the Venezuelan-Brazilian borderland material collected by Koch-Grünberg has been given me for comparison[3]).

A fine-grained, pale-red sandstone from the top of the Roraima is microscopically not to be distinguished from the Surinam ones; it appears to be a crystalline sandstone which consists nearly exclusively of waterworn grains of quartz with crystalline quartz as cementing substance. The same applies to a pale-red sandstone from the Aracasa (left uppercourse of the Uraricuera). From the latter find-spot another couple of samples is present. In some places these samples shows real quartzitic structure, which may altogether be compared with that of the flattened quartzite fragments, which occur as boulders in the Surinam conglomerate. It is notable, that water-worn fragments of jasper are not wanting either, among Koch-Grünberg's samples.

Of importance with regard to the comparison are also the silicified tuffs, which form part of the material. Judging from their appearance Deecke gave these rocks the name of „Hornstein". They are aphanitic, flintlike rocks with shell-like or splintery fracture, varying shades of yellow, green and purple, sometimes banded. Under the magnifying-glass some show zonally distributed, transparent mineral fragments. In a single specimen Deecke thought he saw holes of sponge spicules. On microscopic examination these rocks appear to be silicified porphyry-tuffs. A rock from the left bank of the Rio Kukenang, (which river takes its rise upon the sandstone table of the same name near Mnt. Roraima), above the big Moromelu falls, contains numerous tiny fragments of quartz, sometimes bipyramidal, lamelliform plagioclase and a few grains of ore, together with numerous particles of ash, partly replaced by crystalline quartz, of the same kind as described on page 83. All this together is embedded in an extremely fine-grained polarizing groundmass, coloured red by ferric pigment. Another rock which occurs as tubers in the sandstone of the Sharisharinama chain, on the left bank of the Canaracuni (source of the Merewari) shows the same quartzsplinters, remains of equally orientated ash-bodies in a very fine groundmass, while other similar rocks occur on Rio Hacha (tributary of the Rio Ventuari).

The porphyry-tuffs of the Rio Kukenang and also those of the Canaracuni were doubtless collected in the region of the sandstone formation, and form part of the latter. Considering the relatively great number of samples of this composition in the Koch-Grünberg collection, one may assume that quantitatively they play a large part in the building-up of the formation.

Especially from British Guiana we know the composition of the formation more in detail. There we are concerned with a practically horizontal complex of sandstones with intercalated conglomerates. The maximal thickness is judged at 2000 ft.[4]), comparable to that in Surinam. In many places a perpendicular wall (of rock) rises a few hundreds of metres high from a mighty talus of boulders. Towards the plane the latter passes into a blockfield extending up to a great distance in front of the escarpments. The whole aspect of the landscape corresponds with that in Surinam[5]).

In Demerara, however, the base of the formation locally lies at a higher level, so that the escarpments of the plateau, too, rise higher above the surrounding planes, culminating in Mount Roraima, 2600 m. above sea-level.

The sandstones in Demerara are locally of the same quartzitic character as those in Surinam, and often have a red colour; although a number of other varieties are also mentioned. Cross-

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1) Th. Koch—Grünberg. **86.**
2) J. B. Harrison. **68.** R. A. Liddle. **107.** Alfredo Jahn. **97.**
3) by the kind collaboration of Professor Dr. W. Deecke, Freiburg i. B. See also his microscopic determination of Koch-Grünberg's material in Mitth. Geogr. Gesellsch. München. XII. 1917. p. 36—41.
4) J. B. Harrison. l.c.p. 15; H. J. C. Conolly. **104.** p. 49.
5) For the Mazaruni region there is locally stated "precipice a sheer 1000 ft." with a talus of ½ to more than 2 miles' area in front of the mountain and a distribution of boulders in the plain over a distance of not more than 2 miles, sometimes however up to 4 miles (H. J. C. Conolly, l.c.p. 49). The perpendicular cliffs of Mount Roraima and Mount Kukenang are estimated at 2000 ft. (J. B. Harrison, l.c.p. 15).

bedding is stated to be common [1]). Ripplemarks are not mentioned for Demerara. Conglomerate beds occur scattered throughout the whole of the complex; they cover for instance the Roraima plateau. As in Surinam the conglomerate, shows transition into sandstone or quartzite. The boulders themselves are of varying character, seldom chiefly quartz; sometimes massive and foliated clastic members of the so-called "Volcanic series"; sometimes quartzite fragments occur in them, which, just as in Surinam point to an older sandstone formation [2]).

The conglomerate boulders are always extremely worn and often flattened [3]), exactly like with the quartzite components of the Surinam conglomerate. Locally the distribution of the conglomerate components seems to bear some resemblance to glacial till, but a glacial genesis is not considered probable [4]).

In the case of some abnormally big quartz boulders having a diameter of 2 to 3 ft. local recrystallisation of the sandstone is supposed [5]). Fine grained sedimentary shales and sericite-schists occur here and there.

So while the composition of the sandstone and conglomerates shows many points of resemblance, a few complications occur in Demerara which were not found in Surinam; on the one hand this may be accounted for from a variation in local details, and, on the other hand, from the still very schematic investigations of the formation in Surinam. Harrison states that the base of the formation consists, now of a basal conglomerate, now of a series of "indurated feldspathic mudstones, shales or grits, breccias and pudding-stones" and considers all these rocks to form part of the formation itself. In the Surinam rocks, which, in his time already were described by Du Bois as "crystalline graywacke", Harrison [6]) thought he had found back an equivalent of the basal part of the Roraima formation. Not long ago, however, a geological survey of the Mazaruni and Puruni diamond fields brought to light that in the Mazaruni-district a distinct unconformity exists between the above-mentioned rocks and the sandstone formation proper, which in that region begins with a basal conglomerate[7]). On the strength of these observations Harrison changed his views and no longer considered the above-mentioned rocks as belonging to the Roraima formation itself, but rather to the "Volcanic series" [8]).

Sometimes the sandstone formation in Demerara really begins with a basal conglomerate (e. g. in the Mazaruni-district) [9]). In Surinam, we did not come across a basal conglomerate, but the possibility of its existence remains. In Demerara diabase sheets, of which no trace was found in Surinam, seem to contribute considerably to the building-up of the formation.

But for a few details and complications therefore the sandstone formation in Surinam is, as far as its composition and geological proportions are concerned, altogether similar to the one in Demerara, and it is clear, that the Table mountain is a remnant of the Roraima formation on a modest scale.

Inquiring into the age of the sandstone formation in Surinam therefore means inquiring into the age of the Roraima formation in its entirety. But neither in Demerara nor in Venezuelan Guiana have fossils been found in it.

Brown and Sawkins compare the Roraima formation to the New Red Sand-

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[1]) H. J. C. Conolly. **104.** p. 48, for the Mazaruni district.
[2]) l. c. p. 52.
[3]) l. c. p. 48.
[4]) l. c. p. 48 and 51.
[5]) l. c. p. 48, 50 and 51.
[6]) J. B. Harrison. **68.** p. 83.
[7]) H. J. C. Conolly, l.c.p. 46.
[8]) l. c. p. 31.
[9]) l. c. p. 46.

stone (Permo-Triassic) [1]). Martin thinks it to be Cretaceous [2]). Von Bauer has his doubts about the latter opinion [3]). Harrison compares the formation to the Torridonian sandstones (pre-Cambrian) but emphazises at the same time that he is not prepared to accept the statements of its geological age [4]). Jahn suggests it to be pre-Cretaceous and of Jurassic or Triassic age [5]). Conolly [6]) and Bracewell [7]) express no decided opinion.

In a detailed recent publication on the geology of Venezuela, by Liddle [8]), the Roraima formation South of the Orinoco is compared with rocks of well-known age North of that river. In the Coast Range, the continuation of the Andes, red sandstones lying conformably below limestones of Cretaceous age are considered by Liddle as the equivalent of the Roraima formation [9]). These sandstones which are called "Barranquin formation" must have, according to Liddle, Cretaceous age.

It should be mentioned here, that on a lithological base, another folded formation of Venezuela may be as well compared with the Roraima formation. On the Western side of the Sierra de Mérida and in the boundary-mountains, the Sierra de Perijá, a complex of sediments, called the "Old Red series" is found, consisting of micaceous sandstone, quartzites, conglomerates and some shales, predominantly red in colour. The exact age of the formation is unknown, no reliable fossils having been found as yet; it lies between Middle Devonian (Rio Cachirí — and Rio Momboy — series) and Lower Cretaceous. Some samples which I was able to examine are very like the rocks of the Roraima formation.

Other sandstone formations in Surinam; possibly greater extension of the Roraima formation than is known at present.

With Barrington Brown and Martin [10]) one may also compare a few insignificant exposures of sandstone in the West of the Colony with the Roraima formation. In the Courantyne opposite the mouth of the Kabalebo, 1½ km. upstream, an extremely weathered sandstone rock is exposed, close to the English bank; another appearance at the Tomatai creek further on. Barrington Brown supposes he observed a very steep dip in the first rock and he states that the rock may be altogether compared with the sandstone near Cumuti (on the Essequibo), in the Pacaraima mountains [11]) and of the Itabru mountain on the Berbice [12]). I myself have not been able to discover either strike or dip in the weathered rock, which hardly shows above the water. On the most recent map of Demerara, on which geological data have been marked [13]), it looks as if this

[1]) C. B. Brown. **10**. p. 14.
[2]) K. Martin. **26**. p. 208, and **27**. p. 446.
[3]) P. P. von Bauer. **87**. p. 27—28.
[4]) J. B. Harrison. **68**. p. 23—24.
[5]) A. Jahn. **97**. p. 22.
[6]) H. J. C. Conolly. **104**. p. 22—24.
[7]) S. Bracewell. **108**. p. 21—22.
[8]) R. A. Liddle. **107**. p. 123—124.
[9]) l. c. p. 101—103.
[10]) K. Martin. **26**. p. 210. Do. **27**. p. 451.
[11]) C. B. Brown. **10**. p. 220—221.
[12]) l. c. p. 250.
[13]) F. Fowler. **82**.

sandstone must extend upon the English river bank over a length of abt. 15 km., measured from the mouth of the Kabalebo. On the smaller outline-map which schematically indicates the extension of the Roraima formation in Demerara (Fig. 11), the sandstones are indicated in the same way; the distribution of the sandstones is even exaggerated here. Judging from these data one would expect to find the same formation on the other side of the Courantyne, upon the Dutch river bank. That the extension is indeed less than indicated upon those maps, I was able to state very cursorily when our expedition went back. In the river bed, at least, mostly granites are exposed, while a number of very weathered rocks, which could be seen owing to the low water-level, could not be examined by us. Sandstones, which may be compared with those at the mouth of the Kabalebo, occur in this river near the former village of Itafe on the Kabalebo as appears from Voltz's description and from the rich material collected by him (present in Leiden: Vtz. 865, 866, 867, 872, 873, 874, and also in the Grutterink collection at Delft: V. 3637—3641 incl.). The rocks are brittle, also on account of weathering, but other samples apparently chosen with more care are of a hard quartzitic composition.

Microscopically both types are identical, the brittle "sandstones", too, show interlocking of recrystallized grains of quartz, so that the "sandstones" are weathered quartzites. They contain a varying percentage of sericite flakes and muscovite leaves, and locally show accumulations of grains of ore. Coarser types, with grains of quartz partly the size of a couple of millimetres, are to be found among Voltz's material from Itafé (e.g. Vtz. No. 880); they are conglomerate-quartzites. Microscopically water-worn potash feldspar was also found in them.

These rocks differ from the Roraima formation in Central Surinam, on account of their paler colouring, and microscopically partly on account of a more distinct quartzitic structure.

Further upstream too, along the Courantyne, there are, here and there, some sandstone appearances; one of the spots marked upon the English map is below the first Temehri rock when going up-stream. Besides, extremely jointed sandstone occurs in a great many places in that part of the river, which flows in a South-Easterly-North-Westerly direction, directly following upon the islands which are situated below the Governor falls; sometimes it crops out in the river, and sometimes against the river bank. In the small bend, which (on Käyser's map)[1]) is found there, sandstone rocks are visible on both river banks rendering the river considerably narrower. Material of this exposure is not available; data are found in Brown [2]); he also states a steep dip there.

At the upstream end of that part of the river, near the Akalikatabo island more sandstone rocks are exposed, where (according to Brown) [3]) moreover a contact of granite with the sandstone must be visible. There the granite must intersect the extremely disturbed sandstone as veins of a thickness up to 2 dm. This would, indeed, be a very important observation with regard to the age-relation. I myself have not been able to examine the local situation very accurately, but I did find another complication, possibly on the spot which corresponds with the sketch [4]) in Brown's work, or at any rate on one

[1]) C. C. Käyser. **80**.
[2]) l. c. p. 221.
[3]) l. c. p. 221—222.
[4]) l. c. p. 221. fig. 32.

not far from it. There we indeed discovered in the river a smoothly rounded rock of some tens of metres in circumference, separated from the English river-bank by a narrow strip of water. The rock is dissected by granite-pegmatite veins. Judging from the habitus of the sample one would sooner take the rock to be a quartzite, but on microscopic examination it appears that it is an extremely fine-grained aplitic granite (Y. 310). In connection with this it may be remarked that elsewhere on the Courantyne Brown reported granite-pegmatite veins as granite veins. The possibility is not ruled out that Brown should have mistaken the fine-grained aplitic granite which forms the rounded rock. A further investigation on the spot is very desirable. And Brown's statement, as long as it is not further confirmed, seems by no means convincing enough to serve as an argument in favour of part of the granites being of more recent date than the Roraima formation, as is assumed by Harrison with regard to Demerara. [1])

One might also raise objections against the view, that all these sandstones and quartzites belong to the Roraima formation, as in no case their unconformable position on the basal complex has been established. The steep dips, which Brown mentions, are very suspect, and it is not improbable that these rocks must partly be looked upon as members of the schist-formation. A closer study of the geological relations remains desirable; during our expedition more detailed study was impossible.

Chances of the occurrence of diamond in Surinam in connection with the Roraima formation, in analogy with British Guiana and similar formations in other countries.

The discovery of the Roraima formation gives rise to the question, whether in Surinam the occurrence of diamond is possibly connected with that formation, as is the case in British Guiana. First let it be called to mind, however, that also in other places of South America diamonds have been derived from sandstones, quartzites and conglomerates. In Brazil [2]), in the State of Paraná, diamonds are won out of the weathering-products of a basal conglomerate of a Devonian sandstone formation. In the state of Bahia, diamonds are won out of red quartzites, which partly are so excessively weathered that they can be directly washed for diamonds: the Lavras quartzites. Bahia is at the same time the one and only producer of the black diamonds, the carbonados. In Minas Geraes there were formerly important diamond exploitations in alluvia, formed out of quartzites, near Grao Mogol. These quartzites are possibly connected with those of Bahia, and for both Carboniferous age is assumed [3]). Not long ago diamonds were found in Venezuela, possibly in connection with the Roraima formation [4]).

The diamond exploitation in British Guiana is of great importance for the

1) J. B. Harrison. **68**. p. 25.
2) Chiefly according to J. C. Branner. **88**.
3) Brouwer however has stated that the diamondbearing conglomerates of Diamantina are highly disturbed and intercalated in probably praepalaeozoic schists. See H. A. Brouwer, Sur la nature du conglomérat diamantifère de Diamantina (Brésil). Comptes rendus Acad. Sciences. Paris. CLXXI. 1920. p. 402.
4) Dr. Ahlfeld. Diamantvorkommen in Venezuela. Zeitschr. prakt. Geol. XXXI. 1923. p. 76.

diamond chances in Surinam; and in order to make it possible to draw a parallel, a more detailed account of the latter is given here.

A brief account of the development of the diamond exploitation in British Guiana.

About 1887 or 1888 the first diamonds were found in the Puruni-district. In 1890—91 some hundreds of stones were collected along the Putareng creek, a tributary creek of the Mazaruni in the same district. The great distance from the coast was an obstacle towards further development: it was not until 1900 that this find-spot was exploited, when nearly 5000 diamonds were won from hillside-workings. During the following years the exploitation in that same region increased and new discoveries followed in the Potaro.- Kuribrong.- and Puruni districts. And in the first decade of 1900, "diamonds were found in small numbers at the Barnard Placers in Upper Mazaruni, in the Jimbo-Creek district on the Barima river, in the Cuyuni district (Arimu Creek), at Omai on the Essequibo, at Quintette and other placers in the Potaro-Konawaruk District, and near the Akaiwanna trail from the Essequibo to the Demerara river" [1]). In 1913 and 1914 the right bank of the Mazaruni was also examined and with great success; a vast zone between the river and the edge of the Roraima formation South of it appeared to be diamond-bearing. The occurrence of diamond on the Berbice, discovered in 1926, also points to an extension of the exploitation in the direction of the Courantyne, the boundary-river with Surinam.

In the first years after the war diamond prices rose from less than 10 dollars a carat up to an average of 20 dollars and more, which fact caused the exploitation to become more and more intensive; within a few years Demerara has become a producer which counts for something upon the world market; with a production averaging 200.000 carats during the last few years.

Close connection between the occurrence of Diamond and the Roraima formation in British Guiana.

If one examines the distribution of the find-spots of diamonds in British Guiana it will be seen that they are grouped together to a zone which follows the edge of the Roraima formation: to wit, a zone of some tens of km. width, on the North-Eastern side, situated in front of the escarpment, and including the Mazaruni, Potaro and Kuribrong districts, and many other find-spots of less importance. So the find-spots are grouped around the remains of the formation. The diamonds have never yet been found in the solid rock of the formation, and are exclusively won out of alluvial deposits. The composition of the diamond-bearing gravels, however, speaks strongly for the supposition that the diamonds originate from the Roraima formation. Typical components of the formation occur in them. We find in them the extremely waterworn quartzes coming from the conglomerates. Besides, very often, fragments of sandstone and conglomerate occur in them, the red jasper, which also belongs to the conglomerates, and the idiomorphic quartz-crystals, which must have grown on fissures in the Roraima formation. All these facts together speak for a connection between the occurrence of diamond in Br. Guiana and the Roraima formation. The geological surveys, which were at work in Br. Guiana, consequently assume that the diamonds originate from the formation. There, where weathering products of the formation are mixed with those of the local rocks of the basal complex diamond find-spots appear, when conditions for concentration are favourable. That basic igneous rocks should be the bringers of the diamonds is out of the question; ultra basic rocks are altogether wanting. These

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[1]) J. B. Harrison. **68.** p. 212.

important facts create the possibility of indicating regions which come into consideration for investigation.

The present extension of the formation is indicated on the schematic sketch (see Fig. 11) with regard to Br. Guiana and the adjoining part of Surinam. The region of economical importance in Br. Guiana is to be found at the Northern side of the formation, and includes the fields which are known at present, while on the South-Western side it encloses a few isolated remains,

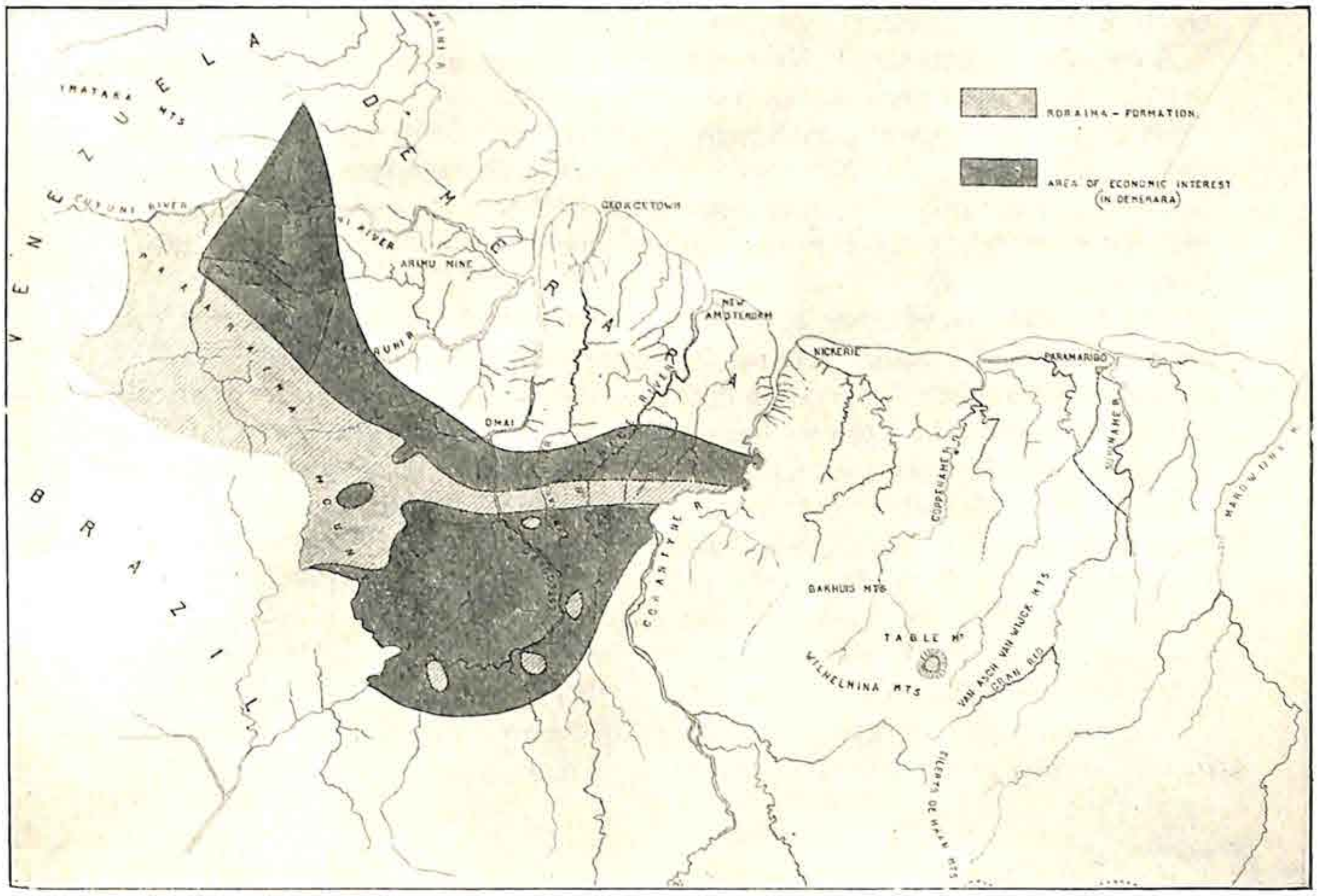

Fig. 11.

which are situated at a great distance from the formation itself, and the appearance of which reminds us of that of the formation in Surinam.

In Br. Guiana the quantity of diamond in every cubic metre of Pay gravel (that is the quantity of diamond per cubic metre of gravel, which comes into consideration for washing) seldom amounts to more than three carats, when there is question of a rich find-spot, and is usually only a fraction of a carat. And if one considers that the diamonds vary from 14 to 4 per carat on an average, it follows that as a rule only, one or a few diamonds are found in every cubic metre. Therefore a thorough investigation must be made in the case of a prospect, the more so because of emphasis is laid upon the irregular distribution of the diamonds in Br. Guiana. In prospecting a remarkable part is played by the heavy minerals accompanying the diamonds. When washing away the lighter sands and gravel heavy minerals are left behind, but they are scarce in proportion to other alluvial diamond fields. This is very advantageous with regard to the concentration of the diamonds. As mineral satellites with the diamond the greatest value is attached to the socalled "tins", i. e. to rutile and anatase, especially when they occur in waterworn condition [1]).

Possibility of finding diamonds in Surinam.

In connection with these accompanying minerals the following is perhaps significant.

Along the trail to the Table mountain as was mentioned before, we came, in the small creeks across gravel with typical waterworn quartzes, with some jasper and typical idiomorphic quartz crystals, all originating from the Roraima formation. In this gravel grains of rutile and anatase occur, and still more in the potholes which have been washed out in the sandstone here and there, which are, of course, pre-eminently suited for retaining heavy minerals.

The question is whether in Surinam too these minerals play the part of "accompanying minerals". It must be stated that these minerals on our trail cannot have had their direct origin in the basal complex, but must most decidedly have originated in the Roraima formation, seeing that they were collected upon the protruding foot. In connection with the chances of finding diamonds one might perhaps say that the extension of the Roraima formation in Surinam is not at all to be compared with that of the same formation in Br. Guiana. It is to be considered that in Br. Guiana the whole of the Pacaraima mountains is built up by this rock while the Table mountain, inclusive of the foot, only occupies a circle with a diameter of about 15 km. The Table mountain is nothing but a very insignificant remainder, compared to the mighty formation in Br. Guiana. Most certainly Surinam's chances are considerably decreased by this, still leaving out of consideration the possibility that the sandstones and conglomerates in Suri-

Fig. 12.

nam are not diamond-bearing, and that, therefore, one would look in vain for diamonds in their weathering products. Such an insignificant difference in composition of the conglomerates and sandstones in Surinam with regard to the rocks of the same name in Br. Guiana is quite conceivable considering the great distance which separates both regions.

As far as the slight extension of the formation in Surinam is concerned, the following may serve; first it is not certain that the formation should be limited to the Table mountain only; the annexed outline represents the

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[1]) Detailed data on the composition of the diamond-bearing gravels and a number of geological data are to be found in H. J. C. Conolly. **104.**

Table mountain once more, seen from top 1040 in the eastern Wilhelmina mountains. To the left of it are two slanting, more or less flattened tops (marked a and b), situated south of the Emma chain. Those two tops may be connected by a straight line, when together they form a plateau of the same aspect as the Table mountain, the more so as the right top shows an escarpment. So possibly these mountains, too, consist of the sandstone formation. But even if the formation has no larger extension than the one we know at present, it is a vast area which is to be considered for prospecting. It may be that the Roraima formation is the bringer of the diamonds, yet the connection is only indirect at present. For it is a known fact, that the find-spots of diamonds in Br. Guiana may lie even as much as 40 km. away from the border of the formation (the Abagai diggings on the right bank of the Puruni) and that the diamond-bearing zone is a few tens of kilometres wide.

Therefore it is not so much the present extension of the formation which ought to be taken in the first place as a standard for the chance of diamonds being present or not. It is much more the question how far the Roraima formation extended; for it is the weathering-residue, mixed with the weathering-products of the local rocks, which, under favourable conditions for concentration may produce workable deposits up to 40 km. distance from the present formation.

That the formation must once have had a very great extension in Surinam follows from the fact that it is at least 650 metres thick. And that such a mighty formation cannot have been limited to a single plateau is self-evident. If one reasons from the standpoint that find-spots are possible at as much as 40 km. distance from the edge of the formation, as is the case in Demerara, we should be able to draw a circle with a radius of 40 km. around the Table mountain; and the areas, especially the more level areas near the Saramacca, Coppename and Lucie rivers, for as far as they would fall within it, would come into consideration for prospecting. It should be mentioned here that this view would be incorrect if an important subsidence of the Table mountain and the underlying basal complex should have taken place, along faults in the latter. In that case diamond-bearing deposits, if any, would have been carried away by erosion, long ago.

THE INTRUSIVE DIABASES, GABBROS, EPIDIORITES AND ALLIED ROCKS.

INTRODUCTION.

We shall occupy ourselves with the latest igneous rocks which break through the basal complex of granitodiorites, ortho-gneisses and schists. This group of intrusives comprises diabases and gabbros and their metamorphic equivalents, epidiorites and schists. The non-metamorphic members, the diabases and gabbros, may be divided into a number of separate groups. Special types with varying quartz percentage, the quartz diabases and gabbros are pretty generally represented; next to these come the quartz-free, normal diabases; besides a small number, which in accordance with their considerable percentage of olivine or hypersthene, are called olivine- and hypersthene diabases or gabbros. All these rocks appear to be closely related in spite of the variability of the mineralogical composition by their being linked up so much by transitions that we can hardly separate them. The frequency of diabase in Surinam struck even the earliest geologists. Quartz diabases have already been described by Kloos. [1])

A great variety in structure appears to exist elsewhere in what is usually called diabase. While dyke-shaped rocks especially show typical ophitic structure, the latter is poorly developed or is entirely wanting in others, particularly when the rock occurs in masses. In this respect the diabases in Surinam behave in the same way as those met with elsewhere. No essential structural difference exists between diabases and gabbros, and for this reason it would, possibly, have been better not to divide them into two groups, [2]) the more so as no great mineralogical differences are to be observed. Yet the use of two denominations has been adhered to, because practically all rocks, occurring in dykes, exhibit ophitic structure, in contradistinction to those occurring in masses.

In imitation of Gümbel diabases and gabbros whose pyroxenes have been superseded by secondary hornblende, are called epidiorite. These behave geologically in the same way and are of the same age as the diabases. This applies with a less degree of certainty to part of the epidiorites, which has undergone more important secondary changes, showing distinct parallel texture and to some considerably metamorphosed schists. Probably, however, the latter should also be regarded as metamorphosed diabases only. It is an open question whether all, diabases, gabbros and metamorphosed rocks belong to a single intrusion period and whether the schists do not partly belong to older constituents of the basal complex.

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[1]) J. H. Kloos. 28. p. 181.

[2]) The Committee for British Petrographic Nomenclature even discourages the use of the term diabase; See Miner. Mag. 1922. p. 139. See also: L. Finckh. Zur Diabasfrage. Zeitschr. Deutsch. Geol. Gesellsch. LXXV. 1923. B. p. 55—58.

We shall first discuss the petrography, the geological behaviour and the distribution of the diabases and gabbros; then the same for the metamorphosed rocks, and the possible causes of epidioritization; in conclusion a few speculations concerning the magma-relationship of the diabases and gabbros will follow.

THE MINERAL COMPOSITION OF THE DIABASES AND GABBROS.

The Plagioclases.

The constitution of the plagioclases of 25 rocks with typical diabase-structure was examined with the aid of refraction index liquids. The names of plagioclases used in the following correspond to the respective percentages of albite-anorthite such as those proposed by Tschermak. The composition of the plagioclases in each diabase appears to vary little, unless zonal structure occurs. The largest variation in a single rock without zonal feldspars ranges from acid labradorite to basic bytownite (50—80 % of An.). Three diabases, which contain zonal feldspars, yield for these from oligoclase (edge-zone) to labradorite (nucleus) or abt. 26—55 % of An. In the non-zonally constructed feldspars, the composition varies maximally from 80 % of An., i. e. a basic bytownite to 42 % of An., i. e. andesine.

If well-developed ophitic structure is present, the shape of the plagioclase varies little. The crystals are invariably oblong-shaped, according to P/M, and flattened at the same time according to M. Accordingly we invariably see crystals in the thin sections, which are now oblong-shaped and pretty well rectangular, now lath-shaped. In the coarse-grained diabases the sections of the plagioclase are less clearly oblong-shaped and rarely lath-shaped; the zone P/M, however, invariably predominates. Generally speaking, therefore, we observe a less beautifully developed network of the plagioclases in the coarse diabases while crossings are much less frequent than in the fine-grained ones. The faces P, M and (100) are often recognizable. Sometimes other faces of the zone (100) : (001) are also observed, when the plagioclase projects idiomorphically into pyroxene or ore which crystallized later. In a number of gabbros the form of the plagioclase is not idiomorphic, but invariably more or less oblong-shaped. The plagioclases always show polysynthetic twin-structure; if zonal structure is present, the lamellae continue through the zones. Sharply defined zones are wanting, the transition in composition of nucleus to edge is a gradual one.

The twinning-law of a number of plagioclases in diabases which invite to a closer inspection on account of their beautiful lamination, has been investigated by the aid of the Federow-stage. Besides the Albite-law, the law corresponding to Carlsbad asserts itself less commonly; sometimes both laws are combined in one crystal, in which case the Carlsbad-lamellae are broader than those according to the Albite-law. Often, too, a crystal that according to the Albite-law is twinned, shows a second system of lamellae, almost crossing that according to the Albite-law perpendicularly; this system is twinned according to the Pericline-law. The lamellae according to the latter law are usually distinctly finer than those according to the former. The intergrowth-plane in the Pericline-law is a face of the zone (100) : (001): the so-called „Rhombischer Schnitt". Some sections approximately perpendicular to the zone (001) : (010) in the cases examined, show the lamellae according to both laws and a trace of the base-cleavage at the same time (Fig. 13). The intergrowth planes of the Pericline-lamellae seem to run almost parallel

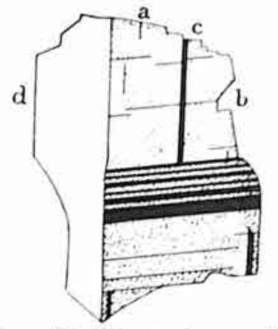

Fig. 13. Plagioclase polysynthetic according to Albite- and Pericline-law. × 35 (Y 206).

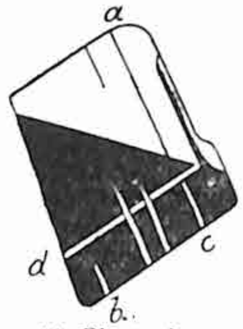

Fig. 14. Plagioclase polysynthetic chiefly according to Baveno-law. × 45 (Y 98).

to the base-cleavage. It is not certain, however, whether the „Rhombischer Schnitt" here is indeed parallel to the base. If we assume that the "Rh. Schn." is parallel to the base-cleavage the plagioclase would bear a good 40 % of anorthite according to Schmidt's [1]) table which is not in agreement with the composition found by the Federow-measurement and the index of refraction method (viz. abt. 70 % of An.). Consequently it is not possible that base and "Rh. Schn." are parallel.

From time to time, too, we meet with the Baveno-law. The plagioclase crystals here show two lamellae according to (021), right and left Baveno respectively. The section approx. according to (100) shows the trace of the intergrowth-plane, more or less diagonally in the more or less oblong-shaped crystal; while in the sections according to (010) and (001) the trace of the intergrowth-plane runs parallel to the edge of (010) : (001). Fig. 14 shows a right Baveno twin between crossed nicols. The one lamella exhibits cleavage according to M (a), the other a few polysynthetic lamellae according to the Albite-law (b-c) and a single one according to the Pericline-law (d) intersecting the preceding ones. The percentage of anorthite of this multiplet, has been fixed at abt. 53 %.

Crossings, i. e. irregular intersections of plagioclases, are common in the fine-grained rocks (see fig. 15).

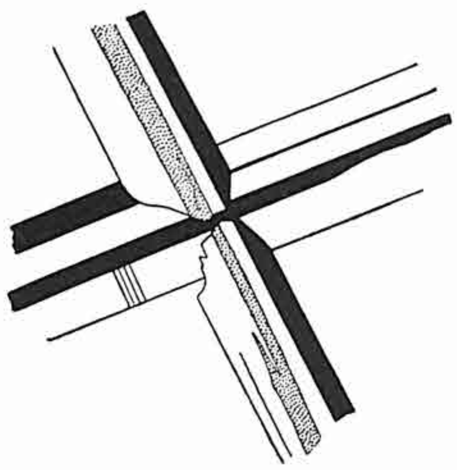

Fig. 15. Crossing of plagioclases. × 40 (Y 66).

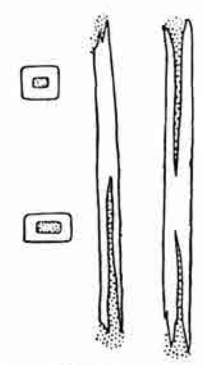

Fig. 16. Plagioclases with central cavity. × 90 (Y 70).

Plagioclases in a hypersthene diabase from Goddo on the Suriname river (Y. 70) reveal a divergent structure. The plagioclases are oblong-shaped but without any definite crystal form, and with a central cavity (fig. 16);

[1]) Ed. Schmidt. Die Winkel der kristallographischen Achsen der Plagioklase. Heidelberg. 1916. p. 50.

Plate 12.

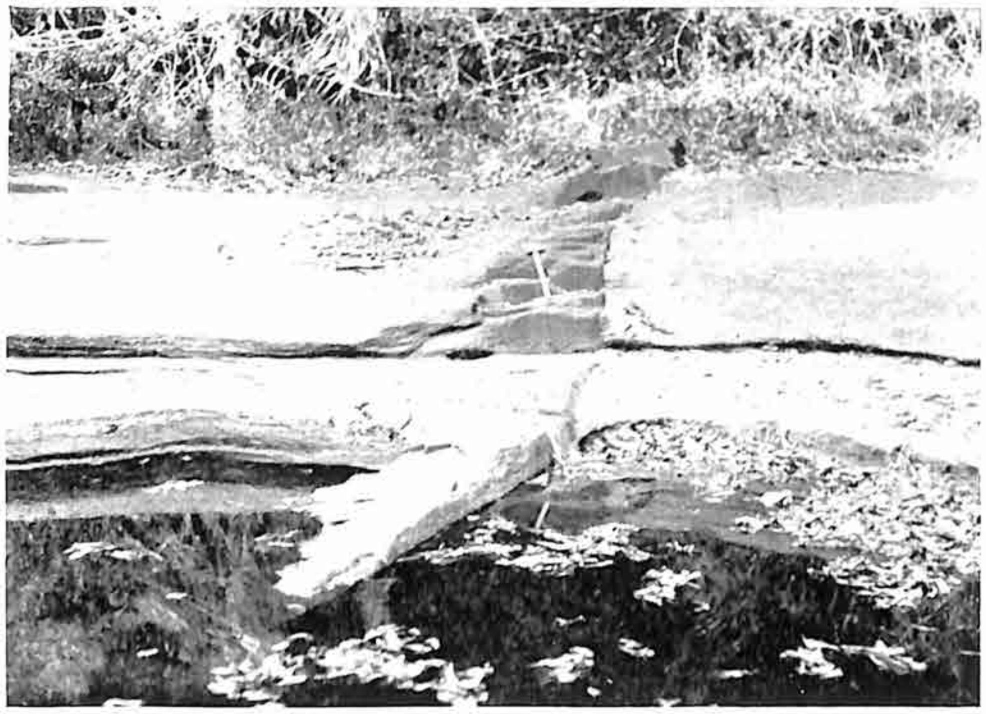

Fig. 1. Diabase dyke traversing porphyritic biotite granite. Granerud near Geddo.

Fig. 2. Monoclinic pyroxene dissected at the edges by smaller and idiomorphic plagioclases in quartz gabbro. × 27. (Y. 216).

Fig. 3. Coarse (110)-cleavage in monoclinic pyroxene, intersected by fine (001)-cleavage. × 105. (Y. 216).

it appears that extremely fine crystalline material is enclosed in it, among which grains of ore are abundant. The same material also sometimes appears interstitially between the oblong-shaped plagioclases. The tubular cavities penetrate the whole length of the plagioclase crystals or the latter are very deeply cleft from the ends, as seen in the longitudinal sections. Apparently we have to do with a skeleton-like growth of plagioclase in which groundmass is enclosed. The phenomenon looks just like that occurring more commonly in basaltic plagioclases.

Primary inclusions are sparse. As primary inclusion an extremely fine dust sometimes appears. It may be present in such quantities that the crystals are obscured and have a gray or pale-brown tint (e.g. Y. 157; V. 2350). This phenomenon is not locally restricted but all the plagioclases of one slide may be more or less obscured by the dust. Besides this, it may be equally distributed over the crystal, or some lamellae are more richly provided with dust than others. Now the centre is more polluted, now the margins, so that a pseudo-zonal structure may appear. This phenomenon occurs both in unmodified and uralitized diabases. On being strongly magnified the dust is resolved into innumerable grains; with strong refraction and apparent isotropism. Similar dust in basic feldspars is frequently recorded in petrographic literature. Fine brown rods, possibly haematite, trending parallel to the intergrowth-planes of the lamellae have been observed in one case (Y. 244). Apatite appears as inclusions, while long apatite needles, too large to be entirely enclosed, intersect the plagioclase. Olivine is rarely enclosed, possibly because it invariably occurs in large pieces. Ore is seldom met with in the plagioclases.

Monoclinic Pyroxenes.

In agreement with the great variability of the rocks, the chemical composition of the pyroxenes is also divergent, which finds expression in the varying optical properties (varying extinction on (010), colour and pleochroism). Some pyroxenes show mauve-brown, rose or even bluish-mauve colours. The violet colours here do not point to titaniferous augite as sections according to the clinopinacoid do not show a strong dispersion of the optical axes. As monoclinic pyroxene in the form of phenocrysts is wanting, we observe no idiomorphic forms, except in a few gabbros where a tendency towards a prismatic form appears. Otherwise pyroxene is irregular in form whether granular or conforming to plagioclase which crystallized earlier; in the latter case we are concerned with the well-known ophitic structure. Sometimes the crystals of pyroxene are very much larger than the plagioclase crystals; in this case we observe coarse pyroxene crystals surrounded by small plagioclase laths which penetrate the pyroxene, so that the borders of the pyroxene show quite a number of re-entrant angles, and plagioclases may even be enclosed (Pl. 12 fig. 2). This is particularly the case in the gabbros from the Central Wilhelmina mountains. The intersecting of pyroxene by plagioclase may go on to such an extent that a great number of pieces of pyroxene which apparently belong to one crystal (parallel cleavage and equal optical orientation) are

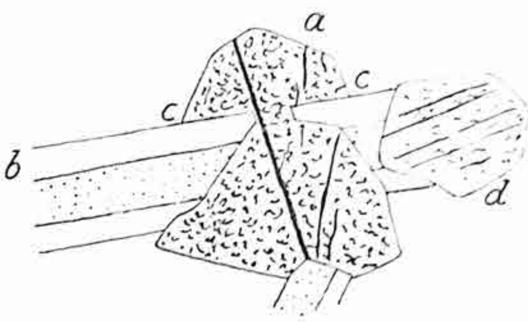

Fig. 17. Contemporaneous pyroxene and plagioclase. × 40 (Y 66).

separated by lath-shaped plagioclases. Deviations in the sequence of age of pyroxene and plagioclase in otherwise typical diabases do occur. The accompanying fig. 17 represents crossing of pyroxene and plagioclase in hypersthene diabase from Goddo, Suriname river (Y. 66). The pyroxene (a) is squeezed by the plagioclase-lath (b), forming one single crystal, while the pyroxene has at the same time grown on along the lath (points c). This relation is only to be explained by contemporaneous growth. Other, granular pyroxenes (d) are certainly older than the plagioclase. Also in some other coarse-grained diabases, granular pyroxenes may occur, which are older than or contemporaneous with the plagioclases.

In the coarse-grained diabases and gabbros, besides the (110) cleavage of the pyroxene a very fine cleavage system, with lines running strictly parallel and close together, occurs. In sections vertical to the prism-zone they dissect the pseudo-rectangle between the prism cleavage. This cleavage lies according to (100); it is the diallage cleavage. A third system looks precisely like the diallage cleavage but is differently oriented. Plate 12 fig. 3 shows a pyroxene of gabbro from the central Wilhelmina mountains (Y. 246). The crystal is intersected almost parallel to the clinopinacoid. The coarse cleavage according to (110) is obliquely intersected by a fine cleavage. It turns out to be the base cleavage. In the case illustrated the angle between the two cleavages is 79°; in sections quite parallel to the clinopinacoid, the angle ought to be 74°.

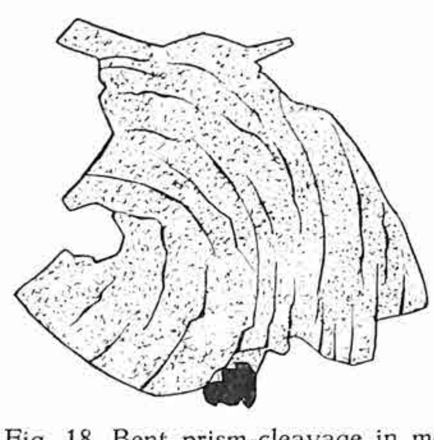

Fig. 18. Bent prism-cleavage in monoclinic pyroxene × 70 (Y 206).

A phenomenon never mentioned in literature is the following: in a number of rocks monoclinic pyroxene shows considerably warped cleavage-lines, now in a few pyroxenes, now in most of them. The trace of the prism-cleavage is bent, the curve sometimes amounting to more than 90° (see fig. 18). For the rest the crystals behave as the others: their proper shape is wanting and they may enclose the ends of feldspar-laths. The c-axis must be curved in the clinopinacoid: sections vertical to the cleavage show no deviation. The Pl. 24 fig. 1 shows a number of pyroxenes with bent cleavage in olivine diabase from the Central Wilhelmina mountains (Y. 206). The bending, however, is not confined to the cleavage only; between crossed nicols that portion of the crystal which lies obliquely to the polarizer direction, remains dark, while the rest is brightly illuminated. If we turn the stage of the microscope the shadow glides on over the crystal as if we were dealing with part of a spherolite. The crystal, between crossed nicols often appears to be divided into fields with different extinction. In this case the cleavage continues through all the fields. Hence we should be inclined to put these phenomena down to intense cataclasm: a warping of the crystals by secondary pressure-action. The structure of the other minerals, however, proves that secondary transformation is not the cause. If the bend, sometimes amounting to upwards of 90°, was formed after complete crystallization, the oblong-shaped feldspars would have broken, or very much bent, so that the ophitic structure would have been disturbed. The other minerals, however, show no disturbance. Transformation after crystallization cannot be the cause. Also it is not a consequence of motions in an already partially crystallized magma for in that case the plagioclases which crystallized earlier would certainly exhibit protoclasm. So we are concerned with primary bending originating during growth. The true cause, however, of the abnormal behaviour may not be ascertained. Many diabases reveal this remarkable phenomenon more or less distinctly; those from the Central Wilhelmina mountains, [1]) from the Gonini [2]) and from the tract between Lawa and Tapanahony [3]); those from the Tosso creek region (side-creek left bank Tapanahony), [4]) from Drietabbetje creek (side-creek left bank Lawa), [5]) from the Lawa near the Bushnegro village of Coermotibo, [6]) from the Gran creek, [7]) from the Marowyne creek, [8]) from the watershed Macami and Savannah creek (side-creeks of the Suriname and Saramacca), [9]) from the Marowyne below the junction of the Lawa and the Tapanahony, [10]) and from the Upper Commewyne. [11]) Hence we see that the phenomenon is not local but regional.

Twins of monoclinic pyroxene occur now in two's and three's, now in a great number in one thin section. The twinning-plane is invariably (100). In sections vertical to the prism-zone both the twin halves extinguish simultaneously; the double-refraction in that case, however, is not equal owing to the varying optical orientation.

Fig. 19 shows the stereographic projection of a twin obtained by a measurement on the Federow-stage. The projections of the β-axes fall next to each other and lie practically within the twinning-plane (I), which is at the same time the intergrowth-plane. The latter plane bisects the angle of the traces of the (110) cleavage (II and III); The axes n_α and n_γ of the two twin-halves ought, if the measurement were quite correct, to lie on the same zonal circle; they are indicated in the figure. The angle between the point of intersection of the traces of the cleavage and n_γ I or n_γ II, gives the maximal extinction. This amounts to abt. 44°.

As has already been mentioned well-defined plagioclases are sometimes enclosed in the coarser pyroxenes. Other inclusions may be olivine, ore, and apatite. Ore is very frequently enclosed. The oldest ore is the well developed octahedral ore, while there is no idiomorphism between the patchy ilmenite

[1]) Y. 206, 207, 210, 243, 300.
[2]) V. 1121, 1123, 1126.
[3]) V. 59, 102, 103.
[4]) V. 194, 197.
[5]) V. 210.
[6]) V. 508, 585.
[7]) V. 874.
[8]) V. 1665.
[9]) V. 1550.
[10]) V. 1702.
[11]) V. 1713.

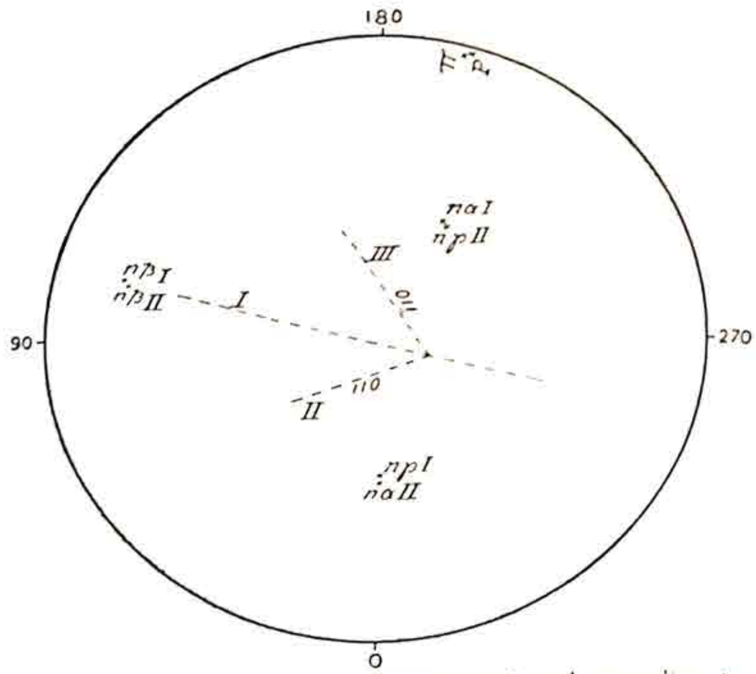

Fig. 19. Stereographic projection of augite twinned according to (100).
π = pole of intergrowth-plane.
P = pole of twinning-plane.

and pyroxene. The enclosed olivine is never idiomorphic. Apatite occasionally intersects the pyroxene in the form of long needles.

Orthorhombic Pyroxene.

Orthorhombic pyroxene occurs in particular in gabbros, where its optical properties are variable. A weakly pleochroitic hypersthene, yet showing red according to n γ, which is optically negative, occurs in abundance in a gabbro from the Central Wilhelmina mountains (Y. 235), from the Avanavero falls (V. 3633) and from the Courantyne river near the Manikobi creek (Vtz. 801). In these normal to coarse-grained rocks they form irregular pieces which are cut up at the sides by minute plagioclase crystals which may even be enclosed. Not always may the orthorhombic pyroxene be called hypersthene. In the above-mentioned rocks by the side of hypersthene appears a practically colourless pyroxene showing vaguely laminated structure in which the lamellae trend parallel to the main zone. This pyroxene has a great optic axial angle, hence its optical character cannot be ascertained. Bronzite is the best term for it; in a few cases however the interference figure is clearly positive and it may be called enstatite. Consequently the percentage of iron in orthorhombic pyroxene varies. Sometimes a remarkable phenomenon is to be seen in the colourless bronzite or enstatite: the crystals are divided into two groups of polarizing fields; the fields of each of the groups extinguish simultaneously [1]) (Pl. 24 fig. 2 and 3). The fields are irregularly distributed over the crystal and are visible both in sections parallel and vertical to the prism-zone; they do not differ in either of these sections. The whole shows

[1]) Y. 228, 230, 231, 240, 245, 329; Vz. 801.

a resemblance to a vaguely developed structure of microcline. Even on being strongly magnified the fields are not resolved into lamellae.

Orthorhombic and monoclinic pyroxene sometimes penetrate each other. The monoclinic one penetrates the orthorhombic one as delicate fibres, parallel to the cleavage or as irregular network or spots (Pl. 24 fig. 3).

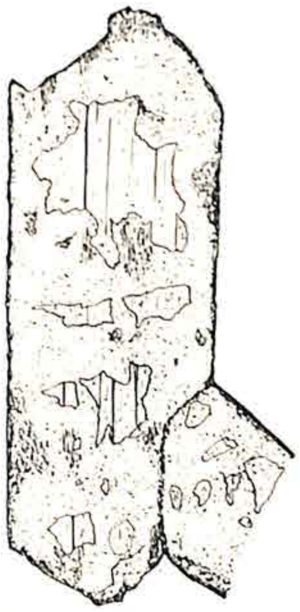

Fig. 20. Nearly complete pseudomorph to hypersthene $\times$ 70 (Y 66).

An orthorhombic pyroxene of another habitus appears in the hypersthene diabases near Goddo, Suriname river. It is rich in pseudomorphs to phenocrysts. The pseudomorphs show the original crystal-shape and patchy relics of the mineral (fig. 20). The latter is distinguished by clearness, stronger refraction and cleavage from the secondary products. Examined on the Federow-stage, the relics invariably show straight extinction. The optic axial plane lies in the main zone. The smallest index of refraction coincides with the crystallographic c-axis, β is acute bisectrix; its optical character is negative. The crystals show the faces (100), (110), (010) in octahedral sections, and end-faces in oblong hexagonal ones. According to the optical character they are hypersthene phenocrysts. Pleochroism is wanting. In the pseudomorphs talc chiefly occurs, together with some chlorite and uralite. In one of the hypersthene diabases a very fine scaly talc aggregate replaces the hypersthene from the sides and especially from the cracks and cleavage.

Hornblende.

Primary hornblende is present in no large quantities in the diabases or gabbros. In the coarse-grained rocks some hornblende often occurs as a continuation of the side of the pyroxene (see fig. 21 near A) without however forming kelyphitic zones (e. g. Y. 231, 246, 269, 339). The amphibole is sharply separated from the pyroxene, but both work into each other very finely. The hornblende is cut off by the feldspar-laths in the same way as the pyroxene. Hence we get the impression that the period of growth of the pyroxene closes with the formation of some hornblende. The same hornblende also appears independently and shares the ophitic-

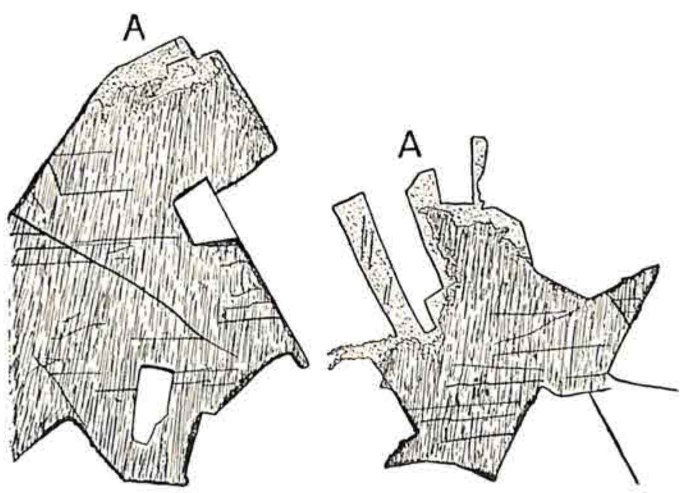

Fig. 21. Monoclinic pyroxene, with continuation of hornblende (stippled) at the borders $\times$ 79 (Y 246).

structure. The cleavage is but moderately developed. The pleochroism ranges from bluish-green to grass-green and yellowish green: n γ > n β > n α. Usually the bluish-green is wanting, hence the colour is n γ > n β > n α. There is no reason for presuming that the hornblende is secondary. Occasionally a single pleochroitic halo is to be seen (in Y. 231, 246). In a few sections basaltic, brown hornblende occurs and behaves in the same way. The very same piece may show in part the green and in part the brown tints. The appearance of hornblende is restricted to the coarse-grained diabases but is spread throughout the whole Colony.

Biotite.

Some biotite is found occasionally in the gabbros. If green hornblende is present in the coarse-grained gabbros, we usually observe some biotite too. The biotite is invariably xenomorphic, and has often grown around ore, being of later date than ore or pyroxene. The biotite occasionally exhibits pleochroitic haloes. On being chloritized a green colour may also occur. In some preparations, however, biotite of a primary nature shows pleochroism of bright yellow to grass-green. The biotite is always of secondary importance.

Olivine.

Some olivine occurs in most diabases; now in such quantities that we might speak of olivine diabase, now as an accessory, while others again are olivine-free. The mineral is not present in the gabbros. The olivine never shows a well-defined crystal-shape, nor it is distinctly corroded. The olivine is partly older, partly contemporaneous (at the periphery) with feldspar and always older than the pyroxene: the latter never impedes the olivine and may surround it. Invariably, irregular large cracks, and rarely some cleavage are seen. The olivine is very clear. The pieces are mostly of the same size as those of the pyroxene, though also large irregular crystals sometimes appear. In very fine-grained diabase olivine is rarely detected. For 2 V. there was found 73°, 75°, 78°, 80° and 84° around n α which indicates an olivine rich in iron. Only octahedral ore occurs as an inclusion.

The change that olivine undergoes is remarkable. We rarely see crystals wholly intact, and usually the mineral is partially or wholly replaced by a more or less homogeneous mineral mass. The latter exhibits properties which we might best compare with biotite: fine parallel cleavage, straight extinction and distinct pleochroism in various tints of green. Sections parallel to the cleavage-lines only show green in the darkest tint. Therefore the pleochroism is n γ = n β > n α. The interference figure is clearly uniaxially negative. The refraction in one direction is the same as that of the balsam sometimes somewhat weaker, in the other directions clearly stronger. All this together agrees with the properties of biotite of a particular type, for biotite with refraction in one direction approximately equal to 1,540 seldom occurs. These features may also be compared with those of talc of a very small optic axial angle with the exception of the distinct colour and the pleochroism. The well-known pseudomorphous mineral to olivine viz. iddingsite does not count because of its much stronger refraction and large optic axial angle. Hence we assume that we are dealing with biotite of a special type. The change in the olivine begins at the periphery and at cracks in such a way that the olivine is penetrated with a network of channels filled with a fibrous material (Pl. 24 fig. 4). At this stage the biotite behaves quite homogeneously. The line of demarcation between the olivine and the biotite is sharp, and the olivine relics are quite fresh. The result of the change is a homogeneous biotite completely replacing the olivine. But we must make a restriction here: in the biotite strings or fibres of intenser refraction, darker colour and different optical orientation may occur. They remind us of the more strongly refracting fibres in pinit-pseudomorphs to cordierite. The homogeneous pseudomorphs sometimes cause us to doubt whether we are really concerned with a biotite pseudomorph; e.g. in a porphyritic diabase from the Central Wilhelmina mountains (Y. 205 B and 206 B). Here phenocrysts of plagioclase and grass-green biotite are present, the latter showing the otherwise lacking corrosion forms of original olivine. Some hexagonal sections deceptively imitate an idiomorphic shape of a porphyritic biotite leaflet, but it is certain that they are pseudomorphs to olivine. Fig. 22 represents a partially completed pseudomorph. Olivine relics are embedded in biotite, bordering on an ore-crystal (b), and on feldspars, one of which has been sketched (c). Near point (e) we observe fibres penetrating from the biotite into the feldspar, along part of the base-cleavage. Near the points (a), too, the biotite has not confined itself to its original space, but has sent out fibrous branches into the adjacent minerals. Some increase of volume of little importance may therefore occur, and at the same time it is clear that we are concerned with replacement of olivine by biotite, which took place after complete crystallization of the rock. There are but a few analogous cases mentioned in the literature on the subject. Sederholm [1]) describes biotite-pseudo-morphous to olivine originating from uralite porphyrites, East of Tavestehus in South-Finland. He concludes a direct transition of olivine to biotite, without intervening products, just as in our case. Subsequent observations, however, have induced Sederholm to assume that an intervening product does occur in many cases. Grains of ore appear first in olivine as nuclei around which the biotite grows.

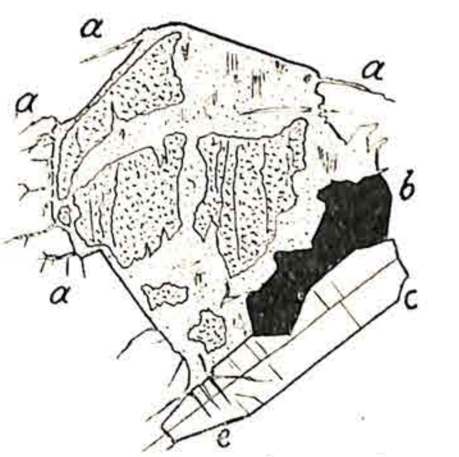

Fig. 22. Nearly complete pseudomorphosis to olivine (with adjacent ore and plagioclase) × 60.

The appearance of olivine by the side of free quartz in many diabases is remarkable. Instead of the ortho-silicate by the side of the free silicium-oxide we should expect meta-silicates.

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[1]) J. J. Sederholm: Studien über archäische Eruptiv-gesteine aus dem Südwestlichen Finland. Tscherm. Miner. Petrogr. Mitt. XII. 1891. p. 106.

Ore.

Ilmenite, titano-magnetite or magnetite form the ore of the diabases and gabbros. In the fine-grained diabases magnetite is present in abundance and may form well-defined minute octahedra. Twins according to (111) are to be recognized by re-entrant angles and a shortening in the direction of the twining-axis. Magnetite is idiomorphic towards the feldspar and the pyroxene; and is often enclosed in the pyroxene and rarely in the feldspar. In the coarse-grained diabases and gabbros, however, patchy ilmenite mostly appears. These patches are for the greater part of later date than the plagioclases. The plagioclase intersects the ore, and the laths with well-shaped ends project into the ore, the plagioclases being sometimes even completely enclosed. Pl. 24 fig. 5 gives the relation; both ore and pyroxene share the ophitic structure. This relation deviates from what we generally find recorded in the literature on the subject, the ore being regarded by many petrographers as older than the feldspar. Grout, however, describes the same relation in the Duluth-gabbro from Minnesota. [1]) This gabbro locally shows diabase-structure. The illustration given by Grout, is just like the Surinam diabases and in this case the ore is also stated to be of later age. In many coarse-grained diabases and less so in the fine-grained ones ore-skeletons [2]) occur (see fig. 23). We observe pieces of ore which partially are still to be recognized by their faces as magnetite, partially pass into skeletons. The spruce-fir-skeletons are numerous. They behave idiomorphically towards the adjoining minerals.

Fig. 23. Ore skeleton. × 50. (Y 210).

In many cases leucoxene is released from titano-magnetite by demixture. Here, we see ore surrounded by rims of strongly refracting titanite. [3]) Usually the ore crystals are in a state of decay, irregular holes get into the sides and finally nothing is left but a mass of titanite in which black grains indicate the remains of the ore. This phenomenon appears both with octahedra and crystal-skeletons.

Pyrite.

Pyrite is wholly wanting in most diabases; but is present in others in varying quantities. The pyrite betrays itself in the rocksample, now as cubes up to 2 mm. in size, oftener, however, as irregularly sprinkled ore. When pyrite has a regular shape it behaves idiomorphically towards the other minerals. Occasionally it passes into limonite.

[1]) Journ. of Geol. XXVI. 1918. p. 631 and fig. 5. p. 632.
[2]) e.g. Y. 157, 206; V. 194, 197, 209, 292, 370, 875, 1122, 1698; C. 23.
[3]) Y. 210; V. 194, 209.

Apatite.

The quantity of apatite varies considerably. In many diabase sections, we fail to discover any apatite, or we observe some very fine needles. In the normal and coarse-grained Surinam diabases very long apatite-needless assert themselves. Their length may exceed their breadth forty times; so their form differs from that of the apatite in acid rocks. The cross-section is hexagonal. The needles may be bent. Cracks running crossways are common. In some coarse-grained diabases short apatite-rods like those in the granites are met with. [1]) These sometimes accompany the needle-shaped forms. With the possible exception of pyrite, the first mineral to crystallize is apatite. In the coarse-grained diabases apatite-needles intersect the ore, plagioclase, pyroxene, hornblende, biotite, quartz, potash feldspar and granophyre. Pyroxene however is rarely intersected, whereas plagioclase and granophyre very often are. We failed to see needles in olivine.

Quartz and Potash Feldspar.

Both minerals are usually found together. Quartz fills the spaces left open by the other minerals. Often triangular pieces of quartz are found between the feldspar-laths; consequently it is primary quartz which crystallized last. The quartz is very clear.

Bubbles of liquid matter in strings [2]), and possibly gas-inclusions too, fairly often occur in the larger pieces of quartz. They sometimes contain stationary bubbles. Differently oriented pieces of quartz together may fill the same cavities. Quartz is either present alone, or feldspar occurs together with quartz as residual crystallization. If larger pieces of potash feldspar are present, the free ends of the plagioclase-laths protrude into them with their proper shape. Such pieces of potash feldspar may exceed a plagioclase crystal in size. The shape of the pieces is always irregular. In a gabbro from the Central Wilhelmina mountains, for instance, we observe irregular patches attaining to a size of 1 mm. (Y. 246). The positive extinction on the clinopinacoid amounts to 4—6° in respect to the base-cleavage. Besides the base-cleavage and that according to the clinopinacoid fine and less regular cleavage may also appear, forming an angle of about 70° with the base-cleavage: the Murchisonite cleavage. The potash feldspar often exhibits typical microcline-structure (see Pl. 24 fig. 6 of a diabase from the watershed between Gran-rio and Pikien-rio, V. 1894). [3])

Part of the lamination-system is often very poorly-developed and the rest is extremely fine, as if the formation were still in the initial stages. In the coarse-grained diabases and gabbros, we meet with the best microcline-structure.

So we see that potash-feldspar is undoubtedly present which is sometimes doubted in the literature on the subject [4]). Nowhere have I found mentioned the

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[1]) V. 2350, 2351; Y. 197, 224, 228, 274.
[2]) Y. 224, 246, 247 B.
[3]) Y. 224, 246, 254; V. 3631, 3632, 3635; C. 82, 86.
[4]) c.p. H. Rosenbusch. Mikroskopische Physiographie der Mineralien und Gesteine. Stuttgart. 1908. p. 1168.

presence of microcline in diabases [1]). Quartz and potash feldspar very often appear in beautiful granophyric intergrowth. Plate 25 fig. 1 and 2 show a strongly magnified intergrowth in quartz diabase: the potash feldspar is in the extinction position, whereas the quartz is brightly illuminated. The quartz mostly has triangular shape. In other intergrowths the pieces of quartz are irregular but invariably bounded by broken lines, in any case not vermiform as in myrmekite. The relationship between quartz and potash feldspar varies. In some sections they are quantitatively about equal, in others quartz or feldspar is in the majority. Occasionally we observe cavities among the other minerals for the greater part filled with quartz, which on one side is still partly intergrown with potash feldspar. The granophyric intergrowth may surround a plagioclase crystal, and radiate from it. In one thin section rich in intergrowth the relative quantity of quartz and potash feldspar was ascertained according to Rosiwal's method: on an average 54 % of quartz was found in the granophyre. Too much value, however, should not be attached to this figure in view of the large variation in the percentage of quartz which different sections show. Consequently it is not probable that we are concerned with a eutectic mixture [2]). Strange enough we very often find mentioned in descriptions of other quartz diabases that quartz is intergrown with plagioclase, contrary to our experience in the Surinam-diabases, in which potash feldspar invariably constitutes part of the intergrowth. In the coarse intergrowths even a distinct microcline-structure may be observed (Plate 25 fig. 4 shows a coarse-grained quartz gabbro from Ebba-top, V. 1371).

PETROGRAPHIC DESCRIPTION AND CLASSIFICATION OF THE DIABASES AND GABBROS.

In the naming, the structure and the mineral combination has been taken into account. The rocks exhibiting more or less clearly ophitic structure whether fine or coarse-grained [3]) are called here diabases; the rest, invariably normal or coarse-grained rocks, are called gabbros. The rocks bearing a quantity of quartz easy to find microscopically, are termed quartz diabases and quartz gabbros respectively. A significant proportion of olivine or orthorhombic pyroxenes may give rise to special types. Structurally no sharp line of demarcation can be drawn between the diabases and gabbros, as we saw above. Whereas the fine-grained diabases clearly show ophitic-structure, there are a number among the coarse-grained ones in which this is less marked, while gabbros, in their turn, have a tendency to show ophitic-structure in parts. Neither is there a sharp difference between quartz-free and quartz-bearing diabases and gabbros respectively, the quartz decreasing regularly from approximately 5 % to 0 %; hence there is no distinct line of demarcation between the quartz-bearing and the quartz-free rocks.

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[1]) Except by J. B. Harrison. **68.** p. 89.

[2]) A. Johnsen. Monatsber. preuß. Akad. Wissensch. Berlin. 26 VII. 1923. p. 209. has shown that intergrowths bounded by broken lines are eutectic, whereas those bounded by curved lines (e.g. myrmekite) are not.

[3]) By coarse-grained rocks are meant all those which show feldspars longer than one to two millimetres, on an average. In a few diabases the feldspars even attain to 5 mm. or more.

The quartz diabases and quartz gabbros.

In the quartz diabases the quartz is often intergrown with potash feldspar, or both occur separately, or quartz occurs alone. The number of rocks bearing granophyre predominates by far, and this type of quartz diabase is characteristic of Surinam. It is comparable with the classical Konga-diabase of Sweden. The percentage of quartz-feldspar-intergrowth has been ascertained by means of the Rosiwal method. A couple of diabases rich in intergrowth yield: 8,1 and 11 % of intergrowth. On the whole we may say that there is a larger percentage of granophyre in the coarse-grained rocks than in the fine-grained ones. This relation, however, is not so pronounced as in some other quartz diabases. Collins has shown for the diabases from the Rainy Lake District, Canada, that the quantity of granophyre is proportionate to the size of the grain of the rock [1]). The denominations quartz diabase and gabbro have been taken in a wide sense here, the names having been extended to rocks relatively poor in quartz.

The mineral combination is plagioclase (labradorite up to and including bytownite), monoclinic pyroxene (developed as diallage or not), ore, and quartz, with or without potash-feldspar. Besides this, we may meet with some hornblende as a continuation of the pyroxene at the edges especially in the coarse or normal-grained rocks. An insignificant quantity of biotite is occasionally present. Apatite needles are common. Pyrite is negligible. The potash-feldspar sometimes exhibits microcline-structure. The ore is mostly octahedral in the fine-grained rocks (magnetite or titano-magnetite) and patchy in the normal or coarse-grained ones (ilmenite). Pyroxene with curved (110) cleavage often occurs here. Olivine deserves special mention. This mineral is very common as an accessory component in the quartz diabases, and in that case, constitutes a low percentage in them (e.g. in a quartz diabase with 5½ % granophyre, 2½ % of olivine was measured). Here the percentage of olivine can have no influence on the name, but in other rocks, by the side of granophyre, a considable quantity of olivine appears, so that we hesitate in applying the same name and to them and doubt if we might call them quartz olivine diabases (e.g. V. 872, 1702).

The ophitic structure is clearest in the fine and normal-grained rocks (Pl. 25. fig. 5). In a number of normal to coarse-grained rocks the intersection of pyroxene by lath-shaped plagioclases is less typical, and the figure more or less approaches the gabbro-structure (Pl. 26 fig. 1) (e.g. V. 210, 292, Y. 341 B.; C. 23). Porphyritic structure is entirely wanting. With typical ophitic structure the sequence of crystallization is: apatite and pyrite; plagioclase, olivine and pyroxene; hornblende and biotite; potash feldspar and quartz. Ore occupies different places; octahedral ore must be the very first, the patchy ore lasting over a longer period. Olivine is little older than or partly contemperaneous with pyroxene, seeing that they impede each other mutually or the former is enclosed in the latter. If the structure is less clearly ophitic the interval plagioclase-pyroxene is less sharp. All rocks are perfectly massive. The fine-grained ones may have a dense basaltic habitus in the sample. The coarse and sometimes also the normal-grained ones clearly show a difference between the coloured pyroxene and the grayish or greenish feldspar material, in which the lath-shape of the plagioclases is more or less to be distinguished.

A few quartz diabases of the Leguan island (V. 2349, 2350, 2351, 2352) and at the mouth of the Tomolin creek (V. 2357, 2358), Coppename river, deserve to be especially mentioned. The fine-grained rocks are all alike. They bear granular monoclinic pyroxene, partly surrounded by a rim of green hornblende, which in parts seems to be a continuation of the pyroxene, while the border between them is not sharply defined. Some brown biotite has grown around the patchy ore (ilmenite). The lath-shaped plagioclase is zonal and richly provided with dust in the basic nucleus. The rocks are remarkable for their quartz-potash feldspar granophyre. This is present in such large quantities that the plagioclases in parts do not join each other but lie in granophyre. In the granophyre we observe quite a number of very long apatite needles. The structure is a poorly-developed ophitic one, the more so, since the quantity of pyroxene is not large.

The quartz gabbros are normal or coarse-grained rocks, which show in the massive sample greenish or gray feldspar and dark, in parts also brownish, pyroxene, all being recognized macroscopically. If the feldspar is white the rocks have typical gabbro habitus on account of the contrast of colour (see the rocks from the Wilhelmina mountains Y. 228 B

[1]) H. W. Collins. Geol. Survey of Canada, Memoir 33. 1913. p. 68.

and C). Microscopically the structure appears here and there to be ophitic or it is wholly gabbroid without any sequence of crystallization between plagioclase and pyroxene. The various types may best be discussed according to their topographical distribution.

In the Wilhelmina mountains we found gabbros on the "Uitzichtsberg" and surroundings (Y. 228, 230, 231, 235, 240), others in the mountain-group 1065 which seem to belong to a very large dyke (Y. 243, 244, 245, 246, 247). Petrographically both groups are very closely related. They are normal or coarse-grained, bear monoclinic pyroxenes, and a varying percentage of orthorhombic pyroxenes, the latter may be so numerous that half of the pyroxene is orthorhombic (Y. 228, 228 C, 235). It is especially in these rocks that the peculiar division into fields occurs in the colourless optical positive enstatite (see p. 102). By the side of this in the same thin section, optical negative pyroxene, sometimes having feeble pleochroism, is found. These gabbros are olivine-free. Now there is some interstitial quartz present, now also potash feldspar, rarely in granophyric intergrowth (Y. 228), sometimes showing microcline structure. Sometimes potash feldspar only is present (Y. 235, 240); strictly speaking we should treat these rocks with the quartz-free gabbros. Ore mostly forms patchy crystals capable of enclosing whole plagioclases. The great difference in dimension between the plagioclase crystals and the pyroxene ones is striking and they show a tendency to ophitic structure. Pl. 26 fig. 1 shows this type. In the case of other rocks the structure is even clearly ophitic (Y. 243). We have gabbros wholly corresponding to the preceding ones from the Avanavero falls on the Kabalebo river (V. 3632—3633). Besides monoclinic, they have also orthorhombic pyroxene, sometimes in such quantity that we might even call one of the rocks a norite (V. 3633). It is a pleochroitic hypersthene showing in parts, laminated structure. Some quartz and microcline appear interstitially. Structurally they once more show a contrast between coarse pieces of pyroxene and small plagioclases and some tendency towards ophitic structure (Pl. 25 fig. 3). The same is the case with normal-grained quartz gabbros, collected near the Kabalebo (on the line van Gennip, V. 3630, 3631, 3635) which bear monoclinic pyroxene only. The very few interstitial quartz and microcline bearing gabbros from the Manikobi creek, Courantyne, are normal-grained, rich in pleochroitic hypersthene. The hypersthene sometimes shows the peculiar division into fields described on p. 102. (Vtz. 801, 923, the rocks are marked on the map, the exact locality, however, not being known). A special type of quartz gabbro comes from the Ebba top. It belongs to the coarsest gabbros known in Surinam. In the sample we observe bluish-black pyroxene crystals enclosing plagioclases at the sides. Microscopically the rocks appear to bear monoclinic pyroxene only and to be rich in interstitial quartz and potash feldspar; the last two may form coarse granophyre, the potash feldspar sometimes also showing microcline structure (see Pl. 25 fig. 4). The pyroxene is bordered at the sides by brown hornblende. The structure shows a tendency, as even the sample suggests, to pass into an ophitic one.

The following rocks are quartz diabases:
V. 12, 74, 194, 197, 209, 210, 292, 366, 370, 390, 419, 495, 507, 572, 585, 714, 739, 751, 780, 800, 873, 874, 875, 906, 1121, 1122, 1123, 1124, 1125, 1126, 1205, 1207, 1378, 1493, 1499, 1550, 1618, 1655, 1665, 1672, 1698, 1712, 1713, 1714, 1725, 1726, 1727, 1728, 1784, 1894, 2206, 2286, 2321, 2349, 2350, 2351, 2352, 2357, 2358, 2432, 2433.
C. 23, 45, 82, 86.
Vtz. 81, 313, 318, 321, 783.
Y. 210, 269, 329, 336, 341 B, 346, 347.
P. 33.

The following rocks are quartz gabbros:
V. 1371, 3630, 3631, 3632, 3633, 3635.
Vtz. 801, 902, 923.
Y. 224, 228, 228 B, 228 C, 230, 231, 235, 240, 243, 244, 245, 246, 247.

The normal diabases and gabbros.

These rocks differ from the preceding ones only by the lack of an easily recognizable quantity of quartz. It is either completely wanting or there are but a few traces of it, usually intergrown as granophyre. They are normal and fine-grained rocks, the latter type being represented in comparative abundance; in accordance with the rule, which is not a hard and fast one, that diabases poor in quartz are as a rule also finer in grain.

The mineral combination is again basic plagioclase, monoclinic pyroxene, ore (octahedral: magnetite or titano-magnetite; patchy: ilmenite). Olivine appears only as pseudomorphs, replaced by biotite. The structure is ophitic; only a normal-grained rock from the Courantyne shows a gabbro-structure and has consequently been mentioned as such (Y. 339).

A very fine-grained diabase from the Biabia fall, Suriname river (V. 1409) forms a divergent type. The quantity of pyroxene is relatively small here. The pyroxenes are very fine crystals, partly grains, partly oblong-shaped (monoclinic pyroxene); partly also prismatic and in this case, a colourless orthorhombic pyroxene; the latter shows the typical cross-fractures.

The structure owing to the slight quantity of pyroxene, is non-ophitic; the plagioclases, however, are lath-shaped.

The fine-grained diabases near Goddo on the Suriname river form another special type, which microscopically shows a considerable quantity of idiomorphic oblong-shaped hypersthene phenocrysts; they are consequently called *hypersthene diabases* (Y. 66, 67, 70). The hypersthene is, for the greater part replaced by pseudomorphs of talc, chlorite, and uralite (see page 103). The groundmass in one of the rocks shows the peculiar tubular shaped plagioclases described on page 98 filled with an extremely fine crystalline mass bearing ore dust, which also occurs interstitially among the plagioclases (Pl. 26 fig. 2). In the groundmass pyroxene is present as monoclinic oblong-shaped or granular crystals.

The following rocks are normal diabases:
V. 22, 59, 102, 103, 868, 1409, 1426, 1430, 1656, 1659, 1661, 1673, 4045, 4046.
Y. 18, 19, 66, 67, 70, 98, 227, 274, 300 (Y. 66, 67, 70 may be called hypersthene diabases).
G. 266, 1923.

The following rocks may be called normal gabbros:
Y. 339.

Olivine diabases.

The olivine diabases once more constitute a special type of the quartz-bearing and quartz-free diabases. An accessory olivine percentage has already been discussed with the quartz diabases. It may increase to such an extent that we get olivine diabases. Consequently in some of these rocks, besides much olivine, a quantity of granophyre of quartz and potash feldspar is present (V. 872, 1702, 1703, 1704). We might call these rocks after the two components, olivine quartz diabases. Other rocks bear but a slight quantity of granophyre or none at all; hence they are the equivalents of the quartz-free diabases (V. 714; Y. 157, 205, 206, 206 B, 207). The olivine is here partially replaced by biotite pseudomorphs.

The porphyritic apophyses (Y. 206 B) of a normal-grained dyke (Y. 206) in the Central Wilhelmina mountains yield a special type. They bear phenocrysts of basic plagioclases and idiomorphic olivine (concerning the behaviour of these apophyses see page 116). For the rest the olivine diabases show the normal ophitic structure.

The following rocks are olivine diabases:
V. 714, 807, 1702, 1703, 1704.
Y. 157, 205 B, 206, 206 B, 207.

THE CHEMICAL COMPOSITION OF THE DIABASES AND GABBROS.

The table annexed gives the chemical composition of some representatives of the three groups. For the sake of completeness the Niggli-values have been added.

As usual the composition differs a good deal within the same group; only a greater number of analyses could give a complete figure of their variability and average composition.

The quartz diabase (V. 1618) though bearing a fairly large percentage of granophyre, has considerably less Si O_2 than the quartz diabases elsewhere contain on an average (cf. last column, first table), possibly in connection with the larger percentage of iron. The rock has the composition of a normal diabase or gabbro and falls within that of the normal gabbroid or noritic magma of Niggli. The percentage of potash, though not remarkably high, is as a rule much smaller in the latter.

TABLE 14.

	Quartz diabase ¹) (V. 1618)	Quartz gabbro (Y. 246)	Normal diabase (according to Du Bois)	Normal diabase (Y. 18)	Olivine diabase (Y. 206)	Average of 12 quartz diabases from several countries according to Daly, Journ. Geol. XXVI. 1918. p. 121
SiO_2	47.62	51.59	46.20	47.13	46.87	52.34
Al_2O_3	14.07	16.88	12.23	15.63	13.91	13.70
Fe_2O_3	7.10	0.09	9.25	13.78	1.26	5.05
FeO	10.21	9.58	8.95	0.80	12.11	8.78
MnO	0.29	0.15	1.10	0.00	0.25	0.23
MgO	5.33	5.33	4.93	2.27	6.26	4.72
CaO	9.00	10.98	8.50	12.40	9.86	8.03
Na_2O	1.18	2.89	3.91	3.92	2.89	2.60
K_2O	1.57	0.98		3.01	1.24	1.17
H_2O+	0.76	0.31	1.72	0.08	1.31	1.56
H_2O-		0.07		0.16	0.25	
TiO_2	2.45	1.18	3.10	0.59	3.72	1.82
P_2O_5	0.51	0.19	¹)	0.23	0.34	
	100.09 ¹) 0.05 SO_3	100.22	99.89 ¹) not recorded	100.00	100.27	100.00
anal.	Koning & Bienfait Amsterdam	Dr. S. Parker Zürich	Weidig Freiberg	Dr. K. Brauer Cassel	Dr. S. Parker Zürich	

NIGGLI VALUES.

	si	al	fm	c	alk	k	mg	Section
V. 1618	119	19.5	52.5	23	5	0.47	0.36	4
Y. 246	106	24	39	28.5	8.5	0.18	0.49	5
Normal diabase Du Bois	109	17	54	22	7	—	0.32	3
Y. 18	110	21.5	34	31	13.5	0.34	0.24	5
Y. 206	109	19	48	24.5	8.5	0.22	0.45	4
Average Daly l.c.	136	21	48	22.5	8.5	0.23	0.39	4

(V. 1618) Normal-grained quartz diabase, Stein creek, Von Hemert Placer.
Mineral combination: labradorite, monoclinic pyroxene, important percentage of ilmenite, granophyre of quartz and potash feldspar.
(Y. 246) Normal to coarse-grained quartz gabbro, top 1065, Central Wilhelmina mountains.
Mineral combination: labradorite, monoclinic pyroxene, some colourless orthorhombic pyroxene (large optical axial angle, probably bronzite), ilmenite, interstitial quartz and microcline, traces of brown biotite and hornblende.
Diabase, Surinam, loco non dato (according to Du Bois). ¹)
Mineral combination: contains traces of quartz.
(Y. 18) Fine-grained diabase, cataract downstream Adiadedde creek, Suriname river.
Mineral combination: labradorite, abundant monoclinic pyroxene, ilmenite.
(Y. 206) Normal-grained olivine diabase, Central Wilhelmina mountains.
Mineral combination: labradorite, monoclinic pyroxene, olivine in part replaced by biotite, traces of granophyre.

¹) G. C. Du Bois. **46**. p. 24.

The quartz gabbro (Y. 246) stands in close chemical relation to the real quartz diabases (see last column first table) and agrees rather with Niggli's gabbro dioritic magma than with the normal gabbroid magma. The first normal diabase falls within the normal type found elsewhere. The percentage of iron is also large here.

Remarkable in the next normal diabase (Y. 18) is the low percentage of magnesium and the high percentage of natron. The percentage of natron is probably partly owing to $Na\ Al\ Si_2\ O_6$ in the pyroxenes; a small percentage of natron seems to occur now and then in the pyroxene of such rocks, and would suffice considering the large quantity of pyroxene in our rock, to increase considerably the quantity of natron in our rock.

The olivine diabase (Y. 206) has the same composition as rocks of the kind have elsewhere. That the rocks of the intrusive diabase-gabbro group may contain an even much larger percentage of magnesium and may have a more basic character, is illustrated by an uralite diabase (an analysis of which is given on p. 125).

THE GEOLOGICAL BEHAVIOUR OF THE INTRUSIVE DIABASES AND GABBROS.

The diabases and related gabbros are undoubtedly the latest igneous rocks. They break through the granitodiorites and the ortho-gneisses connected with them in quite a number of places, they also traverse the quartz-porphyries and the schists of different composition. Finally, at one place, it has been observed that porphyroids are pierced. It is only about the relation to the Roraima-formation that nothing is known. The intrusive diabases and gabbros possibly occur in three different ways.

1) As dykes the breadth and extent of which vary considerably.
2) As intrusive masses (laccolites?)
3) As sheets and cupolas.

The first type has been identified at quite a number of places. The other two are open to discussion.

A. *Dykes.*

The dykes are best illustrated by the data collected during the expedition to the Wilhelmina mountains. We shall follow the route of the expedition and treat the behaviour of diabases and gabbros, including those epidioritized types which are hardly to be distinguished from the preceding ones. Then we shall review what others have published on diabase-dykes.

Going up the Suriname river from Kabelstation on the Colonial railway we find ourselves in a region of acid diorites and ortho-gneisses. Diabases very rarely occur here. We come across the first dyke above the Pitti-pratti island just below the Adia-dedde creek. The dyke, 20 m. broad trends N.60°W. The dyke and the boulders lying on it cause a small rapid in the dry season. The line of demarcation between the dyke-rock and the quartz-mica diorite is sharp. Where the dyke is clearly visible at low water, we observe irregular column-shaped blocks which are directed with their maximum length vertically to the trend of the dyke. In cross-sections they are sometimes clearly hexagonal; we are concerned with contraction-cleavages vertical to the face that cooled down quickest. It is a very fine-grained normal diabase (Y. 18).

Several dykes intersect quartz mica diorite in the Kunkun fall. The river is split up here by numerous islands and forms rapids and falls. The dyke farthest downstream is visible among the islands near the left bank. A second one is found above the principal fall. The latter dyke is several meters thick; the trend is easy to follow, N. 20° W. The dykes consist of fine-grained diabases rich in pyroxene (Y. 19 and 22).

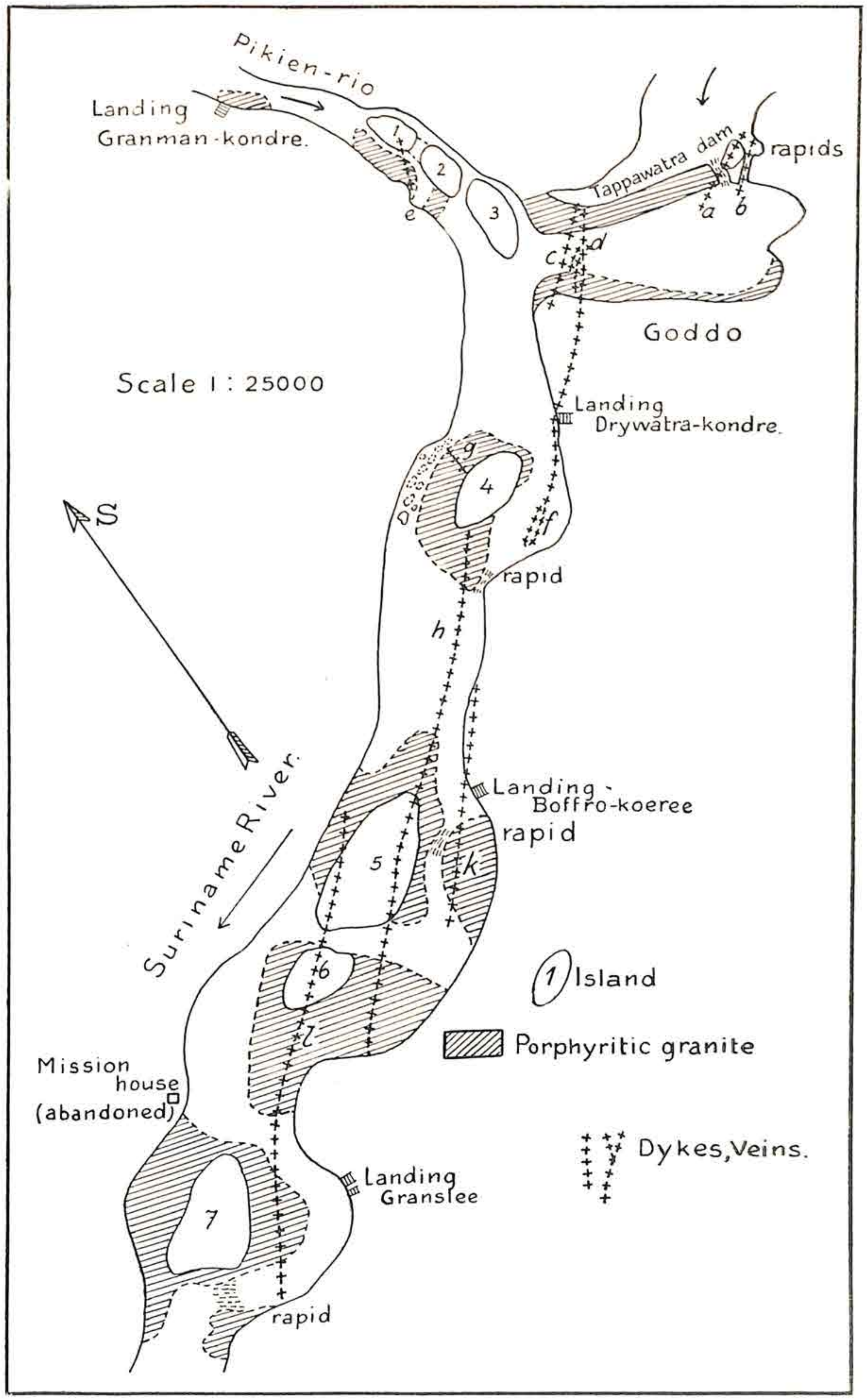
Near the deserted village of Toledo on the right bank there are two small mountains, 100 m. high, with steep sides; one of these is called Monni by the Bushnegroes, it lies close to the river. The Monni is undermined by the current at the foot. The mountain must have a core of diabase, for boulders are found on the slopes. At the foot a dyke is visible, forming a rapid to the right of the large island opposite the Monni.

We do not meet with any diabases in the extensive region of the Gran-rio granites following upon the Bakkrabote fall till we come into the neighbourhood of the Bushnegro village of Goddo. Here numerous diabase dykes are exposed. During the great drought of 1926 these dykes were easy to trace and our expedition staying a long time at Goddo we were able to draw the accompanying sketch (Map II). The village of Goddo lies near the junction of the Gran-rio and Pikien-rio, both source rivers of the Suriname river. This river is drawn on the map as far as 5 km. below the junction. The shaded fields around the islands 1 up to 7 inclusive and along the bank, mark in broad outlines that part of the river bed which was exposed; principally rocks, forming part of a vast granite-complex. The islands also have a core of biotite-granite with microcline phenocrysts. On account of the abnormal drought the stream was confined to the rapids indicated on the map, while pools of stagnant water were lying among them. Even the Tappawatradam shutting off the mouth of the Gran-rio was dry except for small channels on the Western bank. This granite weir is intersected by small dykes of diabase. On the Western bank two small parallel dykes are to be seen (a and b). They intersect the granite practically vertically. The outline is sharp without contact-phenomenon in the granite. The diabase itself is of the same fine grain everywhere. Two more small dykes appear on the East-side of the weir (c = Y. 66 and d), these too run almost parallel. They are only 15 to 40 cm. thick. They run parallel to the diaclases in the granite. One of them emits two branches which soon wedge out and may be traced in the shallow water. They have partly been carved out by erosion. Another dyke of small dimensions appears with the same trend (N. 65° E.) and is 60 cm. thick. This dyke is distinctly prepared out from the granite near the bank, so that we can see its plate-shape (Pl. 12 fig. 1). All these dykes are fine-grained hypersthene diabases. The last-mentioned dyke also crops out near the landing-place of Drywatra-kondre. The breadth varies: in the rock-surface on the Gran-rio it is only 60 cm.; at the landing-place mentioned it attains to 1½ m., while in the rocks farther on (f) it is a dyke of 2 m. in thickness. Two insignificant dykes of small dimensions of another trend we find in the Pikien-rio (e) and near the island marked 4 (g). The last small dyke fills a joint. A joint intersects the granite here, now open and filled with diabase of 2 to 3 dm. thick, and now closed. The dyke (h) has quite a different composition. The rock looks like a fine-grained diabase; microscopically, however, it appears to be a lamprophyre: an odinite (Y. 65). We can trace it still further; going downstream in the rock-face of the island marked 4 the dyke is 60 cm. thick and a continuation of it comes up again on the island marked 5; in the channel between 5 and 6 we see the dyke again and finally in the extensive rock-face East of island 6, where it wedges out, being continued by a joint. Hence there is no difference in behaviour between this odinite and the diabases. The diabase-dyke (k) near the village of Boffrokoeree cannot be traced far. In conclusion there is still another diabase-dyke (l) to be seen for more than a kilometre along the islands 5, 6 and 7. On an average, it is a metre in thickness.

So we see that these dykes, although never thicker than 2 m. may be traced for a considerable distance, now getting narrower now broader. For part of the distance they follow and fill joints as fissure-veins and may wedge out, in which case we find a joint in the continuation. Contraction-joints are sometimes visible in the dykes. In that case the current has partly broken up the dykes, and boulders lie spread about in the neighbourhood on the granite, while a channel in the granite shows the trend of the dyke. Other dykes, however, may be prepared out plate-shaped.

In the Gran-rio and Pikien-rio, sources of the Suriname river, we meet with the same region of porphyritic biotite granite as in the neighbourhood of Goddo. Near the first islands in the Pikien-rio we come across an insignificant dyke in the granite, trending S.E. Near the Kapoesa dam another narrow dyke crops out. In the granite there is a channel from one to one and a half metre wide with perpendicular smooth walls and more than 2 metres deep. This channel is filled with water even in the dry season. The trend is, on an average N. 20° W. and against the left bank below the fall, there is a small plate-shaped diabase-rock of equal breadth and trend as the channel. It is obvious that the channel was once filled with a continuation of the same dyke. Besides this we find a very narrow dyke parallel to the channel, that must have been an apophysis of the main dyke. The trend of the dyke is approximately parallel to the river and the latter could apparently carry off the diabase more easily than the granite, hence a channel with perpendicular walls has been left. It is a fine-grained uralite diabase (epidiorite), which, however, in the sample still shows unmodified olivine-phenocrysts (Y. 78). No diabase is seen up to the Moelai soela; we did not go farther up the river.

MAP II.



Sketch-map of diabase dykes exposed near Goddo, Suriname river.

In the Gran-rio numerous diabase-dykes are exposed. The first diabase is seen on the top of the Grandam, one of the largest falls. A dyke 1½ to 2 metres broad breaks the granite here, trending N. 75° W., and running almost straight across the river. The latter has narrowed down here to a channel 10 metres wide, hollowed out in the granite, over which the water rushes with tremendous force. On the West-side of the channel the dyke is visible; on the East-side we see the same dyke with the same trend but not as a continuation of the preceding one a displacement of 4 m. in a horizontal direction having taken place.

Not until between the Bushnegro village of Bakra-kondre and Tekakosi-dam do we meet with any diabases again. The first is only a heap of boulders, the second a small dyke 45 cm. broad, traversing the granite vertically with a North-South trend, parallel to the trend of the river at that spot.

A little way downstream from the small mountain, on the left bank below the Tekakosi-dam, a dyke at least 10 m. broad crosses the river with a trend N. 25° E. The continuation of this dyke we see with the same breadth and trend in the first rapid at the foot of the Tekakosi rapids. It is an uralite diabase (epidiorite) and fine-grained (Y. 98). At the top of the main fall there is another diabase-dyke visible only 40 cm. broad, trending N. 50° W. and standing vertical. This dyke seems to follow the joints in the granite for they run there partly N. 50° W. dipping steeply to the West and partly N. 100° W. with a dip of 50° N.

In the bend above Bogo-pakoe soela there is another diabase fallen to boulders and crossing the river twice. Between the mouth of the Riomau or Seisoe creek and the Maupee-dam there is a smaller dyke visible on the left bank narrower than a metre, dipping steeply and trending N. 45° E. This dyke has been prepared out by erosion in respect to granite. It is a uralite diabase (epidiorite) extremely fine-grained (Y. 113).

About half-way between the great falls of the Maupee-dam group and the Ston-portoe, we meet with but one single insignificant diabase-dyke, trending N. 45° W. and scarcely visible even at low water. Near the Ston-portoe the river narrows to a channel of some metres broad, enclosed between granite hills. Some narrow dykes of uralite diabase (epidiorite, Y. 131 and 131 B) intersect the granite vertically. These dykes are the cause of the origination of the narrow channel (see for this question page 32).

At the foot of the next large fall an irregular mass of diabase crops out, the extension of which cannot be ascertained. It is a fine-grained uralite diabase (epidiorite) like the one from Ston-portoe (Y. 134). The same applies to the diabase (epidiorite) at the foot of the great fall, near the grave of Lieutenant Eilerts de Haan (Y. 136). Here in the middle of the river we observe diabase boulders with a weathering-crust shining like graphite: we notice the same rock about 100 m. downstream against the right bank. These are the last diabases seen going up the Gran-rio to its source.

Hence all these diabases, partly uralite diabases (epidiorites), break as dykes through the granite, which is developed in various facies.

Let us follow the route of our expedition farther.

After going up the Gran-rio we crossed the low watershed between this river and the Lucie river. At 9¾ km. from the Gran-rio a normal-grained olivine diabase was found on the trail, the geological behaviour of which could not be traced (Y. 157).

The expedition went down the Lucie river to the point where it approaches the Wilhelmina mountains nearest. About 7 km. in a straight line below the spot where our trail meets the river, we saw two insignificant dykes of normal-grained uralite diabase (epidiorite; Y. 179) on the right bank at low water. They are not much more than "veins" of half a decimetre thick, which break through the granite and trend parallel to the river (East-West).

In the hair-pin bend, above the mouth of the Oost river there are some diabase boulders visible just above the water; while at the head of the island [1]) situated at the end of the hairpin bend [1]) there is a dyke, about 15 m. broad, trending N. 45° W. The uralitized rock (Y. 184) of this dyke is somewhat prepared out in respect to the granite. In the channel on the left side of the island mentioned we observe two dykes 1½ to 2 metres broad and both trending N. 65° E. Together with the granite they form a rapid. Opposite the mouth of the Oost river there is another dyke visible on the left bank trending N. 65° E. and about 20 m. broad. It is an intensely uralitized diabase (epidiorite Y. 185) as may be seen from the sample.

From here to where the river modifies its general direction from N.W. to S.W. some more dykes are exposed. The first rapid below the Oost river is formed by several steps, two of which are caused by diabases: the last dyke found downstream is about 30 m. broad trending N. 65° E. The fine-grained uralitized rock, rich in pyrite, (Y. 188) has a tendency to the contraction-cleavage repeatedly mentioned above. A dyke at a second step about 100 m. farther away even attains to a breadth of 40 m. with the same trend. About 200 metres farther going downstream, a dyke of the same breadth and trend forms the last step, of this rapid-complex. Hence we are concerned here with several important dykes of the

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[1]) See sketch Wilhelmina mountains (Map V).

same trend. It is only possible to give the approximate breadth of these three dykes and also of those following. Their contact with the granite is mostly concealed by the water. We can partly trace the dykes by the solid rock, partly by the boulders lying on them. The diabase is usually visible on either bank, the dykes are eroded by the stream and in the dry season an insignificant rapid is formed.

Going downstream we met with eight more dykes of some metres in thickness, all trending N. 65° E., breaking through the granite almost vertically. They occur between the last mentioned rapid-complex and the next small island. To the left of this island and looking downstream, some more important dykes were seen, with an average trend of N. 70° E. a dozen metres broad.

So between the mouth of the Oost river and the place where our expedition had their headquarters, the granite-complex is intensely intersected by diabase-dykes which may attain to a considerable thickness; and which, in so far as samples were collected all consist of uralitized diabase. Exposures of diabase also occur in the Oost river, which joins the Lucie river from the right. Only two insignificant uralitized dykes of diabase (Y. 249) intersect the river before reaching the second great fall. The river is made narrower here by hills of granite on either side, just as at the Ston-portoe in the Gran-rio. Here, too, the river has eroded a channel of about 7 metres wide. On the left hand side the channel shows a nearly perpendicular wall of granite, which in places is as much as 6 metres high and in which vertical gullies have been formed by erosion. The opposite wall is less steep and rounded off. In the channel we observe, besides granite boulders, solid fine-grained rock of uralitized diabase (epidiorite, Y. 253). The surface of this rock is extremely smooth and phantastically worn. Besides scouring-grooves cut into the rock by Indians, there are some pot-holes in the diabase. One of the pot-holes is just on the border-line in the diabase and granite. It is ¾ metre deep and shows the contact between the two. The contact is sharp, the granite showing no modification. The contact-plane between the granite and diabase agrees with the trend of the channel, N. 28° E. and dips 80° to the W. It is obvious that the channel was once filled with a diabase dyke. The steep wall on the left, practically still corresponds to the original contact-plane.

Let us now see what data have been obtained from the Wilhelmina mountains themselves. We can only partly judge the geological behaviour of the diabases and the gabbros here; the exposure is often restricted to boulders or the solid rock is exposed in such a way that we can but conjecture what the relation to the granites is. It appears that, just as in the above mentioned part of the Lucie river, diabases are very numerous, but, in comparison with the granites, they are quantitatively insignificant. Only one single mountain consists for the greater part of gabbro, for the rest we are concerned with dykes or local intrusions. The places where they occur are marked on the map. [1]) It appears that they crop out on the ridges, slopes and summits and in the valleys. We observe clearly dyke-shaped exposures in the valley South of top 1280, running first East-West, later on North-South. They are exposed in a creek and trend N.—S. to S. 30° W. varying in width from 3 to 8 m. Where the contact is visible, they break through the granite vertically. Contraction-joints perpendicular to the contact-plane may sometimes occur. It is an olivine diabase, normal-grained (Y. 205—206). Locally we meet with apophyses which penetrate the granite intensely to about a metre from the contact. The apophyses and the diabase at the contact are much finer-grained than the main mass and are porphyritic; they bear phenocrysts of basic plagioclase and pseudomorphs to olivine. The apophyses are capable of diffusing themselves throughout the granite, which on account of this penetrating material, takes a greenish-blue colour. Microscopically these groups appear to consist of intensely compressed quartz and feldspar, in which the diabase material is scattered about and is only to be recognized by the abundance of ore-dust (Y. 205 B). The cataclasm of the granite here must have been the result of the intrusion of the diabase, for it is restricted to the contact.

The basic rocks in the group of top 1065 are important. This ridge is surmounted by a crest, trending N.N.E. several km. in length. The ridge consists of normal-grained biotite-granite. The core of the main ridge is of a different composition; on the crest enormous boulders and exposures of gabbro are visible. It appears that we are dealing here with a very large dyke-shaped gabbro several dozens of metres broad, and about a km. long. The resistant dyke is responsible for the strongly pronounced outline of the crest; the granite is apparently less resistant (fig. 23). It is a

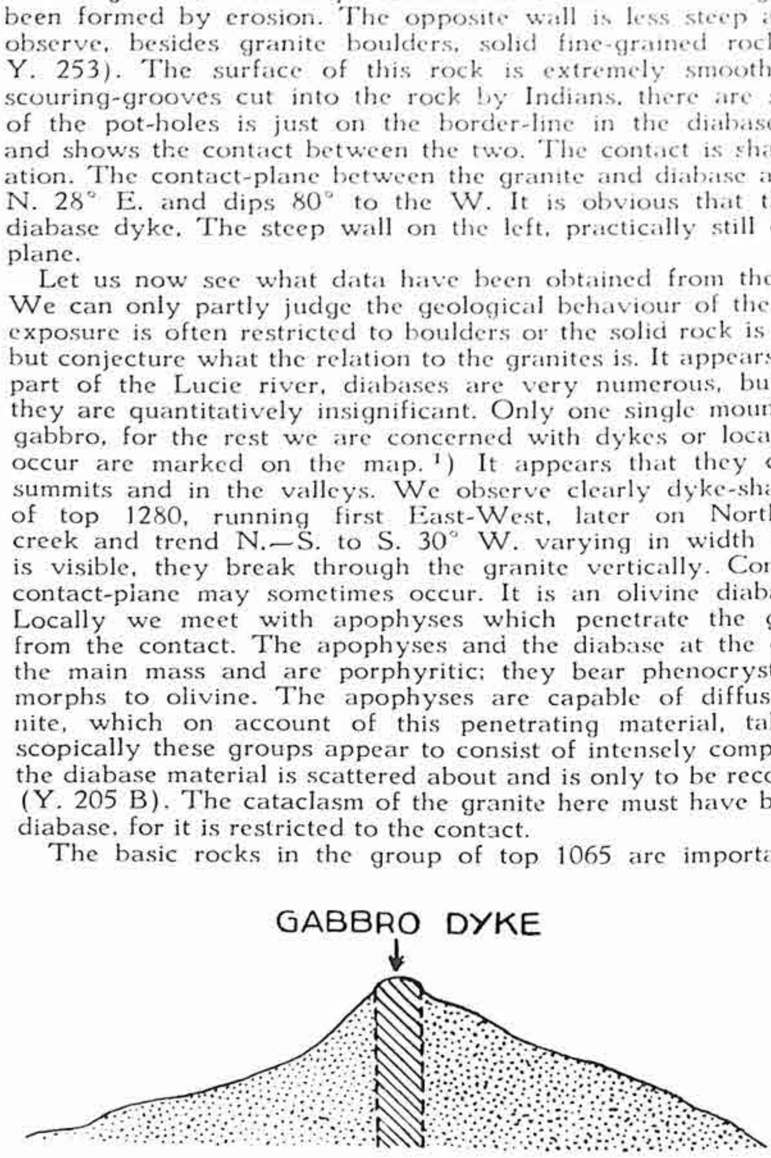

Fig. 24.

[1]) See sketch Wilhelmina mountains (Map V.).

normal to coarse-grained gabbro consisting of monoclinic and orthorhombic pyroxene, plagioclase, ore and some quartz (Y. 246, 247), in parts showing incipient epidioritization (Y. 247). Boulders of finer-grained rock are also to be found on the slopes, possibly from apophyses; the latter have more of an ophitic structure (Y. 243, 244, 245).

Another influence on the relief is caused by a uralite diabase on the West side of the ridge linking up top 1280 in the centre of the mountains with top 850 in the South. It is a normal to coarse-grained diabase, now occurring as outcrop, now as boulders and spread in such a manner that apparently we are concerned with a dyke about 15 metres broad. This dyke crops out in a slope which is interrupted by a terrace on which a small swamp has been formed by stagnant water (see fig. 24). The diabase, offering more resistance than the surrounding granite, is the primary cause of the origination of this terrace.

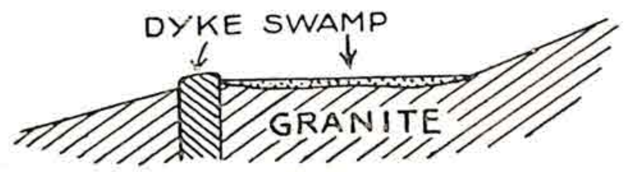

Fig. 25.

The distribution of other diabase-masses, may be seen from the map. They are normal to fine-grained diabases, sometimes uralitized (e.g. Y. 226, coarse-grained); or olivine-bearing (Y. 210, normal-grained) and quartz-bearing (normal-grained Y. 227, 269), while others again, are normal to coarse-grained gabbros which, by the side of monoclinic, also bear orthorhombic pyroxene (Y. 224, 250).

After exploring the Wilhelmina mountains the expedition went down the Lucie river to the Courantyne. The rainy season was closing and the river brimfull of water. Whereas some months before the river bed was pretty-well exposed, rocks were now scanty. Hence the survey above our headquarters was carried out under much more favourable circumstances, which possibly accounts for our not seeing diabase dykes in the river below the camp, whereas above they are numerous. At one place only, diabase was found. Where the spurs of the Käyser mountains approach the river there are two groups of islands. In the right hand channel, along the second group, coarse-grained diabase crops out. At the head of the second island, going downstream, we saw coarse-grained diabase exposed in a rapid to a distance of 10 m. Round about it we found boulders of quartz porphyry but the exposure does not show whether the diabase breaks through the porphyry or the reverse. It is a normal-grained diabase (Y. 274).

The following rocks were exposed in the Courantyne during favourable height of the water, beginning at the mouth of the Lucie river (going upstream).

Opposite the mouth of the New river there is a dyke of fine-grained diabase visible, breaking through biotite gneiss. It is a dyke half a metre thick just opposite the most Easterly mouth of the New river. It trends N. 20° W. It is a normal diabase (Y. 300). Besides this there are still a few narrow dykes which split up once or twice into smaller ones.

There are strikingly few diabases in the Upper Courantyne or Curuni. Brown marked another diabase-dyke near the first group of rapids above the mouth of the New river, but we were not able to find it again.

One single dyke was observed farther upstream. On the left bank a good 10 km. South of the point where 3° N. lat. intersects the Courantyne there are a couple of small mountains near the river. Here, at low water, in the bed of the river, there is a mass of diabase boulders visible near either side, separated in the middle by a rapid. If we joined the two piles of boulders the trend would be NNE. The diabase here follows the trend in the gneiss. This diabase dyke is also marked on Brown's map. [1]) Another is marked on the right bank 30 km. upstream (as the crow flies). This one, however, was not refound.

Diabases in the Courantyne below the mouth of the Lucie river going downstream are at first strikingly sparse. About 40 km. below the mouth of the Lucie river we observe angular diabase-boulders near the mouth of a large creek entering the river from the W. (This creek probably corresponds to the one on the English map [2]) marked Awara-balli creek). There is still another diabase-dyke marked a little farther up on the English map.

There are some important coarse-grained diabase-dykes near the Tiger falls. Before reaching these, however, we pass a small fall on the English bank flowing over a dyke more than 60 or 70 metres wide, trending N. 30° E. Numerous boulders lie scattered on the solid rock. Unlike the more pointed boulders of fine-grained diabase these are rounded off, and resemble the granite boulders. The weathering-crust is dull and rough agreeing with the coarse grain of the diabase; while in the case of fine-grained boulders the crust is usually shiny black. The rock is a quartz diabase, with some granophyre of quartz and potash feldspar (Y. 329). The contact with the granite is invisible. The dyke occurs where the sharp bend in the Dutch bank of NW. to NE. is marked on Käyser's map. [3])

A kilometre and a half farther downstream opposite the English bank two more coarse-

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[1]) C. B. Brown. **10.**
[2]) F. Fowler. **82.**
[3]) C. C. Käyser. **80.**

grained diabases of the same character occur a couple of hundred metres from each other; only heaps of boulders are to be seen against the English bank and the island opposite. They trend again N. 30° E. Both break through granite. These dykes are already in the region of rapids, marked on the map as Tiger falls. About 30 km. farther, having passed the Lord Stanley fall in the meanwhile, we came across important diabase exposures. They are found in the bend from NW. to NE. where the long series of rapids occurs (the Plum- and Twirl-round rapids). Here we see a diabase-dyke of at least 20 m. wide, which can be traced for a considerable distance downstream in a direction N. 5° W. Accumulations of boulders clearly indicate the course of the dyke. Judging from its trend this dyke must disappear farther up into the English bank. In the series of rapids here we see again and again diabase-boulders, indicating the trend of important dykes several km. long, running approximately parallel to the river. It is obvious that Brown meant one or more of these dykes by the long dyke on his map running parallel to the river. All these dykes cut through granite. The granite makes way for quartz porphyry farther on. The latter is also marked on Brown's map. The river here forms a real archipelago, among which lies "Eight Miles island". No map marks all the islands, hence it is not possible to give the exact position. In a quartz porphyry region we repeatedly meet with diabase dykes 10 m. and more wide, which once more can be traced by a covering of boulders. The trend is approximately N. 10° W. Hence we see here that the quartz porphyry is broken through by the diabases. In places, even small apophyses of diabase intersect the porphyry.

We soon reach the most powerful falls in the Courantyne: the Wonotobo falls. At the Dutch bank near the landing-place of the trail round the falls, a diabase-dyke is seen trending N.N.E. It is a coarse-grained quartz diabase (Y. 336). The dyke connects the Dutch bank with an island, but is only visible at low water.

For the first 30 km. below the Wonotobo falls exposure is very poor. Only one small pile of diabase boulders, visible at low water, was seen. Below the first rapids of the Governor falls, another heap of diabase boulders is visible. A mass of diabase was also seen farther up in three rapids approximately in the middle of the river. In the last rapid in the stretch of river studded with islands, below the Governor falls, where the river bends to the NW., we met with a couple of diabase-dykes close to each other, trending N. 60° E. Several dykes of diabase and epidiorite are marked there on the English map, and it is difficult to make out which of the above mentioned two dykes corresponds to them. At the place where "Temehri rock" is marked on the map, on the English bank, we observe a coarse-grained diabase-dyke which may be traced for some hundreds of metres and ends in the Temehri-island. The trend is N. 60° E., parallel to the river. Dyke and island are separated from the English bank by a narrow strip of water. The dyke is some dozens of metres broad. The contact with the surrounding rock is invisible. The rock is coarse-grained with a rough surface. On the large boulders attaining to cubic metres in size, which cover the dyke, Indians have cut very shallow grooves. Farther downstream, where the river flows S.S.E. for a distance of over 3 km., near the English bank there are some huge granite rocks covered with bushwood. Between these rocks and the English bank we see at low water a dyke about 20 m. broad, trending N. 20° W. The contact on one of the sides of the dyke is visible; the contact-plane is vertical. Microscopically it appears to be a normal-grained gabbro with a tendency towards ophitic structure and a trace of quartz and potash feldspar granophyre (Y. 339). About 7 km. above the Cow falls in the middle of the river we met with a broad, coarse-grained occurrence, at least 50 metres broad with a trend approximately N. 35° E., to be traced as groups of boulders. Now follows another important exposure about 2½ km. above the Cow falls: for over a hundred metres on either bank there is a huge accumulation of boulders. The relation to the granite is not visible. It is possible that they have formed a dyke or masses of great dimensions; their composition is not known either. Could we join the boulders of either bank the trend would be approximately NE.—SW. Between the last two islands above the mouth of the Kabalebo river (the Wanuto and Mara-uni-balli islands of the English map) against the Dutch bank, there is an accumulation of coarse diabase-boulders extending over a length of about 150 m.; they possibly correspond with a dyke running parallel to the Dutch bank here. It is a coarse-grained quartz diabase, rich in quartz-potash-feldspar granophyre (Y. 341 B). From here to the mouth of the Kabalebo river there are three more dykes marked on the English map. [1])

Below the mouth of the Kabalebo there are hardly any more exposures; the last solid rock is visible below Matappi creek; it is a diabase or gabbro.

Let us see now what is known elsewhere in the Colony about diabase dykes. On the Lower Marowyne, just above the Merian creek a huge dyke of coarse-grained diabase breaks through crystalline graywacke and mica-quartzites. The dyke is 10—20 m. broad, and trends N. 20° W., crossing the river. The contact with the graywacke was hidden under water during my visit. Microscopically it appears to be olivine diabase, which also bears some quartz and potash-feldspar granophyre (Y. 349; V. 714, 2426). Probably the coarse-grained quartz diabase appearing near Apatoe on the Marowyne also forms broad dykes (V. 419, 2432; P 33).

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1) F. Fowler. 82.

Voltz has already mentioned "Grünsteingänge" among which there are some diabases; [1]) those from the Arusabanja fall (Suriname river) and from the Leguan island (Coppename river) are of that kind. About the latter we know (according to Essed) [2]) that it is exposed as a dyke 50 m. wide in the river, trending SW. and continued on the banks as hills. Microscopically it appears to be very fine-grained quartz diabase very rich in quartz-potash-feldspar granophyre (see page 109, V. 2349, 2350, 2351, 2352). It breaks through ortho-gneisses here.

Brown mentions dykes of the Courantyne, breaking through granites and gneisses, a number of which we have discussed. [3])

Martin discusses dykes of diabases on the Suriname river; e.g. a couple of dykes of quartz diabase near Biabia fall (V. 1409; Y. 347) and likewise the dykes at the foot of the Monni near Toledo, which we have already mentioned above (V. 1426). [4])

Du Bois, it is true, gives no instances of dyke-forming diabases, but says that they break through the crystalline schists and granites. [5])

Instances of diabases forming dykes also occur in the material of the Government Mining Exploration as appears from notes. On the Lawa between the village of Coermotibo and the Cie des Mines d'or a dyke of normal-grained diabase (V. 507) is said to appear not far above the first village; in the Oeman krassiabra fall a couple of dykes trending NW. cut porphyroids; they are coarse-grained diabases bearing some granophyre (V. 495). A little upstream, in the Man krassiabra fall, another couple of dykes of the same type trending N. and approximately 20 m. broad, also cut porphyroids (V. 572).

Middelberg, in the report of the same Exploration [6]) mentions some diabase dykes.

B. *Intrusive masses.*

Some data on masses were obtained during our expedition to the Wilhelmina mountains.

The "Uitzichtsberg" (near rock number 235, see sketch map V) forms part of a group of flat topped mountains. This group has, for the greater part, a granitic composition. The „Uitzichtsberg" proper, with a flat top, slopes steeply on the West, South and East, and granite crops out there at the slopes. The heart of the mountain, however, is of another composition. Quite a number of gabbro-boulders appear on the flat top, and the solid rock is visible in a creek. We are concerned with an important gabbro-mass several hundreds of metres in diameter. Although the actual contact is not visible, it is clear from the form of the mountain that the contact is to be found on the SW. side in any case on top of the steep slope. Granite here forms a rock-mass sparingly covered with vegetation, too steep for ascent, and immediately above it, comes the gabbro; so we get the impression that the granite, being protected by the more resistant gabbro, is preserved from erosion and leans against the gabbo mass (see sketch, A). We might think that the basic rock lies as a covering on granite (B) but the habitus of the gabbro does not allow of this, it is everywhere the same normal to coarse-grained rock. Monoclinic together with orthorhombic pyroxene is present, together with a trace of quartz and potash feldspar. The structure shows a vague inclination towards ophitic diabase-structure.

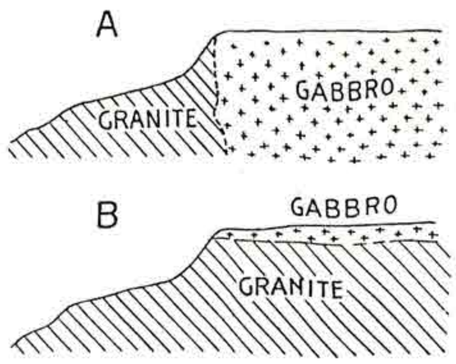

Fig. 26.

Another gabbro probably also forming an intrusive mass, is cut by the large creek rising between the "Uitzichtsberg" and the ridge that runs in a NNE. direction from top 1280. Quite a number of granite boulders, but here and there also the solid rock are seen. It is a normal to coarse-grained gabbro, which, by the side of monoclinic also bears abundant orthorhombic pyroxene (Y. 228, 228 C) with a tendency in places towards diabase-structure.

As far as is known the gabbros on the Avanavero falls in the Kabalebo river also belong to a important mass.

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[1]) See K. Martin. **26.** p. 178—188.
[2]) E. Essed. **105.** p. 339.
[3]) C. B. Brown. **10.** p. 216—232.
[4]) K. Martin. **26.** p. 166.
[5]) G. C. Du Bois. **40.** p. 12.
[6]) E. Middelberg. **64.**

C. Sheets and Cupolas.

Whereas instances of dykes and of masses that leave little doubt are present in the Colony, it is not certain to what bodies the diabase cupolas once belonged. Cupola-shaped hills and small mountains of diabase are frequent in the East of Surinam. They appear especially in the neighbourhood of Berg en Dal on the Suriname river, at the back of Boschland, in the region of the Locus- and Tompi creeks, to the West of Gansee, and very frequently in the region of the Upper Marowyne creek, of the Sara creek and between the latter and the Tapanahony. They are covered with laterites and the core is composed of diabases or uralitized diabases (epidiorites), judging from the boulders that are sometimes present on the summits and sides. The interpretations of these cupolas differ considerably, which is not surprising since the exposure is nowhere of such a nature that we can with certainty judge of their relation to the rocks in the neighbourhood, whether granitodiorites or schists. All geologists are agreed that they are of later age than the latter. The material of which they are composed is, in so far as it has not been modified, a normal or coarse-grained quartz diabase with varying proportions of granophyre; e.g. the rock from the Blue mountain near Berg en Dal (V. 1493, 1499), from the Monni, Suriname river (V. 1430), from several domes in the neighbourhood of the Marowyne creek and the Sara creek (V. 1655, 1656, 1659, 1665, 1672) and from the hills near Man a Sam at the extreme upper course of the Commewyne (V. 1712, 1713, 1714). So petrographically the rocks are the same as those we saw elsewhere as dykes.

The views concerning their geological aspect are as follows: Martin (1888) in imitation of Voltz expresses the opinion that the low mountains, hills, and ridges of hills, on the Suriname river between Koffikamp and Phedra are remains of diabase sheets. Martin quotes Voltz in these words:

„Bei Phaedra befindet sich eine etwa 80 rh. Fuss hohe Anhöhe, welche aus Granit besteht; aber ein wenig oberhalb des Ortes ändert sich die Formation und tritt Grünstein am Ufer des Flusses auf, welcher sich bis zum Sarakreek hinzieht. Als Liegendes dieses Grünsteins wird Granit angesehen: „denn auf dem Boden der kleinen Thaleinschnitte findet man nicht nur überall verwitterten Granit, sondern man trift auch festanstehenden, und Bruchstücke dieser Felsart sind da, wo nur Grünstein als anstehender Fels getroffen wird, keine Seltenkeit." [1])

He himself says:

„Nach dem Biotitgranite erumpirte Diabas, denn Gänge des letztgenannten Gesteins liessen sich deutlich im Granite des oberen Surinam beobachten, und Voltz's Untersuchungen am unteren Flusslaufe führten ebenfalls zu der Auffassung, dass der Diabas sich daselbst deckenartig über den Granit ausgebreitet habe. Auch das Lagerungsverhältniss zwischen Diabas und Schiefer bei Bergendaal läszt sich nur so deuten dass das Eruptivgestein die jüngere von beiden Bildungen darstellt und auf den Schichtenköpfen der archaeischen Sedimente lagert" (l.c. page 190—191).

Brown, although not referring especially to the dome-shaped diabase says of an outcrop of diabase on the Courantyne near Matappi:

"The Matappi rocks — the first met with in ascending the Courantyne river — are composed of a grayish, crystalline-granular greenstone of extreme hardness. This exposure is

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[1]) K. Martin. **26.** p. 182—183.

evidently part of a great layer, and most probably underlies the sandstone which is seen not far to the westward dipping west." [1])

The same representation: a diabase-sheet, on which sandstone rests, is marked on Brown's map on the English bank above the mouth of the Kabalebo.

Middelberg's ideas are much more complicated. [2]) According to him the diabases belong to different successive eruptions, having often occurred at the same place, in which diabases and allied rocks have altered older members of the same composition into schistose rocks, epidiorites, amphibolites and amphibole schists by contact- and dynamo-metamorphism. Besides, the rocks sometimes cover the older ones. No detailed instances of these relations are given, however.

The ideas of Martin, Voltz, Brown and Middelberg, although differing from each other all plead the sheet form of the diabase; they all contain a supposition not expressed by any of them: if we are really concerned with sheets (layers), the niveau of the foot of the domes should approximately correspond to the surface over which the diabase sheets once extended. At this point we come to the important question in how far portions of the present surface of the land can be traced back.

Whether we are dealing with sheets (layers) here seems to be an open question. It is quite possible that we are concerned here with intrusive masses of the type of which instances have been given above. Also it is not altogether out of the question that the cupolas and ridges are parts of broad dykes, in the protection of which less resistant rock masses have been preserved, now covered over with laterites. However this may be, as long as no unambiguous contact is observed of diabase resting with an approximately horizontal foot on older rocks the question must be regarded as unsolved.

THE DISTRIBUTION OF THE DIABASES AND GABBROS IN THE COLONY.

Some geologists are of opinion that diabases are especially frequent in one part of the Colony. Martin assumes a zone with an East-West trend running through the whole breadth of the Colony from the East (on the Marowyne between Albina and Langa tabbetje) to the Courantyne above the Kabalebo river in the East. [3])

Middelberg assumes a region in the form of a triangle, with the Marowyne from Albina and the Lawa as its base, and the Temehri-rock on the Courantyne as its apex. [4])

Indeed, the diabases and related gabbros known at present fall principally in this lastmentioned region, e.g. the districts rich in diabase on the Suriname river between Brokopono and Berg en Dal, on the source of the Locus- and Tompi creek, on the Lawa, between the Suriname river and Sara creek, and the region between the latter and the Tosso creek (side-creek of the Tapanahony).

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[1]) C. B. Brown. **10**. p. 232.
[2]) E. Middelberg. **64**.
[3]) K. Martin. **27**.
[4]) E. Middelberg. **67**.

However, we also know numerous instances, although of slight dimensions, on the Gran-rio, on the extreme upper course of the Lucie river, and in the Central Wilhelmina mountains, and also less numerous ones on the Courantyne far above the mouth of the Kabalebo and on the Upper Coppename river. These are the principal regions. On the Coppename river below the Raleigh falls, diabases are much rarer than we find given in Essed's publication on this region [1]). It appears from his rock samples that what are called diabase and "metamorphic diabase" by him are practically all entirely different rocks, hence the important distribution on the sketch-map (Essed map II) must be left out.

Other regions are strikingly poor in diabase intrusions: e.g. the Suriname river above Kabelstation up to near Goddo; the Courantyne below the mouth of the Lucie river and the whole Upper Courantyne or Curuni. In other regions it is not possible to judge of the distribution through the lack of adequate data.

It appears that the various types of diabases in the Colony are not individually connected with any particular region. The two principal types, the quartz diabases and the normal diabases occur promiscuously. The gabbros are much less frequent and we know them particularly from the Central Wilhelmina mountains, the Kabalebo river near the Avanavero falls and the Courantyne at the same latitude. Olivine diabases are rare, and occur at great distances from each other. The hypersthene diabases are restricted to a few places, near Goddo on the Suriname river.

EPIDIORITES AND ALLIED ROCKS.

As we saw in the introduction epidiorites and allied rocks are metamorphic diabases and gabbros; they have often preserved relics of the latter, either mineralogical or structural. They may be sub-divided into rocks which differ only from diabases by the pyroxenes being entirely or practically entirely replaced by secondary hornblende (epidiorites sensu stricto) and others in which also the feldspars have undergone important change. Let us begin with the discussion of the:

Epidiorites sensu stricto.

These are characterized by the mineral combination of basic or moderately basic plagioclase, and secondary hornblende, usually uralite. We might call them also uralite diabases and gabbros.

In a number of them the composition of the plagioclase has been ascertained. It varies from labradorite to labradorite-bytownite, and in a few with zonal structure to oligoclase-andesine in the outer zone (e.g. Y. 113); consequently the composition of the plagioclase is the same as that in the unaltered diabases and gabbros. Occasionally clouds of fine dust appear in it (e.g. V. 2337, 3471, 3472).

The uralitization of the monoclinic pyroxene begins at the edges. The line

[1]) E. Essed. **105**.

of demarcation between the pyroxene and plagioclase is not sharp in this case, but a fibrous hornblende nestles along the border-line, and penetrates both the pyroxene and the feldspar. This phenomenon expands more and more in the direction of the pyroxene, while a nucleus of the latter is still recognizable by its strong refraction and double refraction, greater angle of extinction and good cleavage. The orientation of the hornblende-fibres with respect to the pyroxene may be different. Sometimes the fibres are combined into groups, filling the pseudomorph without any system. Often, however, the fibres have practically the same orientation. In sections vertical to this orientation, the separate fibres are not to be distinguished; the hornblende-cleavage may be well-defined, which gives the impression of a homogeneous crystal. In sections parallel to the cleavage, the fibres are to be recognized separately individually, having their maximum lengths directed parallel to the prism-zone of the original pyroxene. The degree of fibrousness of the uralite varies: in some cases it is not clear at first sight that we are dealing with secondary hornblende. In the sections vertical to the cleavage the pleochroism passes from practically colourless (according to $n\alpha$) to pale-green ($n\beta$) and in sections parallel to the cleavage sometimes even to grass-green or bluish-green ($n\gamma$). We not only find that the fibres are directed parallel to the prism-zone of the original pyroxene, but also other features of the original pyroxene in the pseudomorphs are met with again. Twins according to (100) are sometimes reproduced by the hornblende showing the hornblende-cleavage in sections vertical to the prism-zone, while the fibres in respect to the original twinning-plane are in the twinning-position. In an epidiorite (uralite diabase) from the Upper Lucie river (Y. 184) there are quite a number of uralite-pseudomorphs showing a time-glass-structure, which latter was never met with in unmodified pyroxene (Pl. 26 fig. 3). The structure is not produced so much by the varying orientation of uralite-fibres, within and without the time-glass as by the latter being rich in pale-brown, extremely fine, strongly refracting grains to be discussed later on. The inside time-glass field is also recognized without crossed nicols. Even the warped cleavages described for a great number of unmodified rocks (see page 100) are found in the uralite again (e.g. Y. 113; V. 1306, 1307, 1308).

Especially in the coarse-grained diabases the uralite is not confined to the space originally occupied by the pyroxene but spreads into the surrounding minerals, hence it is no pseudomorph in a narrow sense. The fibres penetrate into cracks and cleavage-lines of the feldspars, so that the latter are penetrated by a network of frayed, green bands. The hornblende, however, needs not necessarily keep to the cracks and cleavages, in which case, a confusion of fibres and needles fills the feldspar. In many uralite diabases the hornblende bears very fine, strongly refracting grains. If many are present they give the hornblende a brown tint. The material admits of no closer definition, it is possibly epidote or calcite.

In a few thin sections we observe an abundance of greenish-brown spots in the uralite showing strong pleochroism towards a lighter tint (Y. 113, 184, 223). It one direction they refract decidedly more feebly, in the other pretty well the same as the hornblende. The strong double refraction yields a velvety polarization-colour. It is biotite. When the biotite is very fine, which frequently occurs, it seems to be continuation of the hornblende or the reverse. In this case it is not clear whether the biotite arose from the hornblende or the hornblende from the biotite. Biotite never being observed in the unaltered pyroxene, it probaby was formed in connection with the uralite.

Chlorite often accompanies uralite, and apparently is partly formed from it.

A phenomenon often attending uralitization is the appearance of epidote. The uralite diabases are sometimes very rich in epidote. The epidote appears in crystals with well-developed ortho-domatic zone. By the side of this, grains also appear, the faces of which are not recognizable. Now the one form is present only, now the other, but usually both together. Twins according to (100) are sometimes present (Y. 113). The crystals behave idiomorphically towards the other minerals and take their places. The double refraction is strong and points to epidote rich in iron. The epidote is found both in the feldspars and in the uralite without having any crystallographical relation them. The quantity sometimes amounts to a fifth of the total (Y. 185), while in other uralite diabases epidote is completely wanting. Sometimes, too, veins of epidote narrower than 2 mm. intersect the rock.

The ore almost invariably shows titano-magnetite demixture.[1]) Pyrite is present as in the unaltered rocks and exhibits no transformation; neither does the apatite. In a few uralite diabases the granophyre of quartz and potash feldspar is visible (Y. 185, 254); the uralite has probably taken the place of the granophyre of other rocks. Olivine is rare and little modified. The biotite pseudomorphs of olivine are not met with.

From the above it will be seen that the epidiorites "sensu stricto" mineralogically, have a direct bearing on the diabases and gabbros. Sometimes we find relics of the ophitic structure of the diabases, sometimes new products have obscured the original structure completely.

A fine-grained epidiorite (uralite-diabase) from Kapoesa-dam, Pikien-rio, the geological behaviour of which has already been mentioned on page 114, shows numerous olivine phenocrysts attaining to a size of 4 mm. Microscopically we also observe numerous phenocrysts of monoclinic pyroxene. The latter shows a beautifully idiomorphic prism-zone, and incipient epidioritization. The olivine-phenocrysts show beautiful idiomorphism in small crystals; of the two common forms of olivine, flattened according to (010) or (100), the former is present here. At the ends of the prism, end-planes appear, of which the following seem to have been recognized: (021), (011), (102) and (001) (fig. 27). The plane of the optic axes lies vertical to the main zone. Many of the large phenocrysts show distinct corrosion-holes and cavities; filled with the groundmass; this is very clear in a phenocryst of 4 mm. in length; of the crystal there is but a skeleton left (Pl. 26 fig. 5). The groundmass in the corrosion-cavities has, in parts, passed into uralite-needles, mixed with carbonate and talc. The groundmass is abnormally rich in uralite. It consists of oblong-shaped and non-fibrous crystals, shorter than 0.15 mm. apparently having arisen from monoclinic pyroxene. There is basic plagioclase still just visible among them. We find grains of ore scattered everywhere. The structure of the rock is quite massive. Apparently we are concerned here with a

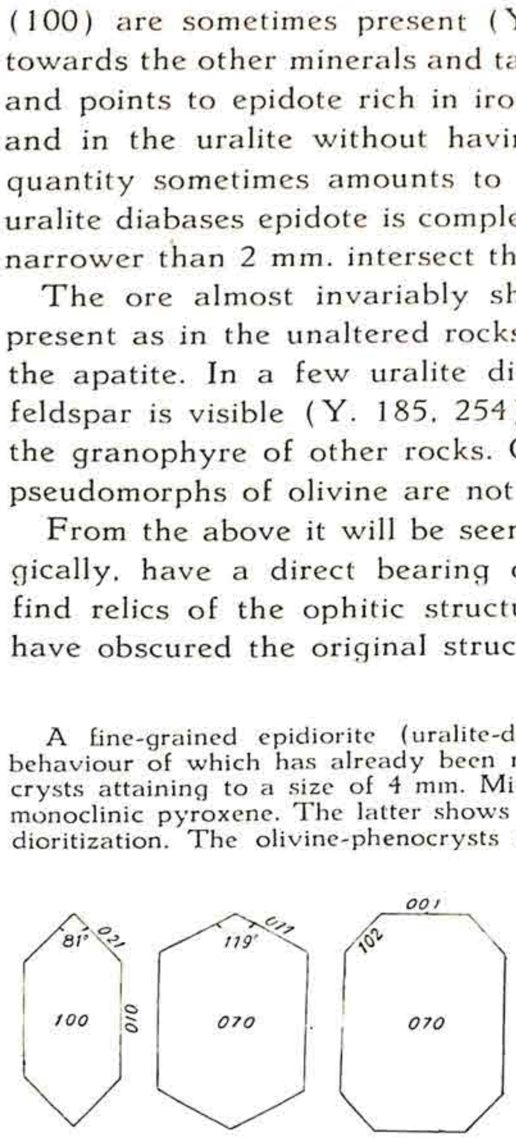

Fig. 27.

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[1]) Y. 113, 131, 134, 179, 184, 185, 188, 223, 249, 254.

uralitized, very basic rock, rich in phenocrysts, among which much olivine is found, and a groundmass which must have had a very large percentage of pyroxene: viz. a diabase-porphyrite or basalt rich in olivine. Its chemical analysis is subjoined.

SiO_2	49.23
Al_2O_3	9.33
Fe_2O_3	4.86
FeO	5.57
MnO	0.16
MgO	14.17
CaO	9.34
Na_2O	3.81
K_2O	1.18
H_2O+	0.83
H_2O-	0.06
CO_2	0.38
TiO_2	0.69
P_2O_5	0.29
	99.90
Anal. Dr. S. Parker. Zürich.	

NIGGLI VALUES.

si	99.5
al	11
fm	60
c	20
alk	9
k	0.17
mg	0.72
Section	3

TABLE 15.

Not a single uralitized olivine-diabase so rich in magnesium and so poor in aluminium has been found in petrographic literature.

By far the greater part of the epidiorites have already been recorded, together with the geological behaviour of the intrusive diabases and gabbros. As shown by samples, epidiorites also occur: on the Coppename river near Pimbahole (V. 2337), near Zonnevisch creek (V. 2338), and Pireen creek (V. 2369); the last-mentioned according to Essed belong to a "dyke-like intrusion" [1]). Further they are met with on the Grandam on the Saramacca (V. 1306, 1307, 1308); on the Litanie (V. 1082); NW. of the De Goeje mountains (V. 220), and to the North of these mountains (V. 329, 357).

The rest of the epidiorites: schistose epidiorites and hornblende epidote schists.

The rocks now to be discussed are partly decidedly, partly in all probability derived from diabases and gabbros and represent a more advanced stage of metamorphism; the change in the original material is not confined to the formation of hornblende (uralite) from the pyroxenes, but most of the other components are also altered. The features by which we can recognise the

[1]) E. Essed. **105.** p. 342, Nr. 30.

original diabase or gabbro are various. There may be relics of the minerals, or relics of the structure reproduced by pseudomorphs, or both together. In a number of rocks these relics are very insignificant or entirely wanting; in that case we are only able to guess what the original rocks were like by comparison with transitional samples and the nature of the new products. Most of the rocks manifest the massive texture of the diabases and gabbros; a number, however, especially the intensely metamorphic ones, have a tendency towards parallel texture or are distinctly schistose. While, of course, the relics in the most intensely metamorphic rocks are sparsest, yet there is no systematic progress of their metamorphism in such a way that a distinct series of minerals successively passes into secondary products.

The following relics may be present:

a. Minerals:

Pyroxene-relics. These are invariably surrounded with fibrous uralite, which is quite the same as that in the epidiorites already described above (V. 943, 945, 1034, 1346). The very fine base cleavage which was sometimes seen in the pyroxenes, may be met with again in uralite, which, on account of a more or less homogeneous structure, lacks the fibrous habitus (see V. 942).

Plagioclase-relics. The original plagioclases have greatly altered; approximately albite has been left by demixture and imitates the shape of the original feldspar (V. 937, 1008, 1023). This albite may show some twinning. In many cases we find an abundance of epidote or zoisite in the form of dust or granules which wholly or partly take the place of the albite.

Ore-relics. These may be of two types: First spruce-fir-like skeletons, secondly patches bounded by broken lines and re-entrant angles, in such a way that it is clear that originally the ore conformed to the lath-shaped plagioclases. Both forms correspond to the typical ore which we have described with respect to the unmodified diabases (see page 106) (Pl. 47 fig. 3 and Pl. 26 fig. 4).

Apatite. Apatite-needles, of the type that is common in the coarse-grained Surinam diabases, are seen here and there.

Quartz. It is not certain whether all the quartz is of secondary origin. Sometimes the quartz envelops the ends of feldspar laths or of pseudomorphs to the latter, just as the interstitial quartz of the quartz diabases and gabbros does. Relics of granophyre are rarely recognizable.

b. Structures.

Relics are still recognized, especially of the ophitic structure of the diabases. The relic-structure is observed in the thin section here and there or in one single spot only. The masses of uralite are quite irregular, but may be intersected by straight lines locally, in that case their shape reminds us unmistakably of the form of augite intersected by lath-shaped plagioclase in ophitic structure (V. 943, 945, 1034, 1346). Plagioclase, whether replaced by dust and granules of epidote or not, may show well-defined, lath-shaped forms, as in diabases (e.g. V. 919, 1016, 1034, 2208). Pseudomorphs conforming to ore will also occasionally show very distinct relic-structures; e.g. aggregates of almost opaque leucoxene, which by its forms, again reproduces the dissected patchy ilmenite, or the spruce-fir skeletons (V. 919, 943, 1004, 1016, 1034, 1612, 2208).

The rocks consist partly of relics and are for the greater part, composed of secondary hornblende, chlorite, epidote-grains, epidote- and zoisite-dust, leucoxene, and sometimes also secondary quartz and some calcite.

We come across remarkable uralite in a rock from Tompi creek (V. 1651). Its equally-polarizing crystals have a short prism-zone. Twins are numerous according to (100), with inserted lamellae. Uralite fibres in great numbers are sometimes inserted on the relatively sharply developed crystal-faces, as beard-like prolongations and oriented in the same way as the main crystals. These fibres occur particularly as a continuation of the main zone. Unlike the large crystals they are distinctly coloured (Pl. 26 fig. 6). We get the impression that, at first a more or less beautifully shaped crystal of uralite was formed and that, later on, a new period of growth set in, during which the fibres came into being.

Chlorite together with epidote-granules is usually present between the uralite-fibres, and it is not improbable that this chlorite partly represents a more advanced stage of modification, in which the uralite breaks up into chlorite and epidote.

Among the aggregates of uralite a mass of fine epidote-granules, particles of chlorite, uralite-fibres and leucoxene is seen, among which clear material of plagioclase and partly also quartz is sometimes visible; the relations of these components towards each other vary considerably. Now the space between the uralite is preponderantly filled with fine granules of clinozoisite, also with coarse pieces of epidote beside them, now plagioclase is present, in which an abundance of fine granules of epidote is scattered. Plagioclase has been replaced by epidote, sometimes also together with uralite fibres and chlorite, in such a manner that nothing but the crystal shape is recognizable. Quartz showing between crossed nicols a pavement of angular grains, or divided into fields and intersected by narrow strings of chlorite, is very peculiar (V. 942).

Leucoxene is common in the form of particles, often, too, in larger spots.

After this information concerning mineral combination and structure of a general nature, we shall go on with a specification of various types of rocks.

A. Rocks with relics.

As typical representatives, clearly recognizable as metamorphic diabases, may be mentioned the rocks from the Lely mountains and environs (V. 919, 937, 942, 943, 945, 1006, 1008, 1016, 1024, 1034), from Tompi creek (V. 1643, 1649), from Witlage placer (North of the Nassau mountains) (V. 2208, 2242), from the Upper Saramacca (V. 1345, 1346), from the Lower Saramacca (Peito creek, V. 1756), and from Matappi creek (Courantyne) (V. 3007, 3018).

In other rocks, relics of minerals or structures are only revealed locally on close examination; the plagioclase has been entirely or almost entirely replaced, consequently uralite, chlorite and epidote are the main-components. The structure is massive again; these rocks are also regarded as metamorphic diabases. We possess samples from the Lely mountains (V. 879, 899, 915, 1023 ┌, 1025, 1029, 1036, 1037), from Tosso creek (V. 967 ┌┐), from the Gran creek (V. 1004, 1005), W. of the De Goeje mountains (V. 235), from the

Saramacca (V. 783), from the territory of the Sara creek (V. 1626), and from Witlage placer (V. 2225). None of these rocks show any porphyritic structure. One rock, however, from the "Cie des Mines d'or", Lawa (V. 498) reveals, even in the sample, recognizable phenocrysts, replaced by uralite. It is possibly a totally changed augite porphyrite, which occurs there.

B. Rocks without relics.

There are other rocks very closely related to those described above differing only by a lack of relics. This difference, however, is not very important: indeed, in a number of rocks, still recognizable as metamorphic diabases, we observe only insignificant relics of minerals and structures: these become vaguer and vaguer so that the rocks gradually pass into those now discussed. These rocks also bear uralite, chlorite and epidote in varying proportions, together with quartz, leucoxene and sometimes albite with some pyrite and calcite. A respectable number are fine- to extremely fine-grained, and it is clear that suchlike rocks are very ill-suited to harbour recognizable relics. In one single repect they may differ considerably from the preceding rocks. By the side of massive types, we find many which show some schistosity both microscopically and in the sample, others again are distinctly schistose, forming a series of transitions from massive types to true schists. If we take into consideration that the rocks with or without relics and with or without parallel texture appear next to each other, we may regard it as a fact that all are metamorphic diabases and gabbros, and, in by far most cases derived from diabases, judging from the prevalence of fine or very fine grain.

The appearance of a varying degree of schistosity should not surprise us. If metamorphism took place under unilateral pressure, the metamorphic rock will very certainly bear the stamp of this, apart from the fact in how far this pressure is to be regarded as the direct cause of metamorphism; viz all the secondary components, in so far as they are developed in an oblong form would have grown out especially in directions vertical to the pressure, with the result that the rock would assume a more or less schistose habitus.

The orientation of the uralite chiefly causes the massive texture. The accumulations of fine epidote-granules, the coarser pieces of epidote, clinozoisite and relics of feldspars, if any, are likewise most arbitrarily developed in all directions. The same is true of leucoxene-masses; they form irregular spots in the thin section. In the rocks with some schistosity and in the true schistose forms, the texture is equally in the first place due to the hornblende. The uralite-like masses are as a rule parallelly directed. The more delicate fibres especially, which appear between the coarser masses of uralite, distinctly show the parallel trend. By the side of uralite a needle to lath-shaped greenish actinolite may be present, showing the typical cross-fractures of this mineral. In a few rocks (e.g. from the Tapanahony, V. 951, and from the Gran creek, V. 1039) this hornblende predominates. But there are other components that contribute equally towards the schistose texture. The accumulations of extremely fine epidote-granules are, generally speaking, not entirely arbitrarily distributed, but arranged in oblong-shaped groups, parallel to the trend of the hornblende. Masses of leucoxene, too, clearly exhibit the same phenomenon; in the transition from ore to leucoxene, the secondary material is drawn out to winding strings (see e.g. V. 1019, V. 1039). This process is clearly shown by a rock from the Lely mountains (V. 1035); in this schistose epidiorite we observe leucoxene-strings parallel to the trend of the whole, and at the same time still distinct skeleton-like forms which are partly transformed and stretched-out pseudomorphs to ore skeletons (spruce-fir-skeletons), as we know them in diabases. The mosaic of feldspar-relics and some quartz, too, may exhibite some indication of parallel trend of the grains. We might call the decidedly schistose types hornblende epidote schists.

The massive, non-schistose rocks for the most part call for no remarks. We possess such-like rocks from the De Goeje mountains (V. 406, 408, 409), from the Upper Lawa (V. 488, 580, 581), from the Lely mountains (V. 879, 882, 895, 914, 915), from the Lower Tapanahony (V. 1047), from the Gran creek (V. 993, 999, 1001), from Witlage placer (V. 1701, 2231), from the Sara creek (V. 1577), from the Suriname river near Grinwisburg (V. 1546), from the Locus and Tompi creeks (tributary creeks of the Suriname river) (V. 1650, 1651), and from the Lower Saramacca (Peito creek) (V. 1754, 1756).

We have fine-grained, schistose rocks, which we may call hornblende epidote schists from Gran creek (V. 992, 1002, 1003), from the Lely mountains (V. 906, 950, 951, 1019, 1035, 1039), from the Upper Lawa (V. 577, 579), from the Dabikwen trail (V. 1538) and from the Assisi creek (V. 218).

A few massive, exceedingly fine-grained rocks must be discussed separately. Hornblende is present here in large quantities; indeed these rocks might be looked upon as hornblendites. This, however, would be a mistake, for other components are to be seen on close inspection. We invariably recognize a mingling of extremely fine epidote-granules and chlorite-scales with colourless material too fine for identification, still glimmering through the hornblende-fibres. The leucoxene forms an exception here: the specks of leucoxene are, it is true, much finer than in the relatively coarse types, but proportionately with the rest of the components, they have not diminished in size. These rocks are linked up with the coarser ones by transitions, and it is highly probable that they are modified, very fine-grained diabases, the more so, as the latter generally bear more pyroxene than the coarser diabases, and consequently will also yield a greater quantity of uralite. We have such rocks from the Lower Saramacca (Peito creek) (V. 1751), from Gran creek (V. 990), from the Lely mountains (V. 880) and from the Lawa below the Soemanjere fall (V. 580).

As in the case of the massive rocks, some very fine-grained shistose types are present, exhibiting a large quantity of hornblende, and we should be inclined to call them hornblende- or hornblende chlorite schists, were it not for the fact, that a considerable quantity of epidote (and clinozoisite) or feldspar and quartz are present. Leucoxene-dust occurs in spots or lies scattered about. However, these special types chiefly consist of fibrous, pale-green hornblende, with a parallel trend. They are related to the preceding ones by transitions. In my opinion they ought also to be regarded as metamorphic fine-grained diabases. There are samples from the Marowyne near Poeloegoedoe (V. 455), from the Lawa (V. 578, 1104), from the De Goeje mountains (V. 409), from the region of the Marowyne creek (V. 1662), from the watershed between the Suriname river and the Mindrinetie creek (Y. 360), and from the east side of the Browns mountain (Y. 363).

Other metamorphic rocks of the diabase formation.

Besides epidiorites we also know other metamorphic rocks derived from gabbros and diabases, apparently having but a very local significance; a brief description of them will suffice.

a. Pyroxene has not been replaced by uralite and epidote in these rocks, but as coloured secondary component, chlorite alone seems to be formed. The calcium percentage of the pyroxene together with that of the plagioclases of which only the albite-molecule is left, is combined by calcite. In this case we are concerned with an albite-chlorite-calcite rock, or, when the calcium has been carried off, with an albite-chlorite rock.

Mineralogically both types are very closely related to the "Schalstein-schists" to be discussed lateron. They differ, however, by the pure pyrogenous origin of the material, without the sedimentary components, as we can sometimes still observe structures of the original igneous rock.

Three rocks collected in the Lely mountains within 200 metres from each other, are remarkable (V. 1025, 1027, and 1028). The samples are fine-grained, almost dense and of a greenish colour. Microscopically they show albite, chlorite, calcite, ore and leucoxene. Relics of the original structure may be seen locally in the thin sections. We observe lath-shaped plagioclases, lying scattered about, just as is the case in the ophitic structure of the diabases. Not only the form of the feldspars but also the Albite-law lamination is recognizable. The plagioclase has for the greater part been replaced by very numerous, fine granules of calcite and in a less degree also by chlorite scales. These also fill, to a great extent, the space between the plagioclases. Locally we observe brown spots, which on being strongly magnified show the same fine scaly chlorite material, together with a brownish matter not allowing of further definition; these brownish portions often have the dissected form of the pyroxene crystals conforming to the lath-shaped plagioclases in typical ophitic diabases. These brown portions and partly also the accumulations of calcite and chlorite take the places of what were once normal-grained diabases poor in pyroxene. Another argument for their diabase nature is provided by the skeleton-like, relatively coarse pieces of ore, of the well-known type. They have remained practically unchanged. In other sections, however, we fail to observe the relic-structure; the recrystallisation of the original material is in a more advanced stage. By the side of very fine granules, calcite is, also present in large pieces and nests, and chlorite has been heaped up to masses showing very anomalous polarization-colours; colourless albite material is vaguely visible. Besides recrystallisation of albite must have taken place. Locally short or isodiametric, and non-idiomorphic crystals appear, which are also recognizable as having been newly formed by the nature of the lamination. The lamellae vary considerably in number and breath in each crystal, and more-over wedge-shaped lamellae shoot out from the edges in quite a number of places, not corresponding with the entire length of the crystal. The grouping into nests and sometimes into veins of these albites also speaks for their secondary character. Where this recrystallisation is much advanced, we can nowhere recognize any primary structure (as in V.1027), and, had this latter rock not been collected together with the two preceding ones, we should no longer be able to recognize it as a metamorphic diabase at all. The lack of quartz (non-twinned albite may be confounded with quartz) is striking. This mineral is, however, present in a rock from the Tapanahony river for the rest showing the same composition (V. 1684).

Together with the rocks from the Lely mountains a massive epidiorite (V. 1025) was collected showing normal epidiorite metamorphism: uralite formed from pyroxene, and replacement of plagioclase by very fine epidote-granules, and of ore by leucoxene; hence the change described above must bear a local character.

A rock found N. of the Nassau mountains is closely related; it yet shows different metamorphism (V. 2250). Microscopically it appears to consist of albite, chlorite, and ore. Here, too, we meet with ophitic structure again, in the well-defined lath-shaped albite which takes the place of plagioclases. Chlorite-scales lie scattered throughout the albite and intersect it in fine strings. It is remarkable that in the advanced chemical changes which these plagioclases have undergone, no secondary accumulations of calcite have been formed, so that the anorthite molecule must have been carried away. The chlorite appears more densely accumulated between the plagioclases and must have taken the place of pyroxene here; of the latter, however, not a trace is to be seen. It is striking that the ore has in part remained unchanged, only disintegrating locally into finer ore-dust and limonite, for the rest showing typical skeleton-forms. Quartz is also lacking in this rock as a secondary product. The texture is quite massive.

From what we have seen in these rocks, it is likely that others may also be recognized as having been derived from diabases, although no primary structure is to be seen. In the first place we allude to a massive rock collected on a trail between the Sara creek and the Tapanahony (V. 1684). It consists of a mixture of calcite, albite, chlorite, ore, and besides these of sericite and a considerable percentage of quartz. This is equally true for a series of three rocks from Mankaba on the Marowyne (V. 1695 and others), being called "Zersetzter Schalstein" by Du Bois [1]). They undoubtedly belong to the diabase group or to the Schalstein group, although it is impossible to make out in how far we are dealing with metamorphic clastic material or metamorphic igneous rocks, as every trace of relics is wanting. The massive texture speaks more for the latter nature. The same also applies to a couple of rocks collected near the left bank of the Marowyne (V. 2202 and 2204); these consist of a mixture of very fine chlorite-scales and quartz-granules, together with some muscovite, and numerous of limonite pseudomorphs to carbonate with calcite remnants occurring in them. The texture is massive.

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[1]) G. C. Du Bois. **40.** p. 24.

Let our mentioning of these rocks here suffice.

All these rocks are marked on the map in the same manner as the epidiorites.

b. A dyke-rock from the Gran-rio must have been subjected to quite a different type of metamorphism, but is probably also derived from a diabase. In the last step of the Maripa-dam cataract of the Gran-rio there is a small basic dyke somewhat carved out in respect to fine-grained bi-mica granite. The dyke may be approached from the right bank, while a channel has been worn in the middle of the step, which in the dry season, drains all the water from the river. The dyke is visible on either side of the channel and has a trend of N. 115° W. Its breadth amounts to a good metre and the dyke breaks through the granite pretty well vertically. The basic dyke is an offset, with a hozirontal displacement of a few metres along a slicken-side, so that the parts corresponding with the two sides of the channel have the same trend but are not, in line and level. The granite shows no change at the contact. The dyke-rock is extremely fine-grained, having a dense basalt-like habitus. Locally there is some finely-divided pyrite present (Y. 121). Microscopically we observe very much hornblende, considerably less biotite, and plagioclase as colourless mineral. Further, there is a fair quantity of secondary epidote, some ore, and titanite. Save some pieces of hornblende, the coloured minerals are smaller than 0.04 mm. The hornblende is irregular in shape; we also find some larger, well-defined prismatic crystals. It is all the same hornblende, with pleochroism of yellowish-green to green and bluish-green. This hornblende had better be called actinolite, the prismatic crystals showing the characteristic cross-fractures. The hornblende has, secondarily, grown into the plagioclase to such an extent that very little is left of the original forms of the latter; it is a moderately basic plagioclase, and polysynthetic. By combining the lamination, still visible between the hornblende, we are able to reconstruct oblong- to lath-shaped feldspar crystals here and there. Hornblende and biotite are irregularly distributed over the thin section. Now we find them scattered all about, the coloured minerals taking almost up together with the plagioclase as much room as the plagioclase, now the biotite and hornblende are heaped up together, so that large spots in the thin section consist solely of coloured minerals. Pieces of epidote, partly with a well-shaped orthodomatic zone with yellow pleochroism and coarse cleavage are spread throughout the whole thin section. A vein of epidote crosses the thin section. Granules of titanite accumulated in groups are common, partly together with the ore from which they originated. Clear quartz is quantitatively negligible. The rock has remained quite massive during metamorphism. The rock differs mineralogically from the epidiorites "sensu stricto" by the nature of the hornblende and the not insignificant percentage of biotite. The appearance as a dyke and the distinctly lath-shaped relics of the plagioclase are arguments for its diabase nature, while the chemical analysis, here subjoined, also agrees with that of normal, quartz-free diabase. Only the percentage of potassium is rather higher than we usually find; this must possibly be sought for in the biotite.

TABLE 16.

SiO_2	48.54
Al_2O_3	13.50
Fe_2O_3	2.01
FeO	7.97
MnO	0.23
MgO	11.02
CaO	9.32
Na_2O	2.73
K_2O	2.58
H_2O+	1.16
H_2O-	0.04
CO_2	0.19
TiO_2	0.76
P_2O_5	0.24
	100.29
Anal. Dr. S. Parker. Zürich.	

NIGGLI VALUES

si	103.3
al	16.9
fm	52.8
c	21.2
alk	9.1
k	0.38
mg	0.66
Section	3

THE GEOLOGICAL BEHAVIOUR AND DISTRIBUTION OF THE EPIDIORITES AND ALLIED ROCKS.

We have already thoroughly gone into the geological behaviour of the epidiorites "sensu stricto" (uralite diabases), when treating that of the diabases and gabbros. It appears that they usually intersect the granitodiorites and ortho-gneisses of the basal complex in the form a dykes of varying breadths (see page 113 to 119). Consequently the behaviour of the epidiorites "sensu stricto" corresponds to that of the intrusive diabases and gabbros. Judging from their structure they are derived in particular from diabases, whether fine, normal or coarse-grained ones. As far as we know, they occur especially in the basin of the Gran-rio, the extreme upper-course of the Lucie river, and the Wilhelmina mountains.

No field observations on the geological behaviour of the intensely metamorphosed epidiorites and the allied schists are available. They have the same distribution in the Colony as unaltered diabase (p. 121). Besides transitional forms between unaltered diabase and highly metamorphic and schistose epidiorite (hornblende epidote schist and hornblende chlorite schist) are collected together in several places. These facts together with the petrographical arguments treated above in detail, render it probable that all belong to the intrusive diabases and gabbros; possibly with the exception of some of the schists, which may be related to the older parts of the basal complex.

PRESSURE-PHENOMENA IN DIABASES, GABBROS AND EPIDIORITES; THE CAUSE OF EPIDIORITIZATION.

The opinion that epidioritization is caused by pressure is so widely held that we may discuss both phenomena here together. It appears, however, that in our case, pressure cannot be of primary importance in epidioritization, although it has in some cases probably operated incidentally.

To begin with it should be mentioned that in the unmodified intrusive diabases and gabbros, pressure phenomena are very rare. The lath-shaped plagioclases may be somewhat warped here and there, and the interstitial quartz may be undulose in places, but the question is, whether these phenomena have not a closer bearing on cooling down and tension subsequent to crystallization. Only in one single gabbro from the Courantyne there are traces of secondary pressure [1]). The same may be said of the epidiorites. The epidiorites "sensu stricto" do not exhibit any significant traces of pressure. Some cataclasm is occasionally visible in the epidiorites, because of the plagioclases being warped and cracked [2]). We may assume that the unmodified diabases and the gabbros, in so far as they bear oblong-shaped plagioclases, must pre-eminently react to pressure, by the warping of the plagioclase crystals.

Let us now resume what changes have taken place in epidioritization. The original material is diabase or gabbro, with basic plagioclase, monoclinic and sometimes also orthorhombic pyroxene as essential components. The first stage of epidioritization is the complete or partial transition of the pyroxene into uralite. The feldspar remains intact in this case, except in so far that the borders are disturbed by fibrous uralite which grows into them. In that case the ore is, as a rule, then still unchanged. Further epidioritization attacks the other minerals, plagioclase and ore, in which, however, different products may be formed. Plagioclase may be broken up into albite and epidote or zoisite, or may be wholly replaced by epidote minerals, in which case the albite percentage in the plagioclase probably takes part in the formation of uralite. Even now the pyroxene need not be wholly consumed. Uralite, may, in its turn, produce chlorite. The ore exhibits very different stages of change which have no bearing on the preceding ones. In addition to this, some biotite may appear even in the uralite diabase stage. So we see that when the stage of epidiorite "sensu stricto" (uralite diabase) has been passed no regular sequence is followed in the later course of the process.

As we have already mentioned, epidioritization, in the literature on the subject is generally ascribed to pressure. In the Surinam epidiorites, however, pressure may not have caused the epidiorites "sensu stricto", for nearly all dykes of epidiorite we know, appear in granitodiorites which show no intense pressure. This was studied more in detail for the uralite diabases of the Wilhelmina mountains and the granites intersected by them. Neither can the more advanced stages of metamorphism, in so far as massive rocks are concerned, be a result of stress, for no doubt, these rocks would have assumed more or less parallel texture: the secondary products would very certainly grow out in directions vertical to the stress; instead of this we still find the original texture.

It is different with the more or less schistose rocks; and especially those which we might call hornblende epidote schists must have been affected by stress, since their texture cannot be accounted for otherwise. But also here stress seems not to be the principal cause of epidioritization, considering what we have seen above. It is probable that dynamo-metamorphism here is but a contributory factor in the process and only orients the new components.

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[1]) The plagioclases are distinctly warped in a gabbro from the Manikobi island (Vtz. 801).
[2]) Such is the case in a uralite diabase from the Upper Lucie river (V. 3472). In a uralite diabase from the Coppename (V. 2369) we observe mylonized portions along micro-faults.

That the replacement of material here may be significant we have seen e.g. in the long extensive masses of leucoxene formed from ore etc.

In my opinion there is an important difference between the nature of the metamorphism of these epidiorites and of other metamorphic rocks the mineral-combination of which is related to them, viz. the Surinam plagioclase amphibolites. The hornblende in the latter differs from that in the epidiorites and this is the same in the epidote and zoisite-bearing amphibolites. In the process of epidioritization the appearance of pseudomorphs and demixture predominate. The nature of the metamorphism is in harmony with conditions such as are generally assumed for the epizone. Part of the mineral combination of the true amphibolites, it is true, adapts itself equally to this same zonal connection, viz: the epidote and zoisite, in so far as they are present, but in the Surinam amphibolites, besides these, garnet, green hornblende and basic plagioclase may be present for the appearance of which a deeper zone is generally assumed.

We might explain the differences between the two groups of rocks by the supposition that locally metamorphism of different intensity has acted at the same time and hence epidiorites and amphibolites were formed by the same geological main cause. An argument against this, however, is, that the geological relations of epidiorites and allied rocks are not the same as those of the amphibolites. The epidiorites are related to the intrusive diabases; the amphibolites, however, accompany the garnet hornblende gneisses in massifs. Hence, unlike the epidiorites, the amphibolites belong to older and more intensively metamorphic parts of the basal complex. In the older geological publications on Surinam and the neighbouring regions, we repeatedly find, however, epidiorites and amphibolites coupled together as if they take the same place in the geological system of the Colony.

AGE OF THE INTRUSIVE DIABASES, GABBROS AND EPIDIORITES.

That the intrusive diabases and gabbros are the latest of all igneous rocks, breaking through the granites and gneisses and the schists of the basal complex, and likewise through quartz porphyry and porphyroids has already been mentioned in the discussion on their geology (page 113). Their behaviour towards the Roraima formation is unknown.

To some extent this is also true of the epidiorites. We have seen that the geological behaviour of the epidiorites "sensu stricto" agrees with that of the unmodified rocks from which they are derived; we have supposed that the same is true for the more intensely metamorphosed epidiorites and probably also for the related schists. So the relative age in regard to the basal complex is for most of them an established fact, but their geological behaviour in Surinam teaches us nothing concerning their exact geological age.

It is possible that the adjoining countries can give some indication. In the surrounding countries we know intrusive diabases and diabase-gabbros of different ages. In British Guiana and in Brazil (in the state of Para), they traverse a basal complex, approaching the composition of that in Surinam. In

Para, where the basal complex is covered by little-disturbed Paleozoic strata diabases break through fossil-bearing Silurian rocks while diabase-tuffs and diabase sills are found in Devonian rocks [1]). Besides we know later diabases in Para, which break through Permian strata, but it is not known how much later they are. In British Guiana the Roraima formation is intruded by sills of diabases and gabbros, which sometimes contribute considerably towards the thickness of the formation. The sandstones and slates of the formation show contact phenomena [2]) so that there is no doubt about their relative ages. The geological behaviour of the diabases and gabbros in neighbouring countries therefore, can give no decisive answer as to the age of the Surinam diabases. It shows however, that they are post-Archean and in adjoining countries partly Devonian, partly post-Devonian, and partly, very decidedly, post-Roraima. Comparison with more distant regions, can yield nothing definite.

The very insignificant pressure-phenomena, which the diabases and gabbros have undergone is an argument for later age. The close petrographic affinity revealed by the rocks, rather points to one single intrusion-period, or to several periods with short intervals, and makes a very great difference in age improbable.

SOME NOTES ON THE GENESIS AND RELATIONSHIP OF THE INTRUSIVE DIABASES AND GABBROS.

Some petrographers are of opinion that the percentage of quartz of the quartz diabases and likewise the percentage of potash feldspar can be accounted for by resorption and recrystallization of included material. For this opinion we find no support in the Suriname diabases. They do not seem to produce any change of importance in the adjoining rock [3]), and inclusions have nowhere been observed. Moreover, it is not clear how we are to conceive this process; if material, rich in quartz, was enclosed and actually resorbed we should sooner expect an alteration of the typical diabase components, than a separate crystallisation of the quartz. Harrison's opinion that the granophyre must be a secondary addition to the same diabases in British Guiana [4]), is not acceptable either. There is no question of the granophyre replacing or affecting the older mineral components, and such irregularities would be sure to appear in diabases with a large percentage of granophyre. On the contrary, the granophyre is the latest crystallization product. The primary nature of the granophyre, for that matter, is accepted by most petrographers though the opinions on the genetic connection between normal diabases and quartz diabases are divided. As we have seen, the Surinam material shows all transitions between both types. The occurrence of olivine besides quartz and potash feldspar in many of the

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[1]) See F. Katzer. **49**.
[2]) S. Bracewell. **108**. p. 19.
[3]) During our expedition, however, I thought I noticed contact-metamorphism of diabases and gabbros on granitodiorites in the field. In our short bulletins this is referred to. Microscopical investigation has shown, however, that the supposed contact-phenomena were nothing but primary differences in the composition of the granitodiorites; locally complications of another nature are also present.
[4]) Harrison. **68**. p. 206—207.

quartz diabases, does not speak in favour of the settling hypothesis of Bowen [1]). This hypothesis, for that matter, has already been refuted by Daly [2]) on the ground that heavy minerals are by no means present in a much smaller percentage in quartz diabases than in normal diabases, and that the former certainly do not show a considerably larger percentage of alkalis.

The appearance of olivine besides free quartz remains remarkable, however; it conflicts with the rule that free $Si O_2$ and orthosilicates do not crystallize in the same rock derived from a normal magma. In some diabases however, the combination has been observed; in the Kinne diabase of Sweden, in the proterobase dykes cutting through granite in the Lausitz (Saxony), and in other rocks of varying composition with quartz syenites as the most acid ones. We might assume that with our diabases, after olivine had been crystallized, a modification in the magma had taken place through supply of more acid material; this is however hardly acceptable, as the olivine certainly does not here belong to the very oldest products of crystallization.

According to the researches of Stark [3]) and Hawkes [4]) about the composition of olivine in rocks of different percentage of $Si O_2$, olivine rich in iron is found in rocks containing a medium or large percentage of $Si O_2$; in accordance with this, measurements of the optical axial angles of the olivine of the Suriname material also point to ferrous olivine.

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1) N. L. Bowen. Journal of Geology. Suppl. XXIII. 1915. p. 46.
2) R. A. Daly. do XXVI. 1918. p. 121.
3) M. Stark. Centralbl. f. Mineral. etc. 1924. p. 44.
4) L. Hawkes. Quart. Journ. Geol. Soc. LXXX. 1924. p. 561. do Geol. Mag. LXII. 1925. p. 192.

ANDESITES OR PORPHYRITES.

INTRODUCTION.

We possess a number of samples of andesites or porphyrites; concerning their geological behaviour, however, very little is known. The majority of them are probably of later age than the granitodiorites of the basal complex, which in one single case has been determined, but this is the only thing we are certain about.

The question as to whether we are dealing with pre-Paleozoic, Paleozoic or later intrusives being undecided, we may use either the name andesite or porphyrite. In naming the sample-material, classification in agreement with the nature of the phenocrysts has been followed; according as plagioclase phenocrysts only, or also pyroxene phenocrysts, are present, the following groups may be distinguished:

a. Andesites or porphyrites.

b. Augite andesites or augite porphyrites.

c. Diopside andesites or diopside porphyrites.

Andesites or porphyrites.

We possess a couple of representatives, little characteristic of this group.

One of the samples comes from the extreme S. W. of the Colony and was collected by the Tumuchumac Expedition, on an Indian trail running to the North of the watershed of the Amazon (V. 1256). It has been described by Grutterink [1]).

To his description we may add that, if we may really call this rock an andesite, it is one of the most acid types, closely allied to quartz porphyry. We are able to distinguish two components in the extremely fine groundmass, the one probably quartz, refracting much more strongly than the other which in its turn refracts less strongly than the balsam; this is probably potash feldspar.

Of the original andesitic composition of the next rock we are far from being certain. It comes from the Lower Tapanahony, near the village of Manlobbi (V. 1046). The sample is fine-grained, massive, and of a green-gray colour. With the aid of a magnifying-glass a number of feldspar phenocrysts are to be distinguished. Microscopically we observe quite a number of plagioclase phenocrysts. Their shape varies from thickly-tabular to lath-shaped. The crystal-faces are well-developed, the crystals, however, have partly the form of splinters, as a consequence of protoclasm. The twinning is still visible, but the original composition of the plagioclases cannot be determined, for secondary sericite-scales are present, and probably the basicity has diminished; the index of refraction at present indicates an acid plagioclase. Dark phenocrysts are absent. The groundmass shows numerous fine plagioclase-laths and has no glass-base. This is clear in places, where the groundmass has not been modified. We see here the plagioclase-laths up to the very finest dimensions passing into a crystalline, inextricable mass. None of the coloured minerals in the groundmass have remained intact, neither has the ore. Scattered among the feldspars there is a considerable qauntity of pale-green and practically non-doubly-refracting chlorite-like substance down to the finest dimensions, which can only be recognized as such on being strongly magnified. A few grains of titanite or leucoxene were probably formed from ore. Although the phenocrysts show no regular texture, the groundmass locally shows distinct flow-texture. This rock will, probably, also have to be classified with the andesites or porphyrites. The absence of coloured minerals as phenocrysts is striking and suspicious. The feldspar of the groundmass as well as that of the phenocrysts probably must have had a less acid composition, hence other allied rock-groups e.g. keratophyres are out of the question.

[1]) J. A. Grutterink. **73**. p. 199—200.

A boulder from Carolina, Suriname river, collected by Martin, has already been described by Kloos [1]).

Augite andesites or augite porphyrites.

We have several representatives of this type which have undergone a partial change.

A rock from the Lombok fall, Nickerie river, has already been described by Beekman [2]).

A couple of samples from the Cie des mines d'or, Marowyne, are so much alike that they may be discussed together. One of them (V. 499) comes from the "Etablissement Pointu"; the findspot of the other is unknown (V. 571). Macroscopically they are massive, fine-grained rocks, showing, by the aid of a magnifying-glass, numerous spots of feldspar in a bluish-grey or more greenish groundmass. In the thin sections we observe numerous phenocrysts of plagioclase and monoclinic pyroxene and hornblende. They lie scattered throughout a fine groundmass. The plagioclase phenocrysts are from oblong to isodiametric in shape. They are, more or less filled with mica-scales and dust; demixture has taken place; the composition is very acid now. The other phenocrysts, likewise numerous, show in the centre remnants of monoclinic pyroxene, surrounded by fibrous hornblende (uralite), or epidote has been formed (V. 571). Some crystals, however, still show prismatic forms with end-faces. In the other, more modified rock (V. 499), a complete replacement of the pyroxene by uralite has taken place, in such a way that the uralite, on account of the parallel arrangement of the fibres, is difficult to distinguish from primary hornblende. The pyroxene phenocrysts here, must have been of a short prismatic shape. Numerous twins occur, sometimes several in the same crystal. Ore-grains in the groundmass are conspicuous. They are octahedral, varying greatly in size. The extremely fine groundmass just allows of feldspar-laths being distinguished locally; it shows flow-structure. In other places it is not possible at all to identify the components of the rest of the crystalline groundmass. The latter is obscured by secondary material, chlorite-scales, dust etc. Ore-granules are present and masses of calcite also occur here and there. In one of the rocks (V. 499) the change in the groundmass is still greater. On the whole these rocks must have been typical augite andesites or porphyrites.

Two other rocks also from the concession of the Cie des mines d'or agree with the preceding ones, but in some respects have undergone even greater changes (V. 68, 110). The groundmass is very obscure, we may discern locally a mass of uralite, chlorite, calcite etc. Numerous phenocrysts are present: plagioclase, and pyroxene, still being recognizable by remnants. Pyroxene crystals seem partly to have been combined into clusters, where the uralite and chlorite-masses now appear, reminding one of tuff- or breccia-structure (see V. 68 in particular). Considered in themselves, we might possibly interpret these rocks as "Schalsteine", but, on comparison with the preceding ones, they appear modified rocks of the same species, rich in phenocrysts.

Diopside andesites or diopside porphyrites.

There is but one single representative, from the Courantyne on the Dutch bank not far from the mouth of the Lucie river (Y. 286).

The massive sample is almost black; it shows a few phenocrysts of pyroxene and plagioclase in a dense groundmass. Microscopically it appears to consist of phenocrysts of plagioclase, diopside, and hypersthene, in a groundmass of biotite, diopside, plagioclase and potash feldspar (Pl. 27, fig. 1). The rock is rich in coloured minerals. The plagioclase phenocrysts are oblong-rectangular to lath-shaped; the longest attaining to 2,2 × 0.35 mm. Besides polysynthetic twinning they also show zonal structure, which is visible on account of a very narrow, feebly refracting rim. This zone is sharply separated from the centre by its refraction and refracts more strongly than the balsam. The composition of the nucleus varies from labradorite to oligoclase-andesine, the rim being still more acid. Many crystals show complications. Throughout the whole crystal we see oblong-shaped spots refracting as feebly as the rim-zone. These spots form a contrast with the more basic parts, chiefly between crossed nicols on account of "speckled" extinction. The maximum length of these spots runs parallel to the trend of the crystal. The plagioclase phenocrysts contain much ore-dust and many larger rounded-off granules of ore, and also a few fragments of biotite and diopside-granules. The diopside phenocrysts have a beautiful shape. Octahedral sections, vertical to the main zone have a well-developed pseudo-quadratic cleavage. Sections vertical to the prism-zone

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1) See J. H. Kloos. **28.** p. 170—171.

2) E. H. M. Beekman. **63.** p. 146—147.

are very feebly pleochroitic; sections parallel to this zone are invariably pale-yellowish-green. The maximal extinction amounts to approximately 41°, hence it is a green diopside. Some beautiful twins according to (100) are present with some intervening lamellae. Besides the diopside often exhibits zonal structure in which the rim polarizes somewhat differently, and the cleavage is more poorly-developed than in the nucleus. The inclusions are the same as in the plagioclase; besides leaflets occur. The hypersthene phenocrysts likewise show octahedral crossections. The (010) cleavage is distinct. The sections show pleochroism of pale wine-red to yellowish-brown and greenish. Numerous brown transparent rods are enclosed (titanomagnetite?), running parallel to the c-axis. In sections vertical to the prism-zone there are two more systems to be seen, while the system first mentioned is visible as minute points, so that the rods are, altogether, arranged according to three systems in the hypersthene.

The groundmass has a remarkable composition. The greater part is plagioclase, next come biotite, diopside, potash feldspar and ore. The plagioclase and potash feldspar have the shape of grains; they are isodiametrical polygons impeding each other, reminding one of "pflaster"-structure (see the clear mineral grains in Pl. 27, fig. 2). The grains are mostly smaller than 80 μ, on an average 50 to 60 μ, hence they are very minute. They are clear, but diopside-granules, decreasing to the finest dimensions, are frequently enclosed. As is indicated by the refraction the plagioclase of the groundmass is partly oligoclase, partly probably more basic. The potash feldspar is clear. It is in the minority with respect to plagioclase, though not insignificant. Next to plagioclase, brown biotite is of considerable importance in the groundmass; after this comes diopside. The pyroxene is without exception granular and mostly smaller than 65 μ, to extremely fine. The groundmass is very rich in coloured minerals, reminding one of lamprophyres.

Geological occurrence and possible relationship.

The only rock of whose geological occurrence we have any definite knowledge is the porphyrite from the Lombok fall, Nickerie river. It cuts a granite-gneiss as a dyke. [1])

The more or less metamorphic rock from Manlobbi, Tapanahony (V. 1046) occurs together with porphyroids, the age of the latter being unknown. The only diopside porphyrite is found at 1 km. above the mouth of the Lucie river in the Courantyne against the Dutch bank as an accumulation of boulders, presumably the remnants of a dyke of several metres broad cutting through granite. Consequently our knowledge concerning their geological behaviour is, as a whole practically nil.

Van Cappelle points out that the andesite from the Nickerie river, is possibly related to the intrusive diabases; indeed it does not differ essentially from a diabase porphyrite.

Probably the augite porphyrites from the Marowyne are also related to the diabases. In places they show a tendency towards epidioritization. Harrison [2]) mentions augite porphyrites from Br. Guiana traversing masses of diabase, and regards them as being contemporaneous with the diabase. The diopside porphyrite referred to probably belongs to the latest intrusions too.

The acid type from the Tumuchumac region petrographically rather corresponds to the quartz porphyries.

None of these rocks show any trace of cataclasm.

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[1]) H. van Cappelle. **62**. p. 42.
[2]) J. B. Harrison. **68**. p. 86.

THE QUARTZ PORPHYRIES, GRANITE PORPHYRIES AND PORPHYROIDS.

INTRODUCTION.

In this chapter are treated quartz porphyries, granite porphyries and their metamorphic equivalents (porphyroids) and some silificated felsites. Of the geology of all these rocks very little it known.

From the large number of samples it appears that quartz porphyries must be widely spread over the Colony. Of granite porphyries we know only a few. Petrographically they partly join on immediately to the quartz porphyries. The porphyroids are partly the metamorphic equivalent of the two former groups; besides we know strongly metamorphic types, clearly schistose, which we may entitle as sericite schists. It is very well possible that part of the porphyroids is older than the porphyries and forms part of the schist-formation.

Owing to the scant knowledge of the geological behaviour of all these rocks our classification has only reference to the petrographic characteristics. Quartz-free porphyries of the trachyte or orthophyre groups are unknown in Surinam.

The Quartz porphyries.

With a few exceptions, all quartz porphyries in Surinam are holocrystalline; almost all of them are massive and have no parallel or fluidal texture. As usual a great number of types may be distinguished according to the structure of the groundmass and the combination of the phenocrysts. These types, as is proved by intermediate forms, give no reason for assuming essentially different rock-groups. As the phenocrysts show no great variation they may be discussed for all types of rock together. As phenocrysts occur quartz, potash feldspar and plagioclase, occasionally also biotite and rarely hornblende.

The quartz phenocrysts are recognizable either in the sample or microscopically, as bipyramidal or rounded grains which may reach a size of some mm. Microscopically they often show corrosion forms: i.e. cavities, filled with the groundmass (Pl. 27 fig. 3). There also occur splinter-like quartzes, or the phenocrysts may be divided into a greater number of fields each of which polarizes by itself, and which fields seem to have been formed by protoclasm (e.g. Y. 144).

Potash feldspar may be idiomorphic (P and M) and twinned. It is remarkable that a feeble or more distinct microcline-structure is to be seen on closer examination in most cases. Microperthite also occurs, and, when this is present together with dust or sericite, it may be very difficult to discern whether we have indeed to do with microcline.

Plagioclase forms tabular or isodiametric crystals with conspicuous idiomorphism. However, it may also be defectively developed as splinter-like pieces.

The twinning is clear, according to the Albite-law, sometimes combined with the Carlsbad-law. The index of refraction at least with the unchanged types, points to albite-oligoclase, oligoclase, oligoclase-andesine or andesine. In many rocks the index of refraction no longer corresponds with the original composition; the disappearance of the anorthite molecule goes hand in hand with the occurrence of secondary sericite and epidote while albite remains.

Protoclasm is often clearly developed in the phenocrysts (Pl. 27 fig. 4). This phenomenon occurs in the feldspars as well as in the quartzes. Especially the plagioclases show crystals that have crumbled to little displaced fragments, while the twinning still shows that we have to do with fragments which originally belonged together.

Biotite is rarely developed as phenocryst. More often, however, we see some biotite heaped together, which replaces the biotite phenocrysts and is regarded as such in the sample.

Hornblende is only present in a single sample (Y. 335), clearly prismatic and with a maximum length of 6 mm.

According to the structure we may divide the quartz porphyries into three types:

a) the groundmass is microgranitic.

b) the groundmass is rich in lath-shaped feldspars.

c) the groundmass is granophyric.

Quartz porphyries with felsophyric groundmass as mentioned by Beekman, [1]) are unknown in Surinam. On the lines of this classification we shall discuss the rocks.

I. *Quartz porphyries with microgranitic groundmass.*

In these the groundmass shows isometric feldspar grains, and likewise quartz grains, only slightly differing in size, without clear idiomorphism. Another form of microgranitic groundmass showing idiomorphic feldspars in a quartz cement is rare. The feldspar of the groundmass is nearly exclusively potash feldspar, while acid plagioclase is very seldom found. The somewhat larger crystals that form a transition to the phenocrysts, may show microcline twinning. The size of the grains is on an average from 15 to 30 μ; in the finest forms even to 10 μ.

According to the combination of phenocrysts several types may be distinguished: viz. quartz phenocrysts, either occurring by themselves or together with potash feldspar phenocrysts; potash feldspar together with plagioclase phenocrysts; quartz, only in connection with plagioclase phenocrysts, or only feldspar phenocrysts.

Of the first type we know a representative collected below the mouth of the Dalbana creek, Kabalebo river (V. 3512). It is a rock of strongly weathered appearance, yellowish-brown, discoloured under the weathering-crust, and with a dusty brown centre. Only sparse quartz phenocrysts and traces of dark minerals may be macroscopically recognized. Microscopically it appears that no feldspar phenocrysts are present. We see in the groundmass flakes of muscovite (primary?), with accessory traces of biotite and some ore. Consequently it is a very acid rock. Closely related are the quartz porphyries with phenocrysts of quartz and potash feldspar, and those which contain plagioclase phenocrysts in addition. Of the first form we know a representative from the Wilhelmina mountains (Y. 221, 221 B), of the last form from the watershed between the Gran-rio and the Lucie river (Y. 144) and from the Lucie river (Y. 273). The colour of the sample varies considerably. In the groundmass fine slabs of biotite and grains of epidote occur, and sometimes as accessoria: ore, zircon and apatite.

Y. 273, in contradistinction to the other samples, shows some parallel texture, which is evident from the equal direction of the phenocrysts and still more from the dark components of the groundmass. Biotite together with some grains of muscovite, epidote and ore is partly

[1]) E. H. M. Beekman. **63.** p. 108.

arranged in strings. This muscovite seems to be of primary nature. Some pyrite occurs. In places the ore shows rims of titanite. Rocks or approximately the same composition (V. 1646, 1647, 1652) occur near the Tompi creek (tributary of the Suriname river). They possess hardly any potash feldspar phenocrysts (except V. 1647); the last rock shows biotite of a greenish-brown colour as phenocrysts and also muscovite crystals. The muscovite is often penetrated by a system of fine cavities; we may savely assume corrosion here. The cavities are of the same kind as has been described regarding the muscovite of the granito-diorites (p. 185). In some places the muscovite is united with biotite in such a manner that primary nature for both becomes probable. These rocks of Tompi creek are mentioned in Du Bois's list of rocks as "Porphyrischer Mikrogranit" and "Quarz-armer Porphyr" [1]). Signs of pressure are of very little importance; undulose extinction of the quartz and feldspar phenocrysts may be present; it is questionable whether we have to do with a secondary phenomenon here.

Immediately related to these quartz porphyries are others which besides quartz show exclusively or chiefly plagioclase as phenocrysts. They deflect from the characteristic quartz porphyries, but they are not related to the quartz porphyrites either, for the composition of the plagioclases is always acid and chemically these rocks can hardly differ from the former. We have samples from the central Wilhelmina mountains (Y. 212, 214, 215, 215 B, 217, 226, 226 B), and from the area between the East river and Table mountain. In Y. 215 B we also see biotite phenocrysts. The plagioclases (albite-oligoclase to oligoclase-andesine) are partly fresh, partly filled with grains of sericite and epidote. This may even go so far that the plagioclases are only found as pseudo-morphs filled with secondary products (Y. 215 B, 217). These secondary products are also to some degree present in the groundmass. Y. 215 and 212 show a not inconsiderable percentage of biotite in the groundmass. As accessories occur titanite, apatite, ore and zircon. These accessories are relatively coarse, compared with the groundmass; this applies especially to the idiomorphic apatite, which forms prisms, the oval zircon, and the titanite which may show the well-known envelope sections, while ore, as octahedra of varying size, may occur in the smallest dimensions. The same type as occurs in the Wilhelmina mountains also appears near the watershed with the Amazon, in the extreme South-West of the Colony (V. 1257). It has already been described by Grutterink [2]). The quartz is very strongly corroded (Pl. 27 fig. 3). The phenocrysts, as opposed to those of the preceding rocks, show signs of great pressure: strong undulose extinction. The groundmass is again the same. Judging from the rectangular sections, the potash feldspar may show some idiomorphism. Quartz porphyry with the same combination of phenocrysts we know also on the Sara creek (V. 1578).

Related to these are some porphyries that show no clear quartz phenocrysts but only feldspar ones. A red rock from the Upper Lucie river (V. 3475) shows some feldspar phenocrysts of millimeter size in a groundmass with clearly parallel texture, as strings of dark minerals have a parallel course. Microscopically both acid plagioclase and potash feldspar phenocrysts seem to be present, the latter with microcline-twinning, but the difference can hardly be traced, as in both the twinning is vaguely developed, and secondary scales of sericite occur. The phenocrysts are oriented parallelly and the groundmass, in so far as it is composed of fine scales of biotite, streaks of ore, etc., is arranged in curves round the coarser crystals. A second rock, is likewise from the Lucie river (V. 3473). The groundmass of quartz and potash feldspar is extremely fine, with an average of 10—15 μ of the grains. Another rock has been described before [3]), as orthophyre. The plagioclase phenocrysts have a very acid composition, as they refract less strongly than the surrounding balsam; consequently it cannot be andesine either (as Grutterink says). Possibly the index of refraction decreased at the formation of secondary epidote and sericite. The groundmass is still finer than with the previous rocks, the grains being much smaller than 15—10 μ. The separate components appear only on close examination viz.: potash feldspar more feebly refractive than the balsam, and quartz, which under diminished intensity of light clearly stands out against it by higher relief. Both components are present in nearly the same quantity. The potash feldspar is locally indistinctly lath-shaped, which is especially clear in case of strong magnification between crossed nicols. The quartz polarizes equally in spots and some granophyre is probably also present. As quartz is of much importance in the groundmass, this rock cannot be entitled orthophyre; it is equivalent to the other quartz porphyries that have no quartz phenocrysts.

With these are related two rocks of the Middle Courantyne river (Y. 334, 335), characterized by a somewhat more basic composition. They show in a dark grey groundmass a number of feldspar phenocrysts, having a size of 4 mm. The samples are rich in black spots which partly suggest amassments of very fine-grained biotite. Some hornblende prisms of 7 × 2 mm. occur (in Y. 335). Microscopically numerous plagioclase phenocrysts appear to be present, and practically no quartz phenocrysts, or none at all (Y. 335). The plagioclase is beautifully idiomorphic, partly clearly twinned, having a composition of oligoclase-andesine and even a more basic one, up to andesine. Traces of zonal structure are present. Remarkable

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1) G. C. Du Bois. **46.** p. 21, No. 182, 188, 183.
2) J. A. Grutterink. **73.** p. 197.
3) J. A. Grutterink l. c. p. 198.

is the large number of idiomorphic epidote microlites that occurs in it. Primary genesis is probable. At any rate, the latter cannot have been formed by separation of the anorthite-molecule from the plagioclase, for the composition of the latter is not subject to variation, whether the epidote does or does not occur. The same epidote microlites are profusely present in the groundmass; not only being of small dimensions as in the plagioclase, but also bigger, up to 0.15 mm. length of the orthodomatic zone; some crystals are still longer in which case they are lath-shaped. These larger crystals are often amassed with biotite, and show idiomorphism towards the mica, and corrosion on a small scale; in short they are the equivalent of the epidote that will be described as primary with regard to the granitodiorites. Many scales of brown-green biotite are present and are locally amassed together with the epidote, moreover ore octahedra, some apatite and sometimes also non-idiomorphic titanite are met with. The percentage of dark minerals is much greater than in the previous rocks. The chief components, however, remain quartz and potash feldspar in micrgranitic relation. The size of both is on an average 25 μ, locally much larger. Some larger quartz aggregates occur. On the whole these rocks are more basic than the foregoing ones, on account of their large percentage of less acid plagioclases as well as of their considerable percentage of dark minerals. This type approaches to the dacites or quartz porphyrites. However, they deviate from the typical representatives of these, possessing much potash feldspar, while apparently plagioclase is of little importance in the groundmass.

II. *Quartz porphyries with a groundmass rich in lath-shaped feldspars.*

The groundmass is developed as oblong or lath-shaped feldspar crystals, while the space between the laths is filled up with quartz, which may be partly intergrown with feldspar.

Of this type we possess, three samples collected on the Gran-rio, immediately below Kaboeba dam (V. 1861, 1862, 1863). The fine-grained, almost dense rock shows in the sample hardly any of mineral grains, and no phenocrysts at all. It has a red-brown colour, in which we may observe vague spots and streaks of very fine, dark minerals. Some veins filled with epidote and narrower than 1 mm., cross the rock in elaborate ramification. Besides, on fissures appear amassments of chlorite (see V. 1861). Not the least parallel texture is present. The lath-shaped feldspars of the groundmass are partly plagioclase, partly potash feldspar. The plagioclase is very acid (abt albite-oligoclase) and twinned according to the Albite-law, while polysynthetic twinning can now be clearly traced along the whole length of the laths, now again is irregularly developed. The laths are maximally 0,45 mm. long, mostly half as long or still shorter. The outline is often interrupted by the adjacent grains of quartz. Besides the acid plagioclase occurs lath-shaped potash feldspar of the same size. It is remarkable that on close examination and strong magnification it shows extremely delicate twinning, and appears to be microcline (see for this twinning especially D. D. 1891 — V. 1862). Besides there also occur somewhat coarser irregular crystals of microcline, which are not phenocrysts, however. There is much secondary epidote, and there are many chlorite-nests. Both together are present to such a percentage that the original mineral combination can by no means have provided all the material, even though dark minerals have possibly been transformed. The veins of epidote, for that matter, point to secondary supply of material. Irregular pieces of dusty titanite, are present which have probably originated from the ore. The rock agrees with phenocryst-free quartz porphyry.

III. *Quartz porphyries with granophyric groundmass.*

Of this type we possess two representatives. The first is from the Central Wilhelmina mountains (Y. 219). The fine-grained, violet-grey rock shows no phenocrysts at all, and on examination appears to be finely crystalline. Microscopically we see some acid plagioclase phenocrysts, with indistinct polysynthetic twinning, and partly filled with scales of sericite. There are no quartz phenocrysts. The plagioclase phenocrysts decrease in size and pass gradually into oblong and lath-shaped crystals, which belong already to the groundmass. It is remarkable that quartz penetrates the small plagioclase crystals with indented strings of quartz-material which are partly arranged parallel to the planes of intergrowth of the lamellae. This quartz-material polarizes evenly and together with the plagioclase forms an abnormal type of granophyre. Oblong potash feldspars, having no clear crystal-shape also occur. These show locally very fine microcline twinning, and may be likewise penetrated with quartz material. It seems as if potash feldspar forms the minority with regard to plagioclase. All the lath-shaped crystals are situated in an extremely fine mass of granophyre of quartz and feldspar. The quartz of the latter is directly connected with that penetrating the laths of feldspar, as shown by the equal extinction. Further we recognize in the groundmass greenish scales of biotite, octahedric ore and some prismatic needles of apatite. Secondary epidote aggregates and grains occur, partly arranged in veins.

A second representative we possess from the Gwitappo fall Tapanahony (V. 1056). The sample is fine-grained, and has motley spots. Here and there we can recognize an occasional quartz phenocryst with the aid of a magnifying-glass. Microscopically we see an irregular granophyre of quartz and potash feldspar; irregular owing to the change in dimension of the quartz-fields. Locally occur lath-shaped plagioclases, partly surrounded by a rim of granophyre, and also some coarser plagioclase crystals which, however, are no phenocrysts. Especially irregular is the structure in one of the thin sections of the same rock (D. D. 921), where we see locally many lath-shaped plagioclases of moderately acid composition, lying in granophyre. Remarkable are the zeolites which play an important part in the construction of this rock. They are radially built, fibrous aggregates, of at least three different types of zeolite, which may be distinguished by their widely differing refraction and double refraction. They partly supersede the other minerals, partly conform to them, especially where they adjoin plagioclase-laths. Some biotite and ore are among the other recognizable components.

As we mentioned already a large number of the Surinam quartz porphyries have undergone secondary changes. These are chiefly the occurring of sericite in the groundmass, whether or not accompanied by grains of epidote and scales of chlorite. The potash feldspar phenocrysts have been little influenced. The plagioclase in that case has approximately the composition of albite. Grains of epidote or scales of sericite have nestled themselves more or less profusely in it, so that it is obvious that the anorthite molecule has been consumed. These changes entail that the porphyries have macroscopically and microscopically an unaltered habitus. Of these quartz porphyries we know a number that show nothing new with regard to the preceding ones. Their groundmass is mostly microgranitic.

They come from the Gros placer (V. 146), from Ballijn Soela, Suriname river (V. 1531), from the Dabikwentrail (V. 1536), from the neighbourhood of the Witlage placer (V. 2247), from the Upper Marowyne river (V. 447) and from the Gran creek (V. 1007).

The geological behaviour of the quartz porphyries.

Half of the quartz porphyries, known at present, have been collected by myself, we know, however, very little of their geological behaviour.

In the field, the quartz porphyries show several forms. Sometimes, they are rounded off blocks of 1 m^3. size and still larger, resembling weathering forms of granite, e.g. on the watershed between Gran-rio and Lucie river (Y. 144). If the blocks are large, there may appear vertical slits of some dm. depth and breadth, separated by sharp walls and caused by erosion. They are deeper and the partitions sharper than those of the correlative weathering-furrows in granite. Again, other rocks crumble into sharp-edged lumps. In the Central Wilhelmina mountains we meet with a whole series of different types, lying together in loose lumps, at the Western foot of top 1280; their groundmass is microgranitic as well as granophyric. Their relation to the neighbouring granites is not clear.. Their variable appearance, agreeing in some cases with that of hornfels, causes confusion in the field. Types with fluidal texture showing itself by ribs of different resistance, occur. These rocks appear in the midst of an extensive area of granite, and this suggests that the porphyries either break through the granites or that they are a facies of the granites. The last supposition gathers some force if we remember that there appear in the Wilhelmina mountains aplitic granites which approach the quartz porphyries, now with granular groundmass, in which sometimes coarse quartzes call forth an almost porphyritic type, now again with granophyric structure. The fact however, that acid porphyry-tuffs take some part in the upbuilding of the Roraima formation makes it not improbable that there are quartz porphyries of later age also.

That the quartz porphyries may form large masses is proved by a hill of a few hundred m. in height, which we passed on our trail from the East river to the Table mountain. On the slopes and on the top, many blocks of quartz porphyry are found, so that the hill also must largely consist of it.

On the Courantyne river, above the Wonotobo falls, near "Eight-Mile island" across a distance of more than 6 km. an uninterrupted exposure of quartz porphyries occurs, as far as I could ascertain in my hurried passage there. They are the relatively basic representatives, described on p. 143 (Y. 334, 335). We see again and again how they are interrupted by dykes of diabase, which send out lateral apophyses into the porphyry. So the porphyries are older than the diabases. The extensiveness makes it not improbable that we have to do with a large sheet of quartz porphyry, resting there on the granites, or that the porphyries are a facies of the granites. The latter is not improbable again if we consider that in the porphyries epidote occurs which may be compared with the epidote that will be described as primary with the granitodiorites, also of the Middle Courantyne area. Scrupulous examination on the spot itself, is desirable however.

As the engineer G. Duyfjes informed me, the mode of occurrence of a quartz porphyry in the neighbourhood of the Witlage placer (West of Bonidoro, Marowyne river) may be explained as a dyke, some metres wide, cutting weathered schists; the latter dip steeply and belong to the phyllite- and graywacke groups, still to be discussed. So the quartz porphyry is of later age than the schists.

What we know about the relation to other formations is consequently very little. It is by no means certain whether the porphyries all belong to the same period of intrusion. There is however no reason to suppose that they show the geologic relation which Harrison assumes for British Guiana, viz. that the porphyries should be older than the granitodiorites and of later age than the gneisses, and that nearly all schists should be connected with the porphyries or be derived from them.

The porphyroids.

About this group we may be short in spite of the variation in habitus. They are mostly rocks which originally must have had the same composition as the above mentioned quartz porphyries, but which have changed more or less strongly. In the groundmass scales of sericite are always present more or less profusely, often accompanied by some percentage of chlorite, or grains of epidote; it is obscured by dust of various sorts. The plagioclase is always approximately albite and shows scales of sericite etc., which often goes so far that we can only see the outlines, whereas the plagioclases themselves are wholly superseded. Still, we can often see something of the twinning between the secondary products. Occasionally the vaguely recognizable plagioclases are divided into several fragments separated by the groundmass, which has undergone the same changes again.

Secondary veins of quartz and quartz-nests often occur. It appears that the groundmass most often had micrographic composition.

Remarkable among these rocks is the great number with only feldspar as phenocrysts, and among these plagioclase preponderates. In this respect they resemble some quartz porphyries. Of frequent occurrence are also types in which the phenocrysts are visible only microscopically, in which case they are very insignificant. These rocks can be recognized as porphyroids on close examination only, and we should be apt to take them for fine-grained sedimentary schists e.g. tuffs etc. In the sample they may be massive or show parallel texture. The massive types are not sharply separated from the quartz porphyries, and with many of them we doubt whether we must group them with the latter. That they need not be a result of dynamo-metamorphism, is proved by the massive types, while microscopically the secondary mica shows no parallel orientation. In this respect they agree with some typical appearances of porphyroid outside Surinam, e.g. that of Mairus (Belgium) and of the Schreckental near Treseburg, Harz.

Other types show parallel texture and vary greatly in habitus. Sometimes phenocrysts may be recognized in the dense, greyish groundmass (V. 2205), then again there is a tendency towards parallel splitting with greyish or lighter tint (V. 496, 583, 584) or they are greenish with felsitic habitus (V. 77).

Others again are clearly schistose. On the wavy splitting-planes they show a silky lustre (sericite). If this is strongly developed, they may be entitled sericite-schists (V. 1394, 1395, 1533, 1534). Accordingly, Martin entitled such rocks of the Suriname river mica schists. Microscopically the parallel texture becomes apparent by a trend towards equal orientation of the scales of mica, strings of epidote-grains and dust-masses of various sorts (see the thin sections of V. 77, 496, 574, 1394, 2205, 2230). The sericite occurring in the vaguely recognizable plagioclase-remnants crosses the latter with the same trend. Chlorite may occur in changing quantity.

Porphyroids we have from the Suriname river (V. 1394, 1395, 1434, 1534), from the Sara creek (V. 1584, 1782), from the neighbourhood of Witlage placer (V. 2205, 2230), from the Upper Marowyne (V. 449), from the Gran creek (V. 994, 1011), from the Lawa (V. 496, 574, 583, 584), from the Lely mountains (V. 877, 878, 900), from the Lower Tapanahony (V. 75, 77, 1044, 1045), from the extreme upper course of the Commewijne (V. 1736) and from Toeval placer (V. 149).

The geological behaviour of the porphyroids.

As has been said, part of the porphyroids, viz. the massive types, cannot be separated from the altered quartz porphyries and undoubtedly they will also be geologically related to the latter.

With the schistose types, the formation of secondary products apparently took place during or possibly by the cooperation of stress. The pressure was certainly not of great importance, for examples of rolled-out phenocrysts, as are often recorded to occur elsewhere with types that pass into sericite schists and gneisses, are not known among the Surinam rocks.

It is not impossible that part of these schistose porphyroids occur included in the schists of the basal complex and that they are older than the massive porphyroids and the quartz porphyries.

Silicified felsites.

The rocks from Toeval placer near the halting-place of Gros placer on the

Colonial railway are very hard, dense and motley with splintery, sharp-edged fracture (V. 147, 2280, 2281). They are greenish, brownish, or red and black, the colours being distributed in such a way as if we had to do with fluidal texture (see V. 2281). Veins of quartz cross the samples in all directions.

Microscopically they show extremely fine quartz mosaic with fine sericite-like material and brownish pigment. The texture is very variable in the same thin section, and also the quantity of mica and pigment strongly varies locally.

Though microscopically the seemingly fluidal texture which one of the samples suggests, comes very little to the fore, we have probably to do here with silicified felsites.

Granite porphyries.

Closely related to the quartz porphyries are some granite porphyries. Their geological behaviour is unknown; it may be that they occur in dykes. They differ from the quartz porphyries, on account of larger dimensions of the components, especially those of the groundmass, while the phenocrysts are mostly much more numerous. The groundmass may be microgranitic or indistinctly hypidiomorphic, or granophyric.

Rocks with microgranitic or indistinctly hypidiomorphic groundmass are known from the Sara creek (V. 1592, 1593), from the Locus creek (tributary of the former, V. 1634), from the Suriname river (V. 1532) and from De Jong placer (on the Colonial railway, V. 155). In the sample they are fine-grained, massive, finely spotted rocks, which mostly show small phenocrysts of quartz and feldspar.

Microscopically we see phenocrysts of acid plagioclase (approximately oligoclase) with or without quartz phenocrysts. The plagioclases tend towards idiomorphism; they are partly replaced by masses of sericite. The quartz phenocrysts may be very numerous, beautifully bipyramidal and partly strongly corroded; sometimes they are irregular quartzes, which through cracks are divided into fields with different polarization (V. 1592, 1593). This may be a result of protoclasm, but to some extent certainly also of cataclasm (V. 1592). Occasionally potash feldspar may occur as phenocryst (V. 1634), showing microcline-structure and regular intergrowth with patchy albite of such proportions that we can hardly speak of microperthite any longer. Biotite may also occur as phenocrysts (V. 1593). The groundmass consists mainly of quartz and potash feldspar, acid plagioclase, mostly in non-idiomorphic grains. It is the coarser equivalent of the microgranitic groundmass of the quartz porphyries. Sometimes the quartz shows a tendency towards bipyramidal shape and the acid plagioclase towards oblong forms (e.g. V. 1532). The biotite is always altered and chloritized, which goes hand in hand with the formation of epidote. Moreover, sericite and secondary muscovite appear profusely. As accessories appear ore, and apatite; in V. 1593 also yellowish isotropic spots of altered orthite; this last mineral points to relationship with the granito-diorites.

Closely related to the preceding rocks are some whose groundmass consists chiefly of an extremely delicate granophyre of quartz and potash feldspar, often radiating from the quartz and feldspar phenocrysts. How little importance may be attached to these differences in structure is proved by a rock from the Sara creek (V. 1594) which occurs there together with other rocks that show a microgranitic groundmass (the already discussed numbers V. 1592 and 1593). We meet similar types also elsewhere at the Sara creek (V. 1570, 1576), at the Tompi creek (V. 1648) and in the neighbourhood of the Gran creek (V. 1014). A rock of our trail East river—Table mountain (Y. 256, see map V) locally contains fluorite. This does not make the impression of having been supplied secondarily.

Porphyroids derived from granite porphyries.

Just as the quartz porphyries pass secondarily into porphyroids some rocks of this kind have been formed from granite porphyries.

We have only samples at our disposal without geological data. Most typical is a rock from the Lawa (V. 582). The sample is very fine-grained, green-grey, with clear parallel texture;

it splits with parallel planes. With a pocket lens we can here and there distinguish phenocryst-like feldspars. Microscopically it shows a structure which at first sight approaches very nearly to mylonite structure. Numerous plagioclases, often splinter-shaped, lie in a much finer, turbid groundmass, which is rich in scales of mica, grains of epidote, and dust. The plagioclases have again assumed the composition of albite by demixture and are crowded with grains of epidote and sericite; however, twinning may still be recognized. The forms are sometimes approximately tabular and idiomorphic; many crystals, however, have broken into several fields, between which the groundmass penetrates; others again are but fragments. Besides there occur here and there groups of quartz-grains that are joined in such a manner as to represent together crushed quartz phenocrysts. The groundmass, in some places where the secondary products occur less frequently, appears to consist of a fine mosaic of quartz grains and much more feebly refractive material, potash feldspar. Sericite and chlorite are present as scales. A grain of apatite may be recognized. There is clear parallel texture. This does not only appear from the equal orientation of the feldspar remnants, but even more from the scaly mica and the grains of epidote; the latter are arranged in strings, which wind themselves between and round the feldspars. The groundmass sooner reminds us of that of the quartz porphyries, the numerous phenocrysts rather suggest granite porphyries. Other porphyroids derived from the granite porphyries, are two samples from the Sara creek (V. 1582, 1583) and the De Goeje mountains (V. 626). They are poor in phenocrysts, the groundmass however is more closely related to that of the granite porphyries. The profuse secondary sericite implies parallel texture, at least so with one of the rocks (V. 1582).

THE LAMPROPHYRE DYKES.

INTRODUCTION.

Among the dyke-rocks cutting the granitodiorites of the basal complex, there are a small number of lamprophyres. They have never been described before. For some of the rocks the dyke-shape was ascertained in the field, during our Expedition to the Wilhelmina mountains; for others the same became evident from older data; for several other rocks the identification as lamprophyres only was the result of microscopical examination and the habitus of the sample. Microscopically the Surinam lamprophyres are divisable into various groups. The petrographical description comprises the following groups.

a. Kersantites.

b. Odinites.

c. Malchites and allied rocks.

In nomenclature it has been our aim to take into account as far as possible the classification, which is used for this very variable group elsewhere. After the petrographical description we shall discuss the chemical composition of a few of the rocks and compare them with lamprophyres from other places. We shall conclude with what we know of their geological behaviour.

PETROGRAPHICAL DESCRIPTION.

Kersantites.

We know a couple of kersantites hardly differing from each other, from the Suriname river, Toemaripa soela (Y. 58) and the Gran-rio between Stonehoekoe and Awa dam (Y. 90). They are biotite hornblende kersantites. A rock from the middle Courantyne is a biotite pyroxene kersantite (Y. 332). Finally we know a rock from the Coppename river (V. 2374) that probably might be called biotite kersantite.

The kersantites of Toemaripa soela have a very fine-grained almost dense groundmass of a grayish colour, in which we can distinguish sparse hornblende laths of a few millimeters in length. Microscopically we see plagioclase, biotite, hornblende, ore and a fine granophyric intergrowth of quartz and potash feldspar (Pl. 27 fig. 5 and 6). The plagioclases vary in size, in the thin section there are a few larger than ½ mm. and we might call them phenocrysts, but transitions down to 0.15 mm. and still less appear. The plagioclase is invariably distinctly idiomorphic, surrounded by xenomorphic quartz and potash feldspar. The crystals are flattened according to 010. Many sections are short rectangular, or flattened and with two faces at each end; these are sections perpendicular to the zone 010 : 100. Others approximately cut parallel to the face 010 are parallellogram-shaped. The crystals have a more or less zonal structure, combined with a few polysynthetic lamellae; the latter intersect the zones. These properties appear even in the smallest plagioclases. A few plagioclases are bent and broken; this is protoclase, for the granophyre penetrates into the cracks. The index of refraction points to labradorite in the nucleus, and to oligoclase-andesine in the rim of the zonal built ones. The plagioclases are unmodified except the centre of a few of the larger ones, which is filled with grains of epidote and fine calcite-patches. The hornblende is also indistinctly porphyritic. Several lath-shaped crystals, some mm. in length, may be regarded as phenocrysts on account of their size. In cross-sections they are hexagonal, the prism-zone, however, is hindered by the larger plagioclases; the crystals are often broken and the pieces removed from each other. The hornblende is corroded and the corrosion cavities are filled with fine biotite scales. This goes on to such an extent, that a considerable portion may be replaced by the biotite. Some hornblende crystals are twinned. The colour varies from a yellowish-green to a greenish-brown, sometimes with an olive-green tint. Biotite is present in innumerous fine patches; they partly arrange themselves around the hornblende, hence the biotite is clearly younger. The colour varies from yellowish-brown to greenish-brown. Ore is present in minute octahedrons never larger than 0.2 mm.; demixture of titanite is visible at the sides, so that we are concerned with titano-magnetite. The granophyric intergrowth confines itself to the space left by the minerals mentioned, as last crystallization. The intergrowth is extremely fine; the structure is the same as that of micro-pegmatite. In favourable cases the refraction of the feldspar may be comparable with that of balsam. It appears to be potash feldspar. The other mineral of the intergrowth is quartz: there are pieces of quartz visible here and there, which may be recognized by means of interference figures and at the same times participate in the intergrowth. Around the plagioclase we often observe intergrowth radiating from it and there is no difference in refraction between the quartz and the rim-zone of the plagioclase, since the latter is oligoclase-andesine.

Of the minerals mentioned, plagioclase is present in the largest quantities, biotite comes next, then hornblende and then the intergrowth, while ore occupies the last place. The rock is characterized by the combination plagioclase, biotite and hornblende, with pretty well pan-idiomorphic structure.

Short apophyses branching off from the main-dyke show some deviation. Microscopically they are distinguished by a greater percentage of quartz. There are numerous easily recognizable pieces of quartz up to 0.25 mm. in the intergrowth behaving xenomorphically towards the plagioclase. The plagioclase has been copiously replaced by zoizite-like dust, epidote, and colourless mica; while independent pieces of epidote are also found scattered in the thin section. The mica is coarser, of a deeper green colour, with a single pleochroitic halo. The hornblende is practically negligible. The larger quantity of quartz may possibly be ascribed to the nearness of the contact.

As we have already stated the kersantite of the Gran-rio is approximately of the same composition (Y. 90). The grain is coarser than in the kersantite of Toemaripa, which corresponds with the greater dyke-breadth. Microscopically there are some differences. The plagioclase shows no ill-defined phenocrysts, is invariably lath-shaped, approximately 0.2 to 0.7 mm. long and 0.2 mm. broad, polysynthetic and sometimes of zonal structure. The index of refraction points then to a composition of labradorite in the core to approximately oligoclase in the rim-zone. The greater length of the plagioclases makes us think of the feldspars of the diabases. The potash feldspar occasionally shows a new feature: besides granophyric intergrowth a few non-intergrown patch-shaped pieces, of a length up to 0.2 mm. occur, having typical microcline-structure. In the literature on the subject this structure is not mentioned for kersantites. Titanite appears again as demixture around the ore, but in addition to this, independent pieces often occur. Hornblende with a bluish-green tint, not as phenocrysts, is sparse. Unlike the preceding rock, apatite is found here: long needles with cross-fractures. No pressure-phenomena.

Another type of kersantite has been collected in the neighbourhood of the Plum- and Twirl-round rapids, Middle-Courantyne (Y. 332). The fresh rock has a dull black weathering crust. Sparse phenocrysts of plagioclase up to 1½ cm. in size, but usually of 5 mm. are present. By the aid of a magnifying glass gray and black particles of half a millimetre may be distinguished: feldspar and coloured minerals. A few black sparkling leaves point to biotite. The sample looks like a basic rock with sparse phenocrysts. Microscopically we observe plagioclase, green diopside, brown biotite, green hornblende, quartz, ore and unidentified needles with traces of potash feldspar (Pl. 28 fig. 1). The oblong, sometimes lath-shaped or isodiametrical plagioclase is idiomorphic towards interstitial quartz but is not clearly older than the coloured minerals. Some plagioclases are larger, distinctly lath-shaped and 2.1×0.37 mm. in size. The lamination is polysynthetic according to the Albite-law, occasionally crossed by some Pericline-lamellae. Many fine rounded off-granules of ore and further numerous apatite needles are enclosed. The composition is that of andesine. Diopside and biotite are present in equal quantities, the green hornblende is present in smaller quantities. The coloured minerals are abundant. Small pieces of diopside are granular, the larger ones oblong-shaped but with an irregular patchy outline. The maximum length is parallel to the lines of cleavage. The extinction of about 40° points to a magnesium-diopside. The colour is very light-green with some pleochroism. Ore grains are often enclosed. As the diopside is frequently intergrown with patchy biotite and also with the hornblende, all have approximately contemporaneously crystallized. The light green hornblende is, like the pyroxene, patchy. The extinction is about 20°. Ore is copiously enclosed. The biotite shows strong pleochroism from bright yellow to chestnut brown. The shape is patchy, only the basis being developed. Apatite needles are often enclosed. Quartz is present in considerable quantity. Plagioclase crystals are sometimes mutually hindered at the edges by quartz. The quartz is xenomorphic towards the coloured minerals; ore, granules of pyroxene and apatite needles are enclosed. Ore is present in fairly large quantities, the larger pieces irregular, the smaller as octahedrons. Some pyrite may be enclosed in it. Traces of xenomorphic potash feldspar are to be seen here and there. The rock is quite fresh, and without pressure-phenomena.

A rock that is very possibly a biotite kersantite, is to be found among the material collected by Essed on the Coppename river 200 m. to the N. of the mouth of the Weri creek (V. 2374). The sample is massive, fine-grained and of a gray colour and non-porphyritic. A contrast between the dark and light minerals may be distinguished; the latter are regularly distributed. Biotite may be recognized here and there by means of a magnifying glass. Microscopically, the rock shows biotite, much epidote, scattered, short lath-shaped plagioclase, quartz, ore and apatite. The biotite is patchy, rarely longer than 0.3 mm. The base is developed here and there. The colour varies from a bright-yellow to a greenish-brown. In places the biotite is accumulated to clusters together with the epidote. The latter strongly reminds us, by its conduct of the epidote of the granitodiorites regarded as primary (see p. 188). The short prismatic crystals are developed according to the orthodomatic zone and cut off the fresh biotite in places in such a manner that we may presume the epidote to be of a primary nature. Many crystals, however, are also unevenly granular. The epidote is light yellowish-green, with feeble pleochroism. The polysynthetic plagioclases are now decidedly oblong-shaped, now short. The longest attain to a seize of 0.6 × 0.08 mm. Generally they are clearly idiomorphic, although sometimes irregular towards quartz. Zonal structure is now distinct, now not developed at all. Judging from the index of refraction, the composition appears to be andesine-labradorite. Potash feldspar is entirely lacking. Primary quartz is present in larger quantities than in the preceding kersantites, and than in most rocks of this group. The quartz fills cavities among the other minerals as last crystallization. Undulose extinction betrays slight pressure action. Unmodified ore is abundant as an accessory, its octahedral shape pointing to magnetite or titano-magnetite. Very long and fine apatite needles, with numerous cross-fractures, are common. Other accessories are not found.

The rock may be classed under biotite kersantites. It differs from the two preceding kersantites by its larger percentage of quartz, its lack of hornblende and potash feldspar. The appearance of epidote, provided it is primary, is very remarkable.

Odinites.

Of this group we have but one representative, namely that from Suriname river near Goddo (Y. 65).

The sample shows a thin, shining black weathering crust, and a dark bluish-gray colour. Some black amphibole-laths of 3 mm. in length are present as phenocrysts, in a groundmass so fine that separate minerals can hardly be distinguished with a magnifying glass. Further minute specks of sparkling pyrite are to be seen. Judging from its appearance we should take the sample for a fine-grained diabase. Microscopically we observe plagioclase, hornblende, ore, quartz, biotite and secondary epidote. The primary minerals occur in this order quantitatively. Hornblende is present as phenocrysts. They are oblong-shaped, with but a moderately developed prism zone. The pleochroism varies from yellowish-green to greenish-brown in the centre and bluish-green at the margins. By the side of hornblende we notice plagioclase phenocrysts, for the greater part filled with secondary epidote and mica-scales. Further there are some phenocryst-like masses filled with uralitic hornblende. The groundmass has the above-mentioned composition. The plagioclase is oblong-shaped; or it is shorter with a zonal structure and in that case also beautifully idiomorphic. The plagioclase of the groundmass is invariably smaller than 0.3 mm. The composition varies from andesine to labradorite. The hornblende-laths are usually shorter than 0.4 mm. and are about 0.05—0.08 mm. broad and distinctly idiomorphic. The colour varies from yellowish-green to green. The laths are present in very great numbers, constituting, we might say, $^1/_5$ of the whole mass, lying all jumbled up (see Pl. 28 fig. 2). It is clear that we are dealing with a primary hornblende. Biotite of a greenish-brown colour is almost negligible. Ore of an octahedral shape is sometimes intergrown with pieces of pyrite; it is probably titano-magnetite. Epidote is of importance as grains heaped up in the groundmass or in the plagioclase-phenocrysts, occurring in that case in the centre. Quartz is not of much importance but varies much in quantity in places; is is very clear. As cavity filling between the older minerals, it sometimes envelops the end of a plagioclase-lath and in this way betrays its primary character. A few quartzes are divided by cracks into fields, polarizing undulosely or separately. Potash feldspar is wanting or possibly there are hidden traces of it in the groundmass. The structure is hypidiomorphic-granular.

Malchites.

We can discuss the three malchites, found in places far distant from each other, at the same time, for they have practically the same composition. They come from the Gran-rio (Y. 110), from the Coppename (V. 2402) and from the Middle Courantyne (Y. 338).

In the sample the rocks from Coppename and Gran-rio are very fine-grained, massive, of a grayish colour; so fine that the components are hardly distinguishable from each other. The rock from the Courantyne is very fine-grained, almost dense, and diabase-like. Microscopically, it appears to be rich in green hornblende and biotite, with much epidote as coloured minerals, and further plagioclase and quartz, with ore, apatite, and titanite as accessories. The coloured minerals are present in smaller, but not much smaller quantities than the colourless ones, while hornblende exceeds biotite somewhat. Hornblende may be indistinctly porphyritic, a few crystals exceeding the rest in size, up to 1.5 × 0.3 mm. Most of them, however, are much smaller; those in the groundmass averaging 0.4 mm. in length. The hornblende is oblong-shaped, with a well-defined prism-zone, while the cross-sections show the well-known cleavage. Endplanes are wanting. Others are shorter and have a less regular shape. The pleochroism is from yellowish-green to grass-green, with a touch of a bluish-green tint. Larger crystals sometimes exhibit an irregular fibrous structure in the centre. All the hornblende, however, is fresh and of a primary nature. Here and there, there are accumulations of the larger individuals, otherwise they are scattered about. The significant, but not so plentiful biotite is generally smaller than the hornblende crystals, and phenocrysts are wanting. Traces of the base are visible here and there. The pleochroism varies from bright yellow to greenish-brown. Pleochroitic haloes occur. The biotite is perfectly fresh. The latter fact is of importance in connection with the abundant epidote. The epidote crystals sometimes have a well-defined shape (V. 2402) and are developed according to the orthodomatic-zone. They often intersect biotite crystals and clusters of crystals, as the primary epidote in the granitodiorites (see p. 188). The longest attain to 0.5 mm. A few coarse pieces are of irregular shape and are twinned. Most of them, however, are much smaller and in connection with their smaller size, colourless. Fine cavities and channels appear up to the centre of the crystals. Plagioclase and quartz are the colourless minerals. Potash feldspar is entirely absent. The plagioclase is present in larger quantities than quartz, but the percentage varies locally and in the different rocks. The plagioclase is, in places, short lath-shaped, with a maximum length of 0.5 mm., the average, however, being 0.25 mm. The laths have a well-defined idiomorphic shape. The polysynthetic twinning is often disturbed by zonal structure. A basic nucleus is clearly separated from the more acid rim zone. According to the index of refraction the composition is oligoclase at the margin, in the nucleus, however, andesine-labradorite or, in very small plagioclases, still more basic. The clearer quartz is distinctly last crystallization. Fine apatite-needles as inclusions are often occur. Undulose extinction points to trifling pressure-action. Of the accessories, the octahedral ore must be mentioned in the first place, magnetite or titanomagnetite, sometimes surrounded by a rim of titanite. Some titanite is present as pale, pleochoitic pieces of irregular form. Apatite may be present in strikingly large quantities in the form of long, often broken needles.

It is not impossible that a very fine-grained, massive hornblende, biotite and secondary epidote bearing rock collected on the left bank of the Coppename river (C. 58) belongs to the group.

CHEMICAL COMPOSITION, NOMENCLATURE AND COMPARISON WITH LAMPROPHYRES ELSEWHERE.

As we have seen the lamprophyres are represented by kersantites, odinite and malchites. The kersantites agree mineralogically and chemically with the more acid representatives of what are called kersantites elsewhere. Mineralogically, this results in the rocks of the Suriname river (Y. 58) and of the Gran-rio (Y. 90) being the same, in the appearance of free quartz, and the predominance of biotite among the couloured minerals, while hornblende is sparse and pyroxene is wanting. This latter stands in contradiction to the frequent occurrence of pyroxene in more basic kersantites. A percentage of free quartz is frequently stated for kersantites. It has even been said that quartz phenocrysts exist in kersantites of South-Thüringia,[1]) but we have the impression that they are more likely to be inclusions. The presence of potash feldspar points to some relationship with the minettes: granophyre of quartz and potash feldspar, however, is also elsewhere found in kersantites. The relatively acid composition also appears from the chemical analyses (see table 17 column I and II). For purposes of comparison the Niggli values

	Kersantite Y. 58 I	Kersantite Y. 90 II	Odinite Y. 65 III	Malchite Y. 110 IV
SiO_2	59.29	57.18	55.58	51.84
Al_2O_3	15.19	18.29	15.13	17.54
Fe_2O_3	2.25	2.38	4.86	2.20
FeO	5.68	3.88	5.42	6.17
MnO	0.12	0.16	0.15	0.19
MgO	3.60	2.57	4.25	5.07
CaO	5.05	5.27	6.96	9.55
Na_2O	3.57	4.56	2.94	3.24
K_2O	2.84	3.46	1.82	2.16
H_2O+	0.63	0.68	1.41	0.93
H_2O-	0.04	0.11	0.02	0.07
CO_2	0.32	—	0.19	—
TiO_2	0.99	0.89	1.24	0.93
P_2O_5	0.40	0.64	0.20	0.42
	99.97	100.07	100.17	100.31

Anal. Dr. S. Parker, Zürich.

TABLE 17.

are given also of the "acid kersantite type" calculated by Beger[2]) as the middle of a series of kersantites from different parts of the world (Table 18, A.) Both our analyses differ from Beger's average-values essentially by larger c and smaller fm. When judging these differences one ought to remember that Beger's rocks have lost calcium by weathering (l.c. p. 306—307) which accounts for the deviating values of our fresh rocks and also for the different tetrahedron section. The value fm of II is remarkably low but falls within the values calculated by Beger (l.c. p. 309). The high quartz value of I is also to be found in several kersantites of other localities (see table l.c. p. 251—255).

[1]) R. Pöhlmann. Neues Jahrbuch. III. 1884. p. 97.
[2]) P. Niggli—P. J. Beger, Gesteins- und Mineralprovincen. Berlin. 1923, p. 308.

Chemically we might just as well compare our rocks with the lamprophyres which were called by Lossen "Biotit-arme Kersantite", and later "Cuselite" (from the Saar-Nahe region): cf. the average values (l.c. p. 324 and 382 and column B in our table). The resemblance with No. I is remarkable, considering what has been said about "c" above. Mineralogically the Cuselites differ essentially from our rocks.

	si	al	fm	c	alk	k	mg	$\frac{c}{fm}$	qz	section
Kersantite Y. 58 I	187.4	28.3	37.8	17.2	16.7	0.34	0.45	0.45	+21	4
Kersantite Y. 90 II	178.6	33.6	28.1	17.6	20.7	0.33	0.43	0.62	—4	4
A	179	28.5	44	9	18.5	0.44	0.54	0.23	+5	2
B	191	32	38.5	10.5	19	0.36	0.55	0.27	+15	3
Odinite Y. 65 III	159.8	25.4	41.9	21.3	11.4	0.29	0.43	0.51	14.2	4
C	144	24.5	42	19.5	14	0.32	0.53	0.46	—12	4
D	140	26.5	41.5	19.5	12.5	0.26	0.56	0.47	—10	4
Malchite Y. 110 IV	131.1	26.1	36,7	25.8	11.4	0.31	0.52	0.70	—14	5
E	167	31	35	19	15	0.26	0.46	0.54	+7	4

TABLE 18.

Our kersantite from Plum- and Twirlround rapids, Courantyne (Y. 332) mineralogically agrees more with the typical kersantites on account of the occurence of monoclinic pyroxene.

It is not so certain whether the rock of the Coppename river near the Weri creek (V. 2374) belongs to this group too. If so, it is a biotite kersantite. However, it contains a considerable quantity of quartz and, mineralogically, does not differ essentially from the quartz mica diorites; possibly it is the dyke-shaped equivalent of the latter, in the same way, as the granites may be intersected by fine-grained micro-granites.

The mineral combination of our odinite: moderately basic plagioclase and hornblende together with the dyke-shape, puts this fine-grained dyke-rock under the spessartite-odinite group. There seems to be no essential mineralogical difference between spessartites and odinites generally. In the latter we usually find green hornblende, in the former usually brown. In the former mostly potash feldspar and quartz occur which may be intergrown to granophyre, while by an increase of the potash feldspar and by a diminution of the quartz, transitions in the direction to vogesites may arise. In the odinites we never find potash feldspar, but some quartz is stated for them. On the whole we may say, however, that different names have been given to rocks having pretty well the same mineralogical composition apart from some varying quantity of quartz and potash feldspar, and the tint of the hornblende. The two groups are not to be separated at all chemically (cf. C with D. l.c. p. 337, 342 and 382). The chemical composition of our rock (column III) may be compared again with Beger's average values of our rock (col. III, C and D). We have chosen the name of odinite for our rock, as potash feldspar is apparently wanting entirely, and as the quantity of quartz is negligible.

The Surinam malchites are all practically alike. The biotite-bearing types (Y. 110, 338, 2402) show mineralogically great similarity to hornblende biotite malchites from Zwingenberg in the Odenwald. The Surinam types are non- or indistinctly porphyritic, while the typical malchites now show some phenocrysts, now none. The chemical composition of the malchite from the Gran-rio (Y. 110) (column IV) agrees fairly well with the average values of malchites generally (column E; l.c. p. 347 and 393) [1]), leaving the inconstant si-value out of consideration.

It may be said that the Surinam lamprophyres according to the few analyses at our disposal, link up fairly well with the corresponding lamprophyres elsewhere, though some values (mg) may show considerable differences.

As has been discussed by Beger in detail (l.c. p. 391—399) the lamprophyre groups are not distributed systematically over the three magma-series of Niggli, except the minettes which fall entirely within the "Kali reihe". A comparison of our lamprophyres with Niggli's magma types is therefore of no use.

GEOLOGICAL BEHAVIOUR AND RELATIONSHIP.

As already mentioned the lamprophyres occur in the shape of dykes. They break through the granitodiorites of the basal complex, hence they are younger than the latter. In the field it is difficult to distinguish the fine-grained lamprophyres from the dense diabases.

The following is known about their geological behaviour. We know dykes of kersantite, intersecting the granites of the Gran-rio massif from two places. Near the Bushnegro-village of Toemaripa the Suriname river splits up into two branches forming an island. On the right hand side branch, at low water, we observe a dyke of ½ m. in thickness intersecting the granite vertically with a trend of N. 80° E. (Y. 58). It may be traced for a short distance and then it wedges out into the granite, to appear again with the same trend somewhat further. It fills a diaclase in the granite; the latter shows no changes at the contact.

A second dyke is met with in the Gran-rio massif above the Bushnegro-village of Stonehoekoe on the Gran-rio (Y. 90). At a small distance from each other there appear two dykes, running N.60° E., both of several metres breadth.

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[1]) Cf. also the average values of Odenwald malchites, calculated more recently by G. Klemm. Über die chemischen Verhältnisse der Gesteine des kristallinen Odenwaldes und des kristallinen Vorspessarts. Notizbl. Ver. f. Erdkunde etc. Darmstadt. 1925. p. 143.

covered with boulders, and visible at very low water. The contact with the granite is invisible.

The behaviour of the diopside-bearing kersantite on the Courantyne (Y. 332) is more complicated. Northwards of lat. 4° N. we find a series of rapids in the river, the Plum- and Twirlround rapids. Here we find ourselves in a region consisting partly of porphyritic granite, the petrographic equivalent of the Gran-rio granite. Near one of the many islands we see how the granite is penetrated by lamprophyre forming a mass of irregular form with a diameter of 10 metres. Small apophyses clearly penetrate the adjoining granite, a proof that the rock is younger than the latter. It is a remarkable and important fact that both the coloured rocks and the granite are intersected by veins of normal-grained granite, looking exactly like the granite in the neighbourhood. It is a massive porphyritic biotite granite, with coarse microcline phenocrysts of 2 cm. in size (Y. 332). We see how this granite forms fissure-veins in the coloured rock (fig. 28). These veins intersecting the surrounding granite at the same time are certainly younger than either. It is probable, however, that the disparity in age is but trifling and the veins still belong to the contemporaneous veins. We can imagine that directly after the crystallization of the main-granite, the lamprophyres intruded and afterwards, still within a short period of time, liquid remainders from deeper parts of the porphyritic granite-magma.

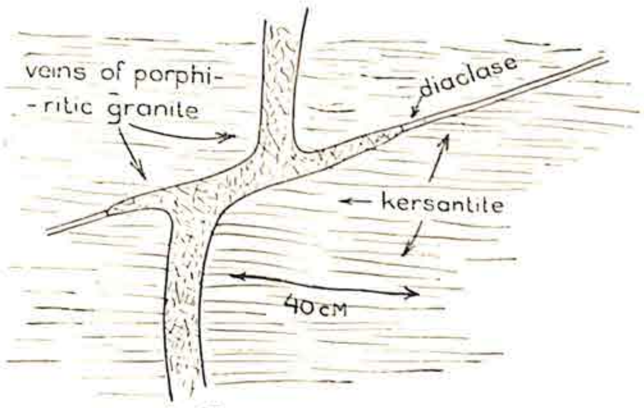

Fig. 28. Kersantite cut by granite veins.

The geological relation of the rock from the Coppename which is possibly a biotite kersantite (V. 2374) is unknown.

The behaviour of the odinite on the Suriname river we find discussed with the diabases (see p. 114). It cuts the Gran-rio granite vertically, below the Bushnegro-village of Goddo, as a dyke of 60 cm. thickness.

Three out of the four malchites occur in dykes. On the Courantyne above the Governor falls on the left bank, we see how normal-grained biotite granite is vertically intersected by a very fine-grained malchite dyke of 2 m. (Y. 338), trending NW. The contact is sharply defined, no change in the granite having taken place. The penetrated granite here is once more the petrographic equivalent of the Gran-rio granite. The second biotite bearing malchite is in a collection made by Essed and presented to the Delft Polytechnic (V. 2402). By Essed it has been erroneously named uralitized diabase.[1]) As appears from Essed's statement, we are concerned here with a dyke breaking through

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[1]) E. Essed. **105.** p. 347.

the biotite granite and sending out thin veins into it: "the tonalite (read biotite granite) has developed on the convex side of the curb on the right bank, in front of the mouth of the Toetoe creek following a S.W.—N.E. course and dipping below the uralitized diabase (sample No. 60) which has sent thin veins into the tonalite, filling pre-existing cracks. These veins are very fine-grained or compact and sharply marked off from the surrounding rock . . ."

The third malchite (Y. 110) cuts the Gran-rio granites about 1 km. above the Bogopakoe fall, Gran-rio. It is a dyke of several metres thickness, covered with boulders, indicating the trend. The contact with the granite is not visible.

It is very probable that the lamprophyres discussed here, are differentiation-products, split off from the granitodiorite magma of the basal complex: all the lamprophyres cut granites, mostly Gran-rio-granites, or their mineralogical equivalent. Besides we have seen in one case that a lamprophyre must be about contemporaneous with granite cut by it. A direct relation with the intrusive diabases and gabbros is out of question.

APLITES AND PEGMATITES.

Leucocratic dykes and veins cut the granitodiorites and ortho-gneisses of the basal complex, and were observed in a few instances also in the metamorphic schists. The dykes vary considerably in mineral combination and in geological behaviour. Those being of granitodioritic mineral combination may be regarded as endogenic differentiations of the rock masses in which they occur, and now as somewhat younger, now as contemporaneous with them. The mineral combination of many others points to hydrothermal-pneumatolitic genesis, while that of other dyke and vein rocks is doubtful.

The geological behaviour of part of the material was observed during our expedition. Of many rocks geological data are entirely wanting; therefore the following classification has been based on the petrography of the samples only.

The rocks will be discussed according to the following scheme:

a. Granite-aplites.
b. Granite-pegmatites.
c. Diorite-aplites.
d. Albitites.
e. Pegmatite-like dyke rocks of simple mineral combination.
f. Quartzites of hydrothermal and hydrothermal-pneumatolitic genesis.
g. Geological behaviour.

Granite-aplites.

Most granite-aplites are pallid owing to pink, grey or white feldspar and grey quartz, and show sparse leaflets of biotite and muscovite. They are massive, normal to fine-grained, frequently unevenly granular with indistinct porphyritic habitus. Microscopically they appear to be made up of quartz, much microcline, very acid plagioclase some biotite and muscovite, and occasionally some epidote, while a number of them are garnet-bearing. The colourless main-components most often do not show the least idiomorphism. Sometimes quartz and microcline show to some degree granophyric intergrowth (see V. 77); or we see some myrmekite of very acid plagioclase and quartz, bordering to potash feldspar. It strikes us, that the potash feldspar has invariably the grating structure of microcline, though often somewhat vaguely. In the microcline fibres of microperthite occur. A special type is formed by a few aplites from the Upper Courantyne, which are almost exclusively composed of an irregular grained mixture of red microcline, and grey quartz (see Y. 292 from the King Frederick William IV fall). Another rock from the same fall, is also composed of red feldspar and grey quartz, but is normal grained. It could be called as well aplite as aplitic granite (Y. 295). Microscopically the rock shows microcline and plagioclase (approximately albite-oligoclase) quartz, and traces of biotite and muscovite. Of the colourless minerals quartz and microcline fail to show the least tendency towards idiomorphism mutually, the plagioclase, however, has a few faces and angles, and is possibly somewhat older than the other colourless components.

Some garnet occurs in the following rocks: V. 24, 46, 47, 524 and Y. 43. One of the rocks is cut by secondary crush-zones in which an abundance of prehnite is invested (V. 524). When all comes to all the granite-aplites have a variable habitus (see V. 24, 46, 524, 628, 669, all derived from the De Goeje mountains; V. 471 from the Lawa; V. 1493 from Madiengo fall; Y. 43 from Koesikamba fall, Suriname river; Y. 295 from the Upper Courantyne; Y. 77 from the Gran-rio).

Granite-pegmatites.

The granite-pegmatites show a close relation to the preceding rocks. In the sample we recognize pink, grey, white, also sometimes bright red potash feldspar with a varying amount of biotite and muscovite. The size of the grain varies largely, often in the same sample. Illustrative of the pegmatites are the coarse potash feldspars of which only some crystal planes have developed. Twins occur; sometimes also pegmatitic intergrowth with quartz is noticeable (Y. 4 B). The potash feldspar again appears to be microcline, and often to be provided with microperthite.

Under the microscope there appears to be only a small amount of very acid plagioclase. Now this may be enclosed as small idiomorphic crystals in the microcline, now it is not in the least idiomorphic, or it is grown together systematically with the potash feldspar as albite-microperthite. Owing to the coarser grain it is easier to recognize the accessoria here than in the aplites. So we can identify magnetite octahedra macroscopically in a rock from Sintia dam Gran-rio (Y. 108). The microscope shows here and there apatite and zircon in the pegmatites.

The coarse grained equivalent of the red aplite from the Upper Courantyne, is also present. Its colour is again to be ascribed to the bright red microcline (Y. 292).

A particular type is the coarse grained pegmatite from the Sir Walter Raleigh fall, Upper Courantyne. This pegmatite is composed of white microcline, grey quartz and some muscovite and biotite, with a varying percentage of garnet and apatite. The mineral components are distributed irregularly; some portions of the mighty dyke only consist of feldspar, quartz and an abundance of muscovite; other portions have the composition mentioned already. The microcline amounts to 4 cm. and is permeated with spots of quartz. Muscovite and biotite appear in truncated crystals to the size of several cm, now separately, now united into strings, and often with a bent basal face. In various places we see groups of red garnet grains of a few millimetres, but in the field garnets up to 2½ cm. were observed, with indications of rhombendodekahedron faces. Notable are also the macroscopically visible apatite crystals, hexahedral columns of a bluish green colour, remarkably idiomorphic, with or without terminal faces. The mineral bears a striking resemblance to beryl (see the samples Y. 313 and

313 B—D). The microscope shows again microcline besides some acid plagioclase (albite-oligoclase).

Finally in the area above the Sir Walter Raleigh fall on the Upper Courantyne, granite-pegmatite dykes were observed, holding tourmaline crystals, to the length of 1½ cm.

Besides the samples mentioned typical pegmatites from the Suriname river are present (Y. 4 and 4 B, Lantiston; Y. 41 from the Bakrabote fall), from the Coppename river (C. 16, Langa fall), from the Upper Courantyne (V. 3498, 3504, 3507), from the Lucie river (V. 3480, 3484) and from the extreme upper course of the Lucie river (V. 3494).

Diorite-aplites.

The only diorite-aplite of importance occurs at Mamma dam (= Sisabo fall) Suriname river. It is a massive, normal, and coarse grained, locally also fine grained rock, of a pure white, here and there with groups of dark minerals, mainly biotite (see Pl. 13 fig. 1). Microscopical examination shows that it consists of plagioclase and quartz, practically without dark minerals. The plagioclase (oligoclase-andesine) shows in its general form here and there well-defined faces. In other places the shape of both minerals shows undulating boundary lines, and reminds us rather of the structure of the ortho-gneisses, which are cut by these aplites. The vague lamellae of plagioclase are sometimes slightly bent and wedge out. Small inclusions of colourless leaflets, also some haematite (?) and dust are present in the plagioclase whilst antiperthitic intergrowth with potash feldspar is noted. The quartz is undulose and partly crushed; many hairlike inclusions and strings of dust or liquid inclusions occur. As to the accessoria only scattered pieces of epidote are to be mentioned, which reminds us of the primary epidote of the granitodiorites and ortho-gneisses, still to be discussed. But also secondary epidote is met with, which fills together with quartz a vein in a thin section. Another thin section (Delft D.D. 1260 from V. 1432) possibly derived from the same rocks, contains besides plagioclase, microcline and some muscovite and ore.

Albitites.

A few rocks may be referred to the group of albitites. A weathered, normally granular sample from the De Goeje mountains (V. 117) is of a grey tinge, partly coloured by limonite infiltration. It might be considered as an aplite. Under the microscope it appears to consist only of albite. The crystals are distinctly twinned, partly provided with fine dust. They hinder each other mutually. In some places there is an insignificant percentage of microcline. Small, rounded garnet grains occur as accessories. Nests of prehnite are distributed among the other components in such way that their secondary character cannot be questioned. The lamellae of the albite are partly bent.

It is uncertain whether the following rocks should be classed here. There is a thin section of material from Akwitiki fall, Lawa (V. 1065; the sample is absent). Again we see the same albite, but also considerable microcline. The former is not distinctly idiomorphic towards the latter. Moreover components of secondary origin are copious. First of all topaz, which occurs in groups of grains that hinder each other mutually, then again in strikingly idiomorphic, short prisms, developed after the c-axis (see for the latter Pl. 28 fig. 3). The topaz shows clear undulose extinction and is distributed in groups along the fractures. Other secondary products are chlorite and epidote, the former derived from biotite.

Allied to these rocks are two samples, the one from the Emma river (V. 1162), consisting of albite, some microcline, and spots of epidote and chlorite masses, with some titanite; the other from the De Goeje mountains (V. 531 sample wanting) consisting of much microcline, albite, with pieces of epidote.

The last three rocks might as well be allied to syenites, judging from the mineral combination, but they are not typical enough on account of the slight amount of dark minerals.

Pegmatite-like dyke-rocks of simple mineral combination.

They are of a very simple mineral combination and mineralogically closely allied to granite pegmatites; they occur in dykes. On account of the lack of feldspar they do not belong to the granite-pegmatites proper.

Of most common occurrence is a pegmatite that consists of quartz and muscovite to a varying amount. The massive rocks show tabular muscovite crystals, and irregular quartz masses which hinder each other mutually. The size of the muscovite crystals varies, they often attain a diameter of several centimeters, even of a few decimeters. These very coarse pegmatites crop out near Guidala on the Marowyne river. In some samples, derived from another locality, the basal face of the muscovite is singularly flexed (see Y. 311 from the Upper Courantyne).

Similar muscovite pegmatites of variable-sized grain we have from the Lower Marowyne (V. 2439, 2440, 2441, 2442, 2447, 3548); from the Upper Courantyne (V. 3504; Y. 311); from the De Goeje mountains (V. 48, 728).

Another type from the Marowyne near Guidala, is composed of quartz, muscovite and black tourmaline, without any distinct idiomorphism in any of the components (see a rock from the " Collection van Heert" present at Leyden).

A great number of quartz tourmaline pegmatites are known. The quantitative relation of quartz and tourmaline is largely varying, sometimes in one and the same sample. The tourmaline appears in grains and large prisms, sometimes in six-sided columns or needles. In a few rocks the tourmaline appears as fine needlets arranged in suns (V. 2217). Such tourmaline-quartz rocks are present from a number of localities, most often collected as boulders from prospect-pits (e.g. V. 338, 869, 1010, 1013, 2329, 2986, 4043).

Quartzites of hydrothermal and hydrothermal-pneumatolitic genesis.

As will be mentioned when discussing the quartzites, there are a large number of samples in different collections, whose purely quartzitic composition hardly allows to decide whether they are recrystallized sedimentary quartz-sands; or whether they have been deposited on fissures at a low temperature and represent silicic acid set free with weathering; or whether, on the other hand, the rocks are of hydrothermal-pneumatolitic origin. Whereas the genesis cannot be traced for many samples, there are a number, which, on closer examination, lend support to the latter genesis.

In a number of more or less pure quartzites that are rather coarse grained or sugarlike crystalline, locally muscovite leaflets are to be noted that have surely originated from magmatic exhalations and cannot be of sedimentary origin. They are distributed through the rock in such a way, that in all probability the quartzite and the muscovite are syngenetic. They might be looked upon as the very quartz-rich and muscovite-poor equivalent of the quartz-muscovite pegmatites discussed heretofore (see e.g. V. 729, 1376, 2445, 3549, 3550, 3553, 3554).

Another mineral possibly of hydrothermal-pneumatolitic origin is pyrite, which enters into the composition of some samples. In V. 71, 1606, there are to be seen pyrite masses to the size of more than 1 cm. spread irregularly throughout the sample. Part of the pyrite may have beautiful forms. In one of the samples pyrite is partly intergrown with hematite (?) and moreover some gold is scattered in this hematite.

It is probable that part of the Surinam gold-bearing quartzes are of the same origin. Although previous explorations have confirmed the assertion that the amount of gold in most Surinam gold-bearing quartz dykes is of secondary origin, this assertion need not hold good for all.

The geological behaviour of the aplites, pegmatites etc.

The granite-aplites occur, in the Gran-rio massif proper, along the Suriname river and the Gran-rio as insignificant dykes, not broader than a few decimeters.

Near the Koesikamba fall (Suriname river), we observe dykes of a breadth of 1 dm., branching radially and running through the granite in every direction. The red aplites from the Upper Courantyne are developed in several places. At the King Frederick William IV fall they form dykes, a few decimeters wide, which run parallel to the texture of the ortho-gneisses. Half-way along the channel a similar aplite occurs of much larger dimensions, as an irregularly shaped mass of at least 10 metres in diameter; at the contact with the gneiss, small apophyses penetrate into the latter parallel to the trend and, as the veins may be very thin we might speak of injection. We might just as well call the main rock mass an aplite as an aplitic granite. In the latter case therefore we might imagine that we are concerned here with an argument for the geological separation between an older gneiss formation and a younger intrusive granite.

The behaviour of a large number of granite-pegmatites has been studied. Pegmatites rich in pink or pallid microcline and largely varying as to the size of the grains in the same sample, are very often met with in the Gran-rio granite massif, on the Suriname river, Gran-rio and Pikien-rio. They attain a thickness of half a metre. Coarse pegmatite dykes of this type are also of common occurrence in the middle course of the Lucie river. These dykes, half a metre in thickness penetrate through granites and acid diorites, and the gneissic equivalents. In some places the dykes protrude platelike, 2 m. high. The red pegmatites from the Upper Courantyne cut, especially on the King Frederick William IV fall, the granitodiorites and ortho-gneisses of varying composition; they run in general parallel to the texture of the ortho-gneisses, and are the coarse grained equivalent of the aplites above-discussed.

At the big fall below the Sir Walter Raleigh fall the same phenomenon can be witnessed, and moreover the pegmatite dykes disperse as extremely fine lenses and cords through the ortho-gneisses of acid dioritic composition, parallel to the texture of the latter. Here, again, there is a case of injection, though on a small scale. The injected parts can easily be traced since the pegmatite-microcline always retains its red colour to the smallest dimensions.

The garnet- and apatite bearing pegmatite from the Sir Walter Raleigh fall, Courantyne, forms a dyke of abnormally large dimensions There the narrow river ramifies round an island. The left channel is closed at the end by a pegmatite dyke about 15 m. wide over which the fall runs down. This enormous dyke probably forms the core of the hills situated on the left bank in line with the dyke. The contact with the adjacent rock is hidden.

We do not know the geological behaviour of the only sample of albitite and the other problematic rocks allied to it. Probably the albitite is a dyke-shaped, alkali-rich differentiation of the granite area in which it occurs.

The pegmatites of simple composition are largely distributed in the Colony, especially the quartz muscovite pegmatite. They intrude granitodiorites, ortho-gneisses and frequently may be observed as dykes of a thickness of more than 1 m. e.g. along the Upper Courantyne.

Of larger dimensions are the quartz dykes. They occur in a great many localities in the Colony, cutting the granitodiorites and ortho-gneisses and the schists. The type that is considered here on account of the amount of muscovite as hydrothermal-pneumatolitic, is largely represented among them. Nothing is known about the downward course of the latter group.

It is not known, whether the "hydrothermal" quartz-dykes form only lenses, ending soon towards the depth, like the secondary, gold-bearing veins of many places of the Colony, or whether they have really a deep-seated origin.

More interesting is the occurrence of the described diorite-aplites from Mamma dam Suriname river. They occur in ortho-gneisses of dioritic composition, ranging from quartz mica diorite-gneisses to hornblende diorite-gneisses (see p. 238—241). The Mamma dam and the Sopo fall are found on either side of a small island. In the rounded rock faces of the Mamma dam we distinguish pretty well purely white aplite dykes and veins. They cut as well the basic as the more acid gneisses. Where a great many aplite dykes are present, they intrude into the rock as a network which, owing to its light colour contrasts with a more or less dark background (Pl. 13 fig. 3). The phenomenon looks different when the veins and the dykes predominate quantitatively, in other words when dark rock masses are lying in a white groundmass as a large

Plate 13.

Fig. 1. White diorite-aplite, composed of plagioclase and quartz and scarce groups of biotite. Mamma dam (= Sisabo fall) Suriname river. (Y. 31).

Fig. 2. Banded hornblende gneiss. Madiengo fall Suriname river. (Y. 28).

Fig. 3. Dark diorite-gneisses intruded by network of light coloured diorite-aplite. Mamma dam (= Sisabo fall) Suriname river.

number of more or less separate blocks. An indication of this phenomenon is already seen on the photo. Martin, who explored this area about forty years before us, has given a clear description and drawings of this phenomenon [1]) (fig. 29 and 30).

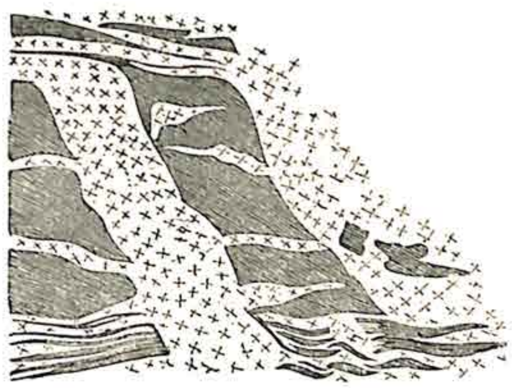

Fig. 29.
± 1/25 Natural size (After Martin l.c.)

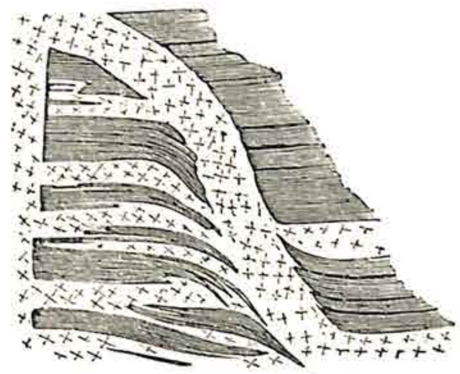

Fig. 30.
± 1/20 Natural size (After Martin l.c.)

Fig. 30 shows indications of movement in these compound masses: the hornblende rich gneisses (a) and (c) are distinctly distorted in the neighbourhood of the dyke shaped aplite mass (b). As both groups on either side of (b) show a distortion in opposite directions the distortion cannot be attributed to the activity of the dyke material of (b) alone.

These complicated masses may be regarded as igneous breccias in the sense of Sederholm, as they have been described from South Finland [2]), though the Surinam ones are only small reproductions of the latter. The pictures from South Finland bear a striking resemblance to those of the Suriname river, but the genesis differs. The aplitic material near Mamma dam does not belong — as in Finland — to a much later intrusive magma which is of different origin incomparison to the fragments of the igneous rocks intruded. The aplites are petrographically closely related to the ortho-gneisses, and by the absence of crystallization sequence, the structure of the aplites does not differ essentially from that of the ortho-gneisses. The whole is, therefore, to be considered as approximately contemporaneous. Martin has already spoken of "Ausscheidungstrümmer".

In conjunction with the foregoing we may discuss the important question of the genesis of the other aplite and pegmatite dykes and their relation to the granitodiorites and ortho-gneisses. We should distinguish between the aplites and pegmatites whose mineral combination does not differ too much from the granites or diorites, and those with another combination viz. the quartz muscovite, the quartz tourmaline pegmatites, and the quartz dykes. The latter group is more clearly of pneumatolitic hydrothermal origin. The material of

[1]) K. Martin. **26.** p. 162—166.
[2]) J. J. Sederholm. On migmatites and associated pre-cambrian rocks of southwestern Finland. Part. I. The Pellinge region. Bull. Comm. géol. Finlande. No. 58. 1923. Do. Part II. The region around the Barösundsfjärd W. of Helsingfors and neighbouring areas. Nr. 77. 1926.

these dykes has probably been supplied by the exhalations of much deeper parts of the magma; these dykes are, therefore, probably much later than the epoch in which the adjacent rock was crystallizing. The first-named aplites and pegmatites, though likewise originating from deeper parts of the magma, and partly also crystallized under the influence of mineralisators, are more allied to the rocks which they cut. There are no arguments lending support to the hypothesis, that the dykes have been emitted by magmas which intruded much later than the adjoining igneous rocks. These dykes have been observed nowhere in direct connection with large and later igneous masses. So the dykes cannot support the hypothesis that in Surinam there have been considerable successive intrusions of granitodiorites. Quite in keeping with this are other arguments of more weight. We shall dwell upon them when we discuss the granitodiorites at large. It will then appear that the Surinam ortho-gneisses are nothing but a structural and textural facies of the granitodiorites, and that as to age there is no essential difference between these two groups. The abscence of crystallization sequence in the aplites of Mamma dam, by which the aplites correspond in structure with the ortho-gneisses which they cut, is once more an argument for their contemporaneous nature with the latter. It may be stated, similar structure relations have been found in contemporaneous gneisses and aplitic rocks in the Schwarzwald. [1])

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[1]) See H. Schwenkel, Die Eruptivgneisse des Schwarzwaldes und ihr Verhältniss zum Granit. Tscherm. Miner. Petrogr. Mitt. XXXI. 1912, p. 177—178.

SOME DIORITE DYKES.

Remarkable because of their geological occurrence are some diorites from the Coppename river: two diorites, namely, which, according to Essed cut the granitodiorites of the basal complex, while the same probably holds good also for a third, as indicated by a note of Voltz. These diorites are the only ones for which an age later than that of the basal complex may possibly be assumed.

According to Essed one of the diorites occurs in the river 200 m. N. of Zonnevisch creek, on the right bank, where a rock-mass of 25 m. broad is to be seen, trending SSW. [1]) This diorite dyke (V. 2344) cuts granites (vide map II Essed l.c.). The second diorite forms a dyke 50 m. broad, opposite the mouth of the Pomo creek (l.c. p. 342; V. 2367, 2368) and cuts biotite hornblende granite according to Essed, which is probably quartz mica diorite according to the samples.

Not improbably Voltz's note that a "Grünsteingang" forms important rapids near the mouth of the Jaba creek, [2]) has a bearing on the third diorite (V. 1464).

Both diorites collected by Essed show such resemblance petrographically, that they may be discussed together ,though they occur at a large distance from each other (namely 20 km., as the crow flies). The normal grained rock is massive and has a dioritic habitus. Microscopically hypersthene, monoclinic pyroxene, green hornblende, brown biotite, plagioclase and quartz are seen, with ore, apatite and pyrite as accessoria. The dark minerals are somewhat in the minority. The hypersthene is shortly prismatic, and rarely shows well developed crystal faces. The cleavage according to (110) is distinct; also the irregular one according to (010) may be seen. The pleochroism is strong, varying from rose-pink to greenish and almost colourless. With the exception of ore grains, no inclusions of any importance occur in the hypersthene. The monoclinic pyroxene sometimes shows oblong forms, but generally it is shorter and irregular in shape. The extinction angle amounts to 50°. The pleochroism is very weak. Octahedra of ore occur as inclusions. It is characteristic for these rocks that hypersthene and monoclinic pyroxene are nearly always surrounded by rims of hornblende. The border between pyroxene and hornblende is not all clearly defined, both minerals penetrating each other. The pleochroism of the hornblende varies from light yellow to brownish-green or green. Biotite crystallized later than pyroxene, for it may partly surround the latter; besides a rim of hornblende may be present between the minerals mentioned, enveloping the pyroxene. It is remarkable to see how the hornblende and biotite conform their shape to the clearly idiomorphic plagioclase. The idiomorphic ends of the plagioclase protrude into the dark minerals and the phenomenon may resemble the ophitic structure of diabases to some extent, in case the pyroxenes are much larger than the plagioclase crystals. Biotite may even fill the interstices between the plagioclases, the crystallization of the mica lasting longer. The oblong or lath-shaped plagioclases are distinctly idiomorphic, with quartz as latest crystallization between. The Albite-law of the plagioclase may be combined with the Pericline-law. Zonal structure is but slightly developed. All the plagioclases are turbid with a very fine, dark pigment, a small zone at the edges excepted. On powerful magnification we detect that the pigment consists of needles arranged according to two or more systems. Plagioclase contains from 40 to 50 % of anorthite; the rims are somewhat more acid. Ore is abundant in both rocks (magnetite or titanomagnetite). It has a long crystallization period. The smallest grains may be idiomorphic in which case they are generally enclosed in the colourless minerals. We frequently observe rims of biotite around the ore. Pyrite is insignificant (V. 2344). The apatite partly shows idiomorphism: it has a shorter or longer prismatic form and clear end-faces: an obtuse pyramide and (0001) may be present, a fact seldom reported elsewhere. It is remarkable also that the apatite may show pleo-

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[1]) E. Essed. **105.** p. 336 (V. 2433; called "hyperite" by Essed).
[2]) vide K. Martin. **26.** p. 185.

chroism. The latter is probably caused by enclosed and extremely fine rods [1]), which lie according to the c-axis. They occur through the whole crystal, but here and there they are heaped up causing different intensity of the colour of the apatite. This pseudo-pleochroism varies from dark bluish gray (according to the c-axis), to violet-red. Other apatite crystals are quite colourless.

The dark minerals show a tendency to be heaped up together, with the accessoria. The sequence of crystallization is the following: ore, apatite, then hypersthene, monoclinic pyroxene and plagioclase, and then hornblende and biotite. In one of the rocks hypersthene is present in abundance (V. 2344), in the other rock (V. 2367) the hypersthene is of little importance. The rocks may be called quartz-bearing hypersthene hornblende diorites, and quartz-bearing augite hornblende diorites. The name „hyperite", as used by Essed, is erroneous.

The third rock has already been described by Bergt.[2]) and we may refer to his description (V. 1464). Bergt was the first to record the striking idiomorphism of the plagioclases. These plagioclases are partly very small and in that case show distinct zonal structure. They lie in a groundmass of quartz. Most remarkable is the form of the titanite in this rock. The mineral never shows idiomorphic shape, but occurs in irregular pieces, which may enclose small plagioclases. This phenomenon goes on to such an extent that true skeletons forming one crystal are shown by the titanite (fig. 31). Such skeletons conform strikingly to idiomorphic plagioclase: so the titanite is, without any doubt, of later date than the latter. This behaviour is quite different from what is generally to be seen elsewhere. The same deviating behaviour of titanite has been mentioned by Horn and Teall for "borolanite" from Assynt, Scotland; the skeletons of titanite conforming to pyroxene, orthoclase and nepheline.[3]) Hatch reports feldspar crystals enclosed in titanite [4]) from Madagascar; Berwerth mentions the same for plagioclase at Ditro, Hungary;[5]) Machado for pyroxene from Brazil;[6]) Ramsay and Berghell the same for pyroxene from Finland.[7])

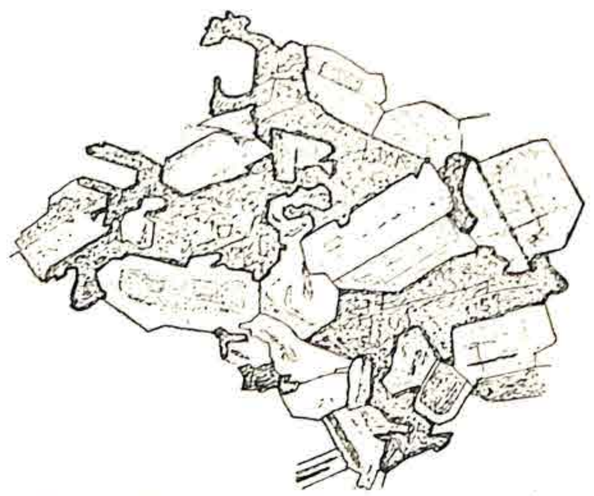

Fig. 31. Titanite-skeleton embracing idiomorphic plagioclases. × 69 (V. 1464).

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1) c.p. P. Ramdohr. Not. Bl. Ver. f. Erdkunde. Darmstadt. 1923. p. 164.
2) W. Bergt. **45.** p. 148.
3) J. Horne and J. J. H. Teall. Trans. Roy. Soc. Edinburgh. XXXVII. 1891—92. p. 174.
4) F. H. Hatch. Quar. Journ. Geol. Soc. XLV. 1889. p. 342.
5) F. M. Berwerth. Jahrb. Siebenbürg. Karpathenvereins. 1905. p. 12.
6) J. Machado. Tscherm. Miner. Petrogr. Mitt. VII. 1888. p. 318.
7) W. Ramsay and H. Berghell. Geol. Fören. Förhandl. XIII. 1891. p. 300.

THE GRANITODIORITES AND ORTHO-GNEISSES.

INTRODUCTION.

The granitodiorites and ortho-gneisses are represented in a larger number than any other group of rocks in Surinam. They form the greater part of the basal complex, not including the extreme East, where metamorphic schists dominate. If we take the divergent composition and varying structure of the Surinam granitodiorites and ortho-gneisses into account, it is conceivable that in petrographic literature on Surinam there prevails the greatest confusion in the nomenclature, more than with any other group.

In our research we had at our disposal thin sections of a large part of the old material, while a great number of new sections have been made. This has also been done for those rocks that differ little in outward habitus so that all identifications of the granitodiorites have been made on the base of microscopic examination.

The first question suggesting itself in working up the extensive material is, what system of classification and description must be followed. Field-observations point to the probability that no complicated structures, as a result of repeated intrusions and important tectonic disturbances, occur in the igneous part of the basal complex. As a matter of fact, during our expedition, a large number of granitodiorite-types appeared to show in the field relations which render it very improbable that they should be of different ages. Quite a number of rock-types appear to belong to extensive massifs. It may seem rash to apply this view also to the rest of the many rock-samples, collected by others, concerning which there are hardly any geological notes; but on the other hand, this material consists for a great deal of the same types of rock, and we may conclude from the map that the same associations occur side by side. The geological relation mentioned, in all probability holds good for a large part of the material and may be accepted, as long as no observations pointing to the contrary have been made.

Of a great number of granitodiorite types we find the mineralogical equivalents among the ortho-gneisses. As for many of these ortho-gneisses a direct connection with the granitodiorites in the field has been observed, and as on the other hand no proofs have been found anywhere in Surinam pointing to a discrepancy between the two groups, the discussion of the ortho-gneisses is inseparable from that of the granitodiorites. A detailed discussion of the nature of the ortho-gneiss characteristics and of the question whether these are of primary or of secondary nature, is found in a separate chapter. It may be said in advance that primary nature is probable.

For part of the granitodiorites and ortho-gneisses, however, the question of possible differences in age must remain unanswered, viz. for a number of independent types. Consequently, all things considered, there appears to be no call for separating the treatment of the granitodiorites and ortho-gneisses.

On the lines of one of the usual petrographic systems we might carry through a division into principal groups according to the mineral combination, and in each of them distinguish a number of types and treat these by themselves. Taking the structural characteristics into consideration, we might apply this system to the normal igneous rocks as well as to the gneisses and to the gneissic intermediate forms. This system would have special advantages for those samples that were collected far from each other, in areas little known geologically. This has not been done. In the discussion a topographic-petrographic division has been followed. In some vast areas, it should be remembered, definite mineralogical types preponderate, and these areas each by itself form more or less of a unity; some smaller regions show a mineralogically stronger variation of local character; of others again we possess too few data to give a survey of the whole.

The following topographic-petrographic groups have therefore been drawn up:

A. The granites and ortho-gneisses of the Gran-rio massif.
B. The diorite-facies of the Gran-rio massif.
C. The gabbros and granitodiorites of the De Goeje mountains.
D. The gabbros, granitodiorites and ortho-gneisses of the Nickerie region.
E. The "remaining" granitodiorites and ortho-gneisses.
F. The "remaining" gabbros.
G. Some syenites.
H. The venites.

For the sake of general orientation some data about these groups follow here. It appears that all rocks belong to the calc-alkali-series. The Gran-rio massif occupies the centre and South-East of the Colony, and, apart from some locally included schist-complexes and later basic dykes, seems to be one whole. In this area biotite and biotite hornblende granites occupy the largest extent, while in the North-East and North a zone is joined to it, where, besides the same granites, also diorites occur. They are mostly acid diorites (quartz mica and quartz mica hornblende diorites), very closely related to the granites. In both areas we find rocks with normal structures and a smaller number with the characteristics of ortho-gneiss. These granites and acid diorites are considered to belong all together to the same massif. The granites of the core I have called Gran-rio-granites after the most typical representatives on the Gran-rio river. The name of "Gran-rio massif" may also be extended to the above mentioned diorites, and, further on, we shall comprise the core of granite, as well as the diorites and granites of the border country, under the name of *"Gran-rio-massif"*. The diorites will be called *"the diorite facies"* (of the Gran-rio massif) for short.

As opposed to the preceding area, the De Goeje mountains and the Nickerie region are characterized by far-reaching differentiation, which was alluded to above. In the De Goeje mountains we meet with a radical change of rocks at short distances, these rocks ranging from granites as the most silicic to gabbros as the most basic ones. These rocks occur within the Gran-rio massif, and indeed the most acid members of this series are nothing but granites that show no essential difference with the Gran-rio granites. The same applies to part of the acid diorites. The more basic members, the basic diorites and gabbros, however, belong to a type, such as is known within the Gran-rio massif only in the De Goeje mountains. About the geological relation of these rocks to the preceding ones we are uncertain. It may or may not be that the various differentiations are united to large masses and dykes, intruding into metamorphic schists and into the rocks of the Gran-rio massif, which occur in the neighbourhood; possibly, however, they are nothing but a facies of this massif.

The gabbros and granitodiorites of the Nickerie-region in the same way locally show very considerable variations in mineral assemblages, ranging from granitic to gabbroid composition. Mineralogically they are related to those of the De Goeje mountains, but they, too, bear a local character. These rocks are partly contemporaneous with the granites of the neighbourhood, they traverse each other mutually.

Outside the areas discussed we know granitodiorites and ortho-gneisses, and besides some gabbros and syenites. The granitodiorites and ortho-gneisses, generally speaking, do not differ essentially from the rocks of the Gran-rio massif. We might, therefore, discuss them together with the latter. We will not do so, however, first because of the rocks being scattered to such a degree all over the rest of the Colony that their geological relation both mutually and to the rocks of the other areas, is doubtful. Secondly we know part of these rocks only from field-observations. Besides there is a reason of technical nature; the variability in characteristics of secondary importance makes separate treatment desirable.

Finally there are a few more gabbros about whose geology nothing is known; we shall discuss these separately under the heading "Remaining Gabbros".

Syenites appear to be of very slight importance in Surinam. The little that is known about them will be found under the heading "Some Syenites".

Locally venites were met with by our expedition. Their genesis, as is generally the case elsewhere, is not known with certainty.

In view of the scheme given above, we shall discuss the different rock-groups. With every group the reader will find geological data in so far as these are known. A discussion of the minerals of the granitodiorites and corresponding ortho-gneisses precedes the descriptions of the rocks owing to the equality among the different groups. The minerals of the rocks from the De Goeje area, Nickerie-region etc. are found treated in the chapters on those areas owing to their local characteristics.

The secondary phenomena in all granitodiorites and ortho-gneisses have been treated together, comprising metamorphism in its widest sense: beginning with the changes which are still connected with the last stage of magmatic activity (auto-metamorphism), and followed by all phenomena pointing to external influences and the renewed forming of minerals and structures joined to these (allo-metamorphism). It is not always possible, strictly to separate what falls under auto- and allo-metamorphism from the primary mineral characteristics, and accordingly some liberty has been taken in the treatment. As has been mentioned, the gneiss characteristics of the majority of Surinam ortho-gneisses are regarded as being of a primary nature, and consequently they are not discussed in the chapter on allo-metamorphism. With a number of gneisses, however, it appears that the gneiss characteristics are a result of intense pressure and these gneisses are discussed along with allo-metamorphism. This holds good as well for the remarkable pseudo-tachylytes, which are regarded as products of allo-metamorphism.

Finally there follow some general speculations on the igneous rocks of the basal complex.

The scheme of treatment of the granitodiorites and ortho-gneisses is as follows:

I. The primary minerals of the Granitodiorites (Sensu lato).
II. The Granites and Ortho-gneisses of the Gran-rio massif.
III. The Diorite-facies of the Gran-rio massif.
IV. The Gabbros and Granitodiorites of the De Goeje mountains.
V. The Gabbros, Granitodiorites and Ortho-gneisses of the Nickerie region.
VI. The "remaining" Granitodiorites and Ortho-gneisses.
VII. The "remaining" Gabbros.
VIII. Some Syenites.
IX. The Venites.
X. Auto- and Allo-metamorphism of the Granitodiorites and Ortho-gneisses.
XI. Further discussion of the Ortho-gneisses and the genesis of the Ortho-gneisses.
XII. General speculations on the igneous rocks of the basal complex.

I. THE PRIMARY MINERALS OF THE GRANITODIORITES (SENSU LATO).

Quartz.

Quartz can mostly be macroscopically recognized as allotriomorphical grains. In the sample the quartz often shows cracks, which points to pressure. The colour varies from pure white to various tints of gray, and often with a glassy lustre on the planes of fracture. The colour of quartz in some coarsegrained granites of the Gran-rio is conspicuous: the grains are opal-blue. [1]) Microscopically quartz seldom shows idiomorphism. In that case it is the well-known bipyramidal quartz ("quartz granulitique" of Michel Lévy); by the side of larger and irregular pieces of quartz a large number of small diamond-shaped or square sections appear, often with more or less curved crystal faces, while the direction of extinction coincides with the diagonals of the figures. These small pieces of quartz are enclosed in and act idiomorphically towards plagioclase and potash feldspar. It is the only example of quartz distinctly older than the minerals mentioned [2]) (Pl. 28 fig. 4). Although the idiomorphism of quartz is an exception, other colourless minerals, plagioclase, potash feldspar and also the dark minerals are not always idiomorphic towards quartz. Quartz which wholly conforms to plagioclase and so clearly crystallized out latest is to be met with in a number of granites, and in the quartz-bearing diorites. This relation, however, is usually less pronounced, although the form of the feldspars proves that the plagioclase crystallized earlier. Quartz, wholly conforming to idiomorphic potash feldspar is rare and mutual hindrance is general. Many varieties in structure occur. When dealing with the ortho-gneisses we shall see how the mutual relation between quartz and feldspar contributes in a considerable degree to the characteristic structure of those gneisses, and the same is the case in the intermediate forms between these gneisses and normal eruptive rocks. In a number of the granites one finds the typical granophyric intergrowth of quartz and potash feldspar. Now and again one sees an idiomorphic potash feldspar crystal surrounded by granophyre. [3])

Quartz is never idiomorphic against the coloured minerals but the latter are in their turn rarely idiomorphic in respect to quartz. The first crystallizations apatite, zircon, monazite, orthite, titanite, ore and sometimes also small and mostly rounded grains of the coloured minerals occur as inclusions in the quartz. Fine brown needles are pretty generally regarded to be rutile. They lie scattered about without order. Widely distributed are also hairlike needles which are mostly somewhat curved. If the microscope is now adjusted to the higher and then again to the lower parts of the thin section they appear to be no needles but extremely fine leaves, more or less curved as a screw-plane. They are so thin that they are only visible in perpendicular sections.

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1) Y. 130, 132, 135.
2) Y. 145, 189, 239, 241, 251, 340 B.
3) Y. 194.

Liquid inclusions belong to the most conspicuous inclusions. They are arranged in strings or distributed irregularly throughout the crystal. The strings may continue through aggregates of quartz granules which polarise differently and prove that these granules have belonged once to a single crystal. The cavities filled with liquid are irregularly shaped. Vibratile or stationary bubbles are very frequent. Crystals in the liquid never occur.

Potash feldspar.

Macroscopically recognizable potash feldspar is especially met with in the Gran-rio granites as coarse phenocrysts. The phenocrysts vary from 5 mm. to 4 cm. They are tabular according to M.. The face M and the base are invariably clearly defined. The face(101)is seldom recognizable. Twins according to the Carlsbad-law are very frequent. On the planes of fracture perpendicular to 010 different lustre of both specimens is visible as a result of the varying intensities of reflection at the base-cleavage, which is differently oriented in both specimens. Other laws have not been recognized macroscopically. In the sample we often see how leaves of biotite are enclosed by the phenocrysts. Where phenocrysts are struck by thin sections they often appear to enclose plagioclase, quartz and biotite, which also interrupt the margin of the crystals, so that the margins are not older than these minerals of the groundmass. These phenocrysts show without exception microcline structure and must be called microcline in contradistinction to what was stated in former rock-descriptions from Surinam, where they were frequently called orthoclase. Their true nature can easily be ascertained by crushing a phenocryst and studying it in liquid under the microscope. The colour of the phenocrysts is feldspar-grayish, pale-flesh-coloured or red. In some gneisses of granitical texture coarse microclines, rounded-oblong shaped, typical "feldspar-eyes" to the size of 4 cm. are found. This eye-structure is not to be ascribed to crushing.

According to the rule that potash feldspar crystallized later than plagioclase and before quartz, we should expect xenomorphism towards soda-lime-feldspar and idiomorphism against quartz. This perfect order, however, occurs extremely seldom and even then only approximately. In biotite granites of the Central Wilhelmina mountains [1], for instance, we find idiomorphical potash feldspars, tabular and flattened, according to M. Abundant perthite and dust prevent the detection of microcline structure. This feldspar shows fine idiomorphism towards quartz (Pl. 28 fig. 5), but in its turn conforms to the acid plagioclase (albite-oligoclase). This relation also occurs here and there in the granites of the Gran-rio massif. More often we find that potash feldspar conforms to plagioclase, but in respect to quartz shows no order so that the potash feldspar is pronouncedly younger than plagioclase and contemporaneous with quartz. This state of things is met with in the Gran-rio granites and also rather often in other granites. Generally, however, a less clear sequence between potash feldspar and plagioclase is met with, though the latter is older than the potash feldspar as shown by a number of idiomorphic angles and

[1]) Y. 82, 196 B, 199, 201, 203.

faces, and by its large size. This condition is most frequent in the granites, no matter from what region, and also in the acid diorites which contain traces of potash feldspar. Accessory microcline here invariably fails to show any order with respect to quartz, and often conforms to plagioclase. Potash feldspar shows a systemless structure and intergrowth with quartz and plagioclase which points to an equality of age in a number of very acid granites, especially from the Wilhelmina mountains. Potash feldspar shows also defective idiomorphism, but of another type towards the other colourless main components in the ortho-gneisses. Simultaneous crystallization with quartz has taken place in granophyric intergrowth.

Besides the ordinary base- and clinopinakoid-cleavage and that according to 110 sometimes a more irregular cleavage-system is developed forming an angle of more than 70° with the base-cleavage: the Murchisonite-cleavage.

It is remarkable that potash feldspar in the Surinam granitodiorites and in all mineralogically corresponding ortho-gneisses is almost exclusively developed as microcline, which applies both to potash feldspar of the groundmass and phenocrysts. Sections parallel to the clinopinakoid are, however, not to be distinguished from those of orthoclase by extinction, since the structure of microcline on that face is not visible. If we assume that the lamellae which, on the face (001), run parallel to the clinopinakoid, are twinned corresponding the Albite-law (intergrowth-plane abt. = twinning plane = (010), it is clear that we shall not recognize any lamellae of that system in sections parallel to (010) as the direction of extinction of the lamellae is the same. For the lamellae standing perpendicular to the former system we may accept the Pericline-law (twinningaxis = b-axis, intergrowth plane abt. = (100)). And as the b-axes of these lamellae stand practically perpendicular to the face 010 the Pericline- and the Albite-laws differ in this case from each other only by another intergrowth-plane: so the extinction on the face (010) is also the same for both systems of lamellae and no structure can be recognized by a varying extinction on the face (010). In the thin sections therefore we always see some sections without lamellae by the side of laminated microcline. These sections may account for the fact that in the descriptions of the Surinam granites published formerly, orthoclase besides microcline, is mentioned as being of importance. Another phenomenon may also be the reason of orthoclase being mentioned. The microcline-structure may be partly well and partly indistinctly developed in the same crystal. In places the structure may be wanting, and in the rest of the sections so delicately developed that a superficial examination would fail to reveal it. We get the impression that the structure is about to disappear or to arise and suchlike spots show an extinction that approaches zero. This phenomenon is often accompanied by undulose extinction. Another source of confusion are twinned plagioclase crystals cut according to (010) no account being taken of the difference in the index of refraction of the two minerals. Exceptions to the rule occur, however. When treating the granitodiorites we shall see that a number of granites and acid diorites, contain orthoclase instead of microcline. A second but less constant exception is met with in granite-gneisses from the Coppename river near Copencrissi, Tjakka-tjakka-ston, Pimba-hole, Longoston and near Kaaiman-ston. In those from Pimbahole microline is exclusively present: in the others, on the contrary there is more orthoclase with the characteristic straight extinction in the symmetrical zone, partly, however, with local indication of microcline structure. In the latter case both the extinction typical of that of microcline and that of orthoclase appears in the same crystal, agreeing with what has been said above. Twins according to the Carlsbad-law are fairly common in the microclines of the groundmass. Twins according to the Manebach-law are rare. [1]) So are those according to the Baveno-law. These latter are only met with in the granites of the "De Goeje" mountains (in the SE. of the Colony on the Lawa) [2]), and also in a single rock of the Emma river. [3]) They are remarkable for their abundance in the rocks mentioned. The crystals with Baveno-twins are now clearly, now less clearly developed according to zone P/M. The twinning-plane is at the same time intergrowth-plane or the latter is an irregular one. Pl. 28 fig. 6 shows a twin of the well-known type, but not quite cut perpendicular to the zone P/M, while Pl. 29 fig. 1 shows a triplet developed according to P/M, cut approximately parallel to the zone and more or less perpendicular to the intergrowth-plane. The multiplet of Pl. 29 fig. 2 is much more complicated. It shows two squares with diagonals and perpendicular lamellae-complexes, while besides these two have grown together with a larger crystal showing one lamellae-system. We may regard this combination as a quadruplet of crystals twinned in couples according to the Baveno-law, the whole being twinned with a crystal according to the Manebach-law.

Microperthite very often occurs in microcline. Various types are to be distinguished. One common form shows the spool-shaped fibres of plagioclase, most of them with their maximum length uniformly directed, more or less according to (001) or (100). The microperthite may also form a network of more irregular fibres and bundles, and is then mostly coarser than the first-mentioned. Still coarser, patch-shaped plagioclase masses sometimes penetrate the microcline in all directions and often show lamellae-structure and in this way betray their plagioclase-nature [4]). Such coarse perthite appears especially in the pegmatites, but also in the granites. In the cases examined the perthite shows the refraction of albite or of plagioclase which is very poor in anorthite. Sections according to

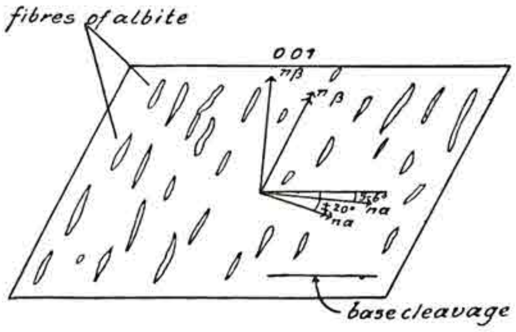

Fig. 32.

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1) V. 393.
2) V. 538, 545, 622, 658, 659, 660.
3) V. 1157.
4) Y. 61, 191, 203.

(010) yield for the microcline 4—6°, for the perthite 19—21° extinction angle with respect to the base-cleavage of the microcline (see fig. 32); this likewise points to albite. The intergrowth-face is (010) with the same orientation of the c-axis. It is probable that we have to do with a demixture in the case of the delicately fibrous perthite. On the other hand the coarser patch-shaped perthite, which takes the place of a considerable part of the potash feldspar crystal, is probably a primary perthite. It is possible that in other cases we find both together. Grutterink, in his detailed description of the microcline in the granites, collected by the expedition to the Tumuchumac mountains [1]), has already mentioned two positions which the albite in respect to microcline may assume: the albite appearing in two positions, differing 180° on the c-axis. Grutterink established this at sections of the symmetric zone, the position of which in respect to the vertical was determined by measuring the extinction-angle of the microcline lamellae (l.c. page 1136). Both types of intergrowth appear simultaneously in the same rock. Much variation exists in the quantity of perthite present. The ortho-gneisses of the Coppename are extremely rich in short or oblong, spool-shaped fibres which are mostly not bent at all.

The plagioclases.

Macroscopically the plagioclases in the sample are seldom conspicuous by their size with respect to other minerals; phenocrysts never occur. Only in a few eye-gneisses of the Coppename do rounded plagioclases attract the attention by their relative size and shape. The plagioclases show, in so far as there are more or less idiomorphic crystals, tabular shapes, flattened according to (010), and with varying length of the zone P/M, or they are almost isodiametric. How strongly the degree of idiomorphism and by this also the more or less distinct order of crystallization varies, has already been discussed. Beautiful idiomorphic plagioclases occur in a number of granites, acid diorites and also in quartz-bearing diorites rich in hornblende. More common, however, in the granites and acid diorites are plagioclases, which by a few idiomorphic faces and angles, sometimes also by large size, show that they crystallized earlier than quartz and potash feldspar. From distinct idiomorphism to irregular crystalloblastic-like forms all intermediate types occur, and, as this mineral is an essential element, it may be rightly said that plagioclase influences the structure more than any other mineral. This will especially be brought to the fore when treating the ortho-gneisses and gneissic rocks. A lack of order in crystallization also occurs in some very acid granites especially from the Wilhelmina mountains.

The plagioclases are, as usual, for the greater part twinned according to the Albite-law, sometimes combined with the Pericline- and the Carlsbad-law. Sometimes we also see plagioclase crystals containing but two lamellae; these are

[1]) J. A. Grutterink. **73.** p. 1133—1137.

twinned according to the last-mentioned law. [1]) That the twinning structure is always far from being well developed deserves our special attention. In different rock groups e.g. often in the acid diorites and the ortho-gneisses, there

Quartz hornblende diorites; partly biotite-bearing					28 39	174	
Quartz mica diorites, hornblende-bearing				14 15 16 27	33 92 105 124 125 314	21 40	175 175^{B}
Quartz mica diorites			9 11 13 279. 319	17 20 23 47 49 282	12 24 25 288 319	186.	
Aplitic quartz mica diorites	1. 2 3 7. 7^{B}	13.					
Biotite granites hornblende or pyroxene bearing.			114. 116 118 122 145 148 182 182^{B} 209 321	36. 53 73 74 80. 82 83 88 89. 96. 107^{B}	54 57 57^{B} 59 69 71 72 86 97 114. 116 118 119 122 148 168 182 182^{B} 183 209	40	
Biotite granites.	8. 149. 193 203. 233. 236. 241 242.	129. 337	45 128 191 232 252 290 320	75 82 85 87 106 130 141 164.	50^{B} 50^{C} 62 68 93^{C} 93^{D} 99 99^{B} 107 109. 190 251 285	107	
Bi-mica granites	117. 120. 132 138. 151 152 153. 176. 283		160				
Aplitic granites	165. 194. 194^{B} 196. 198. 229 234 237 270 272 295		111				
	Albite or albite-oligoclase 0 − ± 14 %	⟶	Oligoclase ± 20 %	⟶	Oligoclase andesine ± 33 %	⟶	Andesine ± 42 % An.

TABLE 19.

appears vague lamination, or the latter is absent in most crystals. Evidently this defective structure is the reason why in the older Surinam literature orthoclase has been repeatedly mentioned.

The anorthite percentage of the plagioclase keeps within the boundaries

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[1]) V. 1181, 1596.

0—50 % (albite up to andesine inclusive). Report of still more basic plagioclases occurring here and there in the former literature, has proved to be incorrect. In general the common rule applies that with a greater percentage of coloured minerals a plagioclase richer in anorthite also appears.

Table 19 illustrates this once more for 140 granites, acid diorites and a few corresponding ortho-gneisses, collected by our expedition. The granites and acid diorites are arranged along the ordinate in the order of ascending percentage of the coloured minerals. The composition of the plagioclases is to a large extent determined by comparing the refraction-index of the feldspar-powder with liquids whose refraction-index had been verified in every examination, in part too, by comparing with the refraction of adjoining quartz and balsam in the thin sections. These methods only allow of approximations; their reliability is especially slight in distinguishing the most acid feldspars: albite and albite-oligoclase as their differences in refraction are very small. (For the denomination with descending anorthite percentage Weinschenk, Die Gesteinsbildenden Mineralien, 1901, table 14, has been followed, and the classification has therefore been carried further than in the denomination of Tschermak, which has been followed in this work elsewhere). In many cases when the composition was determined by liquids the plagioclases appeared to be intermediate between Weinschenk's types so that more types have been inserted in the table. The change in anorthite percentage of the plagioclase of each rock separately is slight. There appear next to each other: albite up to and including oligoclase, oligoclase up to and including oligoclase-andesine; the latter up to and including andesine. Albite and andesine never occur in one sample so that the composition is very constant. An exception to these rules are the zonar plagioclases, but even the difference in extinction and refraction among the various zones is generally very slight. No recurring zones are met with.

Sometimes we find in the plagioclases hexagonal brown, mica-like leaves, mostly in large numbers together. This is probably hematite. [1]) Besides one also notes polygonal oblong or parallelogram-shaped ones. In the rocks which contain this hematite other leaflets of larger dimensions appear in the plagioclase at the same time. They are quite colourless, their refraction is decidedly stronger than that of oligoclase or oligoclase-andesine, and they seem to possess little or no double-refraction. These, too, are hexagonal, with a greatly varying maximum-length. Mostly they appear in great numbers per plagioclase-crystal [2]).

Fine crystalline dust often occurs also [3]). Little brown bars cut obliquely at the ends, possibly "rutile", are arranged according to several systems [4]). Other brown and more oblong, needle-shaped, very delicate inclusions are sparse and do not follow any system [5]). Black dust, showing partly an octahedric shape, is certainly ore [6]). Innumerous delicate, irregularly bounded

[1]) Y. 23, 24, 27, 30, 71.
[2]) Y. 20, 23, 24, 30.
[3]) Y. 24, 33.
[4]) Y. 69, 71, 72, 79, 175.
[5]) Y. 17 etc.
[6]) Y. 69, 71, 182, and 182 B.

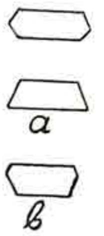

Fig. 33.

cavities, with gas or liquid, refracting very much more weakly than the plagioclase sometimes occur [1]). Consequently, insignificant inclusions and demixture-products of all sorts are common. Microlites of epidote occurring in plagioclase are more remarkable. They are short prisms, sometimes of some length, developed according to the orthodomatic zone, having a hexagonal cross-section and faces at the ends (fig. 33). One of the end-faces is often missing so that the shape (a) occurs or the faces at the ends are not equally developed (b). Besides, shorter granular crystals are found. The prisms have a brilliant lustre and are quite sharply defined. They are always smaller than 0.08 mm. and lie in the plagioclase devoid of any definite order. The larger ones are yellowish in colour. The plagioclases in which they occur, are quite fresh, and, as they occur together with inclusions of a positively primary nature, such as, for instance, small pieces of biotite, the epidotes also seem to have primary nature. They may in their entirety be compared with the primary epidote-microlites from the granites of the Central Alps described by Weinschenk (Gross-Venediger) [2]). They are, however, rare in the Surinam granites. They must not be confused with the more frequent minute crystals of epidote, mostly accompanied by secondary mica, which very frequently occur in plagioclases, the secondary nature of which will be accounted for later.

Antiperthite [3]) is fairly frequent: spots of potash feldspar rectangularly or polygonally bounded and mostly many together. Larger spots are more irregular in shape. Where they border on the balsam, they refract much more weakly than the latter, which points to potash feldspar. In some sections the antiperthite clearly shows microcline-structure [4]), whether it be the system that is seen in microcline in sections approximately parallel to the face (100), or the grating structure. In that case one of the lamella systems is invariably parallel to the albite-twinning of the plagioclase. So the potash feldspar is oriented in the same way as the plagioclase, as far as the (010) face is concerned. Let us suppose, with Dittler and Köhler [5]) that the antiperthite is primary intergrowth and no demixture, in that case the appearance of antiperthite in the quartz mica diorites is remarkable: potash feldspar spots also appear there in the centre of the plagioclases, and must therefore have crystallized before the latter.

Myrmekite, worm-shaped quartz in plagioclase, where the latter comes in contact with potash feldspar, generally occurs in granites [6]), and also in acid diorites when these contain a trace of potash feldspar, and in the corresponding ortho-gneisses. The structure and relation of these minerals in myrmekite has already been subjected to an intensive research [7]); for which we

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[1]) Y. 69.
[2]) E. Weinschenk, Beiträge zur Petrographie der östlichen Centralalpen special des Gross-Venedigerstockes. Abhandl. Königl. Bayer. Akad. Wissensch. XVIII. 1895.
[3]) Y. 30, 37, 89, 107, 107 B, 114, 177.
[4]) Y. 37, 89, 114, 177.
[5]) E. Dittler and A. Köhler. Tscherm. Miner. Petrogr. Mitt. XXXVIII. 1925. p. 229.
[6]) Y. 57, 83, 111, 128.
[7]) E. Becke. Ueber Myrmekite. Tscherm. Miner. Petrogr. Mitt. XXVII. 1908. p. 381—382; do J. J. Sederholm, On Synantetic Minerals. Bull. Comm. géol. de Finlande. Nr. 48. 1918.

may refer to the older literature. The first six points drawn up by Becke also apply to the Surinam myrmekites. Point 7, the connection between the quantity of quartz in the myrmekite, and the composition of the plagioclase has not been further investigated. Let us add that no clear connection exists between the appearance of biotite-symplectite and myrmekite, as supposed to exist by some petrographers; the symplectite also occurs in the quartz mica diorites, in which myrmekite is wanting. In a few rocks by the side of the normal myrmekite a complication appears; in that case we observe a clear minute rim of quartz of some hundredths of a mm. round the plagioclases. The rim is only present where the plagioclase borders on potash feldspar and is wanting between plagioclase and quartz, in that case it is synanthetic in the sense of Sederholm. In Pl. 29 fig. 3 (biotite granite from Bakrabote fall, Suriname river) the plagioclase (oligoclase-andesine) shows a weaker double refraction than the quartz rim. Other plagioclases, besides the rim, show interior myrmekite. Rims which at first sight seem to be of a similar nature, and whose appearance is the same, but which on closer inspection turn out to be more strongly refracting, twinned plagioclase, are also seen,[1]) now and then.

Biotite.

As is usual in the case of granitodiorites and ortho-gneisses of the calc-alkali-series, the coloured mica invariably behaves pseudo-uniaxially with pleochroism which on the base does not appreciably differ (meroxene or lepidomelane). The idiomorphic biotite, which is often found mentioned with regard to igneous rocks does not occur in the Surinam granitodiorites, not even in the porphyritic ones, where by the side of feldspar, we should expect a well-defined generation of biotite. Of the faces of the biotite the base shows inclination towards idiomorphism. In that case the crystals cut the colourless minerals with one basal face, seldom with two basal faces, so that these faces must have been formed earlier than the minerals, which are conformable to them. Mostly, however, we meet with biotite crystals of irregular shape, with bends and indentations etc. without system, the breaks in the crystal being filled up with the colourless minerals. From this structure we may conclude that biotite in general, or in part, is older than the colourless minerals, while in many cases in which there are more or less clearly defined cavities, filled up with the colourless minerals, we must imagine a simultaneous crystallization. In many cases, however, we observe larger cavities deep in the coloured minerals, which are probably caused by corrosion. The following examples may illustrate this.

Plate 29 fig. 4 shows a fresh biotite in biotite granite from the Suriname river. The rock is a granite with a fair quantity of plagioclase showing some sequence of crystallization in respect to quartz and microcline. The crystal is cut pretty well perpendicular to the base-cleavage. Round about it lie undulose quartz (A) and ill-defined twinned plagioclases (B). Both minerals behave abnormally in respect to the biotite. The biotite only shows a very small face (C) that has possibly belonged to the base; while on that side a very large

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[1]) E.g. the granite-gneiss V. 1484 of Carolina, Suriname river.

cavity filled with plagioclase occurs in the crystal. On the opposite side the biotite is just as defective; the quartzes penetrate into it there, so that but a narrow communication is left while the biotite at (E), between quartz and plagioclase is reduced to a narrow and bent offset. Yet by optical orientation, it is proved that the different parts belong to a single crystal. The biotite-skeleton of biotite granite from the rapid of Biahatti, Suriname river shows similar structure (Plate 29 fig. 6). This crystal is also cut pretty well perpendicular to the cleavage and shows large irregular cavities bounded by curved lines, filled with the adjacent quartzes (A) while it behaves xenomorphically in respect to a well-defined plagioclase-crystal (B). A hardly isolated patch of biotite (C) also seems to belong to the skeleton, according to its optical orientation. The patches of biotite (D) and (E) originally belong to a single crystal as well, as is shown by their corresponding optical orientation, but to a large extent this biotite has now also been replaced by plagioclase. The same is seen in a biotite granite from the Feroelassi falls, Suriname river (Pl. 29 fig. 5). Although the biotite fragments hardly cohere any more, they appear to belong to one crystal, the equally oriented cleavage and polarization taken into account. The centre has been replaced by a clear quartz, forming part of a crystal that stretches far beyond the biotite, while the offset is jammed in between two plagioclases. These figures, it is true, have all three been taken from the Gran-rio granite, but they occur just as well in other granitodiorites, now more, now less clearly. That we are not concerned with accidental sections, is clear.

The same phenomenon, but with smaller dimensions also occurs: whole groups of little biotite-crystals may be pierced by perforation and cavities (Pl. 30 fig. 1, biotite-group of quartz mica diorite, lowest fall of the Miengotiri falls, Suriname river). Still intenser perforation is illustrated by fig. 34 [1]). The biotite is here penetrated by a network of numerous, very fine tubular cavities so that it sometimes has a spongy structure. Now this is the case in the whole crystal, now locally. In favourable sections we can see how quartz and plagioclase fill the channels. The fine perforation occurs principally in biotites of slight dimensions, but sometimes in the larger ones too.

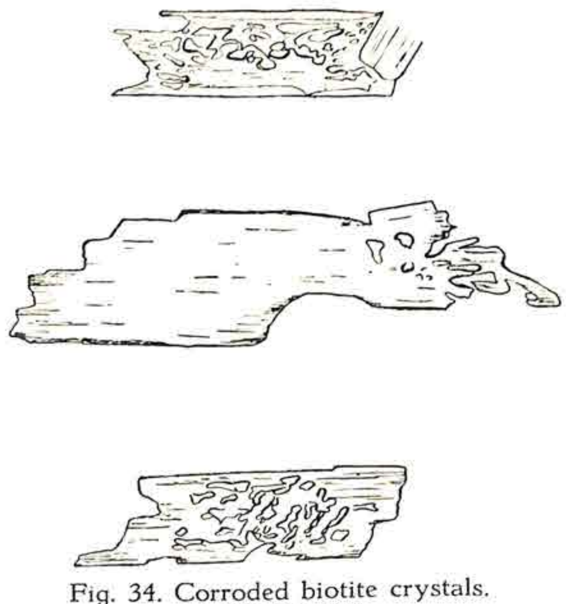

Fig. 34. Corroded biotite crystals. × 80 (Y. 33).

Either together with these phenomena or separately we fairly frequently observe in the rocks described the following: round about the irregular biotite-crystals appear small scales of the same mineral which lie in large numbers as "outposts" in the

1) Y. 14, 15, 23, 114, 343; V. 130, 865, 961, 962, 963, 1131, 1136, 1446, 1529, 1651, 1666, 1671, 1678.

adjacent quartz, plagioclase and microcline. These little scales are oriented in the same way as the larger crystals around which they are arranged. Similar pieces around the larger biotite crystals, as well as the fine, more or less vermiform penetrations mentioned above, we find in literature denoted under the name of symplectite. It may be accepted that all these phenomena, since they are connected by transitions and appear together, may be ascribed to the same cause e.g. to corrosion. Corrosion is especially probable for the outposts round the large crystals oriented in the same way as these: the magma separated the biotite remnants before the crystallization of the colourless minerals was entirely finished. For the quartz and feldspar, especially in the more delicate structures, follow the faces which are appointed to them by nature: the cleavage-planes, which they have enlarged.

Sederholm [1]) has discussed these relations for Wiborg-rapakiwi. There, too, we meet with coarse corrosion-cavities in the biotite, filled with clear minerals, and with vermiform quartz, which is regarded as a true phenomenon of corrosion (l.c. p. 116). Sederholm does not explain the small scales which lie arranged round the larger biotite-crystals, as outposts in the adjacent plagioclase, as caused by corrosion; on the contrary, he regards them as crystal-skeletons and secondary in respect to plagioclase (l.c. page 129—131). Great value is, in some cases, attached to the appearance of myrmekite together with biotite [2]). The clear connection between myrmekite and the corrosive structure of biotite does not apply to the Surinam rocks, as all the types described also appear in quartz mica diorites, in which potash feldspar and quartz-plagioclase myrmekite are wanting.

Probably all the divergent phenomena in the Surinam biotite, mentioned above, ought rather to be caused by corrosion. But there remains the difficulty of judging in how far all non-idiomorphic biotite were attacked by corrosion, since we meet with from the typical corrosion forms, as illustrated in the first three figures, all transitional stages to crystals which are not idiomorphic but fail to show the deep cavities at all. If, for instance, we go over the distribution of the biotite-types in the rocks, we shall find, for example, in the rocks collected by the expedition to the Wilhelmina mountains, that the non-idiomorphic crystals without clear corrosion-cavities predominate over the rest by far [3]). But these again are connected by transitional types with the partially idiomorphic ones, which are in the minority [4]). We might regard the partially idiomorphic biotite crystals and those, which do not show a single well-defined face, but no typical corrosion cavities either, as partly having crystallized synchronically with the colourless minerals.

The colour and the pleochroism of biotite varies considerably. The scheme of absorption is $n\alpha < n\beta = n\gamma$. Between the absorption according to $n\alpha$

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1) J. J. Sederholm, On Synantetic Minerals. Bull. Comm. géol. de Finlande, Nr. 48. 1918. p. 115—122.

2) See among others: Heikhi Väyrynen, in Bull. Comm. géol. de Finlande. Nr. 57. 1923.

3) Y. 17, 20, 21, 23, 25, 26, 30, 30 B, 33, 36, 37, 50, 51, 52, 53, 54, 57, 57 B, 62, 71, 72, 73, 79, 80, 83, 85, 86, 87, 88, 91, 92, 93 B, 93 C, 94, 96, 97, 99, 109, 114, 116, 114, 116, 118, 119, 122, 124, 130, 141, 145, 146, 177, 180, 182, 182 B, 186, 281, 288, 290, 297, 309, 315, 316, 317, 320, 327, 328, 337, 341.

4) Y. 12, 14, 15, 24, 25, 40, 47, 49, 51, 68, 69, 282, 285, 314.

and the other two axes there is much variation: $n\alpha$ mostly being yellowish-green and $n\beta = n\gamma$ green-brown in varying tints. Greener micas also appear, especially in the acid granites, sometimes even with a grass-green coulour and less strong pleochroism. Sometimes a dark-brown or chestnut-brown colour according to $n\beta = n\gamma$ and a bright-yellow according to $n\alpha$ appears, for example in the quartz mica diorites of the De Goeje mountains; sometimes even micas, which vary rather much in colour may occur in the same thin section. Possibly the sagenite-bearing micas belong to those originally containing titanium. As usual the needles are arranged according to three systems.

In general, biotite is with the base idiomorphic towards hornblende; besides this confused intergrowth with this mineral sometimes occurs, so that both were formed synchronically. A similar phenomenon is sometimes the case between biotite and diopside. In the muscovite-bearing granites, biotite is sometimes found intergrown with muscovite with parallel bases; in that case they are synchronical. Muscovite growing around biotite does not occur.

In a few biotite granites we find some muscovite as small crystals with a clearly developed base enclosed in the outer parts of much larger biotite-crystals.

Other idiomorphic inclusions are: ore, apatite, zircon, titanite, orthite and primary epidote. Pleochroitic haloes around inclusions and adjacent minerals are to be seen around zircon, apatite, titanite, orthite and epidote, but generally around the former two. Those around zircon-grains are very frequent; they are at the same time the best-developed haloes, often forming a complete circle.

Haloes with two zones are rare [1]) and when they occur we find around the grain a less absorbing field, which gradually merges into a more strongly absorbing one, forming the outside edge of the haloes. Haloes forming an irregular dark border we see especially surrounding apatite-crystals.

Peculiar mineral aggregates frequently occurring in biotite, but of doubtful primary nature, are still to be discussed. They form lenticular masses, now decidedly flattened, now again distinctly convex, invariably inserted parallel to the cleavage of the biotite. Judging from the optical properties it seems that we are not always concerned with the same material. Mostly the lenses are filled with a colourless, finely-dotted polarizing mass, an aggregate, refracting equally strongly as the biotite [2]). Other, especially flattened lenses are filled with a lemon-yellow epidote refracting more strongly than the biotite [3]). In case of the convex lenses it is improbable that we have to do with secondary minerals for were this so, a pronounced bend in the biotite cleavage would certainly have been the consequence. Moreover the lenses are usually not accompanied by secondary minerals, so that they rather seem to be of a primary nature.

Muscovite.

Muscovite is common in the granitodiorites and ortho-gneisses. In many

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1) V. 1574.
2) Y. 50, 79, 83, 97, 119; V. 1108, 1235, 1423.
3) Y. 116; V. 1194.

cases it is difficult to make out whether we are concerned with primary or secondary muscovite, for neither the habitus, nor the distribution of the mineral invariably give a decisive answer. Muscovite of an undoubtedly primary nature occurs evenly distributed in some granites, by the side of biotite and is about the same size as the biotite. This muscovite, which is macroscopically recognized as a typical element, shows defective idiomorphism; the base is here and there developed, the prism faces seldom are, or the entire crystal is irregular in shape and often frayed at the edges. Similar muscovite is present in some regions on the Upper Gran-rio, at the Saramacca river, etc. in typical bi-mica granites. Another type of muscovite that is also to be regarded as primary, is muscovite which has regularly grown together with biotite [1]): the two micas penetrating each other with parallel bases.

Of a secondary nature are certainly sericite or muscovite which we find in the plagioclase of many quartz mica diorites and granites, leaving the other minerals undisturbed; this sericite will be discussed in detail later on. Secondary is also the muscovite which is irregularly distributed all over the rock, viz. which is attached to special zones: arranged in streaks along cracks or crush-zones or appearing, where the mineral grains join each other, so that it is clear that minute openings and cracks have formed the approach for the mineral. Of a problematic nature is muscovite which neither shows regular distribution and relatively coarse shape, nor the ordered intergrowth, nor the typical local distribution, which is not confined to the plagioclases, and which is mostly present as very poorly defined crystals in many of the granites, quartz mica diorites and ortho-gneisses. For this muscovite there are no arguments available for its primary nor for its secondary character. Now and then the base of this muscovite is present and we may speak of idiomorphism; much more common, however, are irregular, patch-shaped or distinctly perforated or rosette-like scaly masses. These varying properties may account for the varying places in the sequence of crystallization which is mentioned in the literature: Rosenbusch regards the mineral as being older than the colourless minerals, Michel Lévy [2]) regards it as very late, even more so than quartz.

Another structure illustrated by Plate 30 fig. 2[3]) frequently occurs in the Surinam rocks. It shows a crystal cut approximately perpendicular to the basis and penetrated by very delicate vermiform cavities. The latter are not bound to the cleavage. In some cases we can see the clear minerals penetrate into them at the mouth of the minute channels. Quartz and plagioclase seem to form part of the filling; we are, however, unable to follow the connection with the adjacent minerals further inside, as the channels are too fine. Now the cavities are channel-shaped, now again irregular pores, but there are transitional stages. The same structure we find described and illustrated by Adams, of biotite granites from the Pelly river, Yukon District, Alaska. [4])

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1) Y. 49, 117, 120, 176.
2) A. Michel Lévy. Structures et Classification des Roches Éruptives. Paris. 1889. p. 15.
3) do Y. 284, 285, 318; V. 38, 115, 125, 176, 471, 477, 756, 765, 1664, 2366.
4) F. D. Adams. On some granites from British Columbia and the adjacent parts of Alaska and the Yukon District. Canadian Record of Science. 1891. p. 351—354.

Here the cavities are interpreted as having been caused by corrosion, and the colourless minerals have crystallized in them later on. At first I was convinced that this was the case also with the Surinam muscovite, but afterwards I had some doubts, because quite the same phenomenon occurs in muscovite whose distribution in strings along cracks undoubtedly points to secondary origin, so that magmatic corrosion is less probable.

Inclusions are rarely present in muscovite. Sometimes pleochroitic haloes appear around very fine grains, probably zircon. [1])

Amphiboles.

The granitodiorites and ortho-gneisses discussed here, only contain green hornblende. The shape of the mineral is that which we generally find recorded in petrography for the corresponding rocks. Hornblende in the granites, in the diorites rich in quartz and the corresponding ortho-gneisses shows poorly defined idiomorphism. In some cases the prism zone of the crystals is partly developed, so that we can see a few hexagonal sections in a slide, but in the majority of rocks this idiomorphism is wanting too, while well-defined end faces are invariably wanting. In the granitodiorites rich in hornblende we oftener see that plagioclase and quartz conform to hornblende, the latter showing prismatic crystals. The idiomorphism here is, however, not absolute, the rule only applies to part of the crystals: others show mutual impediment. This relatively large degree of idiomorphism also appears elsewhere in diorites rich in hornblende.

Fig. 35.

Besides the above-mentioned the following abnormal type has a fairly large distribution. Especially in the Gran-rio granites we see in the sample, by the side of coarse microcline phenocrysts, hornblende crystals of a cm. and more in size, showing no trace of idiomorphism (fig. 35). On the contrary, the borders are broken by a number of enclosed mineral-grains, plagioclase, potash feldspar and quartz, which sometimes are found even in the centre contrasting strongly with the black hornblende by their light colour. Usually these grains are rounded off, at any rate, without crystal faces. Many of these hornblendes are perforated to such an extent that they are real skeletons, which are only to be recognized as crystals by their identically oriented cleavage. Microscopically the same phenomenon is repeated in the groundmass of the granites mentioned. Plate 30 fig. 3 shows such a hornblende-crystal in biotite hornblende granite of Nieuw Goejaba, Suriname river. As is shown by its polarization, cleavage, etc. it appears that we are concerned with one crystal. Irregular cavities bounded by curved lines, are filled up with quartz (A), which in parts conforms to plagioclase (B). The latter, however, fills a cavity in the hornblende on two sides (C). The same applies to the laminated microcline (F). We see still better developed skeletons in a biotite hornblende granite of the Gran-rio (Pl. 30 fig. 4). They enclose numerous grains of quartz, plagioclase and microcline, which again show curved boundary lines. These two examples illustrate a type appearing fairly

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[1]) Y. 176.

frequently, mostly in the porphyritic Gran-rio granites, but also in other granites, quartz mica diorites and a few ortho-gneisses. From the skeletons up to the hornblende with some indications of idiomorphism, all transitional stages are met with, often in the same slides.

What may be the cause of this abnormal form? Did the crystallization of the hornblende continue so long that, to a great extent, it was synchronical with the colourless minerals? Or has the hornblende been corroded by the magma, out of which the colourless minerals crystallized? The latter is most probable in the case of the coarse hornblende phenocrysts in the Gran-rio granites. In how far this also applies to the smaller hornblende crystals is uncertain: for, if we accept it for all skeleton-like crystals, the question arises whether a great part of the hornblende in the rocks mentioned owes its lack of crystal form to corrosion, for, as has been remarked, all transitional stages between the typical skeletons and the irregular crystals exist. However this may be, the rule we often find mentioned according to which hornblende in granitic rocks crystallizes before the feldspars, does not generally apply to the Surinam rocks.

For the rest this mineral presents nothing very typically. Twins according to a face of the zone (010) — (110) occur with or without intermediate lamellae. The maximal extinction on the clinopinacoid goes up to 18°. The pleochroism varies from yellowish ($n\,\alpha$) to brown-green or grass-green ($n\,\beta$) and from browngreen, and grassgreen to bluish-green ($n\,\gamma$).

In respect to biotite hornblende behaves xenomorphically; or both have grown together irregularly and so are synchronical. Its relation with regard to primary epidote is less clear. Hornblende and green diopside have grown together and are therefore synchronic. [1]) The older minerals ore, apatite, zircon, titanite, and orthite are sometimes enclosed. The ore is now idiomorphic, now irregular in shape. Haloes are sparse [2]) in hornblende, they probably occur around small grains of zircon.

Monoclinic pyroxene.

In the granitodiorites and ortho-gneisses, in so far as they are discussed here, monoclinic pyroxene is of slight significance. Green diopside with weak pleochroism occurs in a number of the Gran-rio granites. Maximal extinction was fixed at 36°, with the aid of the Federow-stage. The form is short prismatic with a poorly defined prism-zone, while good end-faces never appear. In a few cases we observe the same shapes as in biotite and hornblende which are ascribed to corrosion. Plate 30 fig. 5 shows a coarse piece of diopside together with biotite, ortho-rhombic pyroxene, ore, and apatite in biotite granite (Sinti dam, Gran-rio). Two coarse cavities bounded by curved lines, are filled with quartz (A) and indistinctly laminated plagioclase (oligoclase-andesine) (B). Here, too, corrosion seems to be the most probable explanation. The diopside in the Gran-rio granite is of about the same age as biotite and

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1) Y. 14, 125.
2) Y. 86, 89, 114, 182 B.

hornblende; at any rate intense intergrowth with hornblende occurs [1]), while the mineral sometimes impedes biotite or behaves xenomorphically against it. Ore and apatite occur as inclusions.

Orthorhombic pyroxene.

What has been said about the monoclinic pyroxene may be repeated here. In so far as the granitodiorites and ortho-gneisses come up for discussion here, they contain no orthorhombic pyroxene of any importance. This pyroxene is present in but a few granites [2]). Pyroxenes which at the periphery and at the cracks have a tendency to change into a secondary product, show indistinct idiomorphism. The prism-zone is developed best. We see cavities penetrating deeply into the crystal, bounded by curved lines, of the same type as may occur in biotite, hornblende and diopside. In Plate 30 fig. 5 we see the same phenomena simultaneously in the orthorhombic pyroxene (A) and in the diopside (B). Plagioclase (C) and quartz (D) fill large cavities and replace what once seems to have been pyroxene. Cleavage according to (110) is clearly developed. The crystals are hypersthene, now practically colourless, now with weak pleochroism, from rose or rosy-brown (according to $n\alpha$ and $n\beta$) to light-green (according to $n\gamma$). The optical axial plane lies in the main zone.

Primary epidote.

In a great many granitodiorites and ortho-gneisses we meet with an epidote differing from the epidotes described in literature, especially by its relation to the other minerals. Pl. 30 fig. 6 and Pl. 31 fig. 1. show suchlike epidote. Where it borders on biotite, every face cuts this mineral straight off. Instead of the irregularly developed masses, which are characteristic of secondary epidote, we are here concerned with a mineral that impedes biotite as if it were wholly or partly older. Another difference with secondary epidote is the homogeneous composition. Instead of the speckled polarization-colours, which are attributed to varying iron percentages, the tint of the whole crystal is pretty well equal. So we may ask ourselves if we are really concerned with epidote here. An inquiry into its optical properties will give the answer. Plate 31 fig. 4 shows a coarse crystal that on the one side shows a tendency to idiomorphism against biotite and on the other is most irregularly bounded by plagioclase, about which more will be said. Two cleavage systems which cut each other at an angle of 60—63° are very clear and equally conspicuous. The optic axial plane lies in the face of the drawing. As the figure shows, the angle of extinction of $n\gamma$ to one of the cleavage-systems is 27—30°, that of $n\alpha$ abt. 3° in respect to the other system, all the angles being given approximately. Other sections show two cleavage systems parallel to the orthodomatic zone. The optical axial plane lies perpendicular to the same zone; the axial angle is abt. 77° rund $n\alpha$, so the optical character is negative. It is remarkable that

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1) Y. 57, 71, 79, 107 B.
2) Y. 107 B; V. 1224.

both cleavage systems, according to (001) and (100) are equivalently developed contrary to the more usual relation: according to (100) more distinctly than to (001). Twins rarely occur [1]), but in a few rocks they are numerous. [2]) The pleochroism is sometimes more, sometimes less distinct, ranging from very pale yellowish green to pretty well colourless, while the lemon-yellow colours which are frequently shown by the secondary epidote are not seen.

Table 20 I gives the chemical composition of primary epidote concentrated from a quartz mica diorite (V. 384):

	I	II
$Si O_2$	37.53	37.44
$Ti O_2$	2.70	—
$Al_2 O_3$	19.36	22.61
$Fe_2 O_3$	12.94	14.79
Fe O	1.05	—
Mn O	0.70	—
Mg O	0.43	—
Ca O	21.92	23.29
$H_2 O+$	2.09	1.87
$H_2 O-$	0.09	—
Anal. Koning & Bienfait, Amsterdam.		

TABLE 20.

The epidote-powder was not quite titanite-free. The $Ti O_2$ percentage of the analysis is, however, considerably larger than was expected. $Na_2 O$, $K_2 O$ and $P_2 O_5$ have not been ascertained owing to the slight quantity of epidote-powder available, cerium, lanthanium and didymium could not be demonstrated.

If we assume the epidotes to be a mixture of $X = H_2 Ca_4 Al_6 Si_6 O_{26}$ and $Y = H_2 Al_4 Fe_6 Si_6 O_{26}$ and calculate the composition in percentages for $X : Y = 2 : 1$, we find Table 26 II. This composition comes very near to that of our primary epidote.

Contrary to the characteristic behaviour of the primary epidote towards biotite, the first mineral namely being idiomorphic against the latter, the epidote behaves quite differently towards the colourless minerals (plagioclase and quartz) in the quartz mica diorites and corresponding ortho-gneisses and also against potash feldspar in the granites. The boundary lines are almost invariably irregular. Both the minerals penetrate each other, and at the same time pieces of epidote seem to be detached from the main crystal, but, optically, are equally oriented with it. They are surrounded by the material of the colourless minerals and lie in and in front of irregular inlets and cavities in the epidote, as if the adjacent clear minerals had forced their way in. It is obvious that these loose pieces are connected with the main crystal outside the face struck by the section of the slide. The connection of the colourless

1) V. 953, 1137, 1138, 1139.
2) V. 295, 953, 1135, 1137, 1138, 1139.

mineral, filling the cavities, with the adjacent crystals is clear by identical orientation. This penetration may go to the centre of the epidote-crystal. In that case the filled cavities are vermiform, while from one side especially they penetrate the epidote. We observe again the connection of the material in the channels and the adjacent colourless minerals at the mouth of the channels. Fig. 36 shows an epidote that borders on plagioclase (oligoclase-andesine) (a).

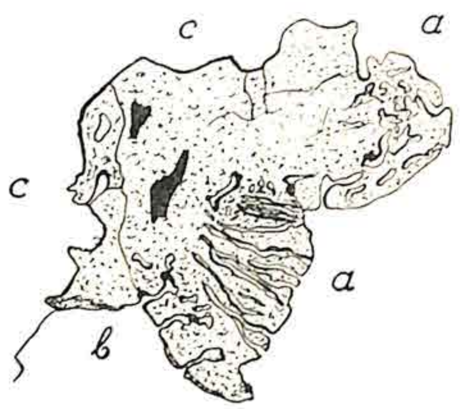

Fig. 36. Epidote showing corrosion channels. × 50. (Y. 28).

Fig. 37. Corroded primary epidote. × 140. (Y. 29).

and quartz (b) while on the other sides lie ore and epidote (c). Two grains of ore are enclosed. Both the plagioclase and the quartz penetrate the epidote. Well-defined vermiform channels provide an entrance to the plagioclase, situated on the right, and are filled with it; the quartz taking a less prominent part in the penetration. The example has been taken from a quartz hornblende diorite-gneiss, from the Madiengo fall, Suriname river.

A second illustration (fig. 37) shows an epidote which, in accordance with its general form and optical orientation, appears to be cut perpendicular to the orthodomatic zone. The slide is from an ortho-gneiss of quartz mica dioritic composition from the same findspot. Epidote is the principal coloured mineral. The surrounding plagioclase penetrates as far as the centre.

The question is whether the colourless minerals have penetrated into the epidote, or the reverse: the epidote, of secondary origin, during growth repelling the colourless minerals more and more. The latter supposition, however, must be rejected. For, as has already been remarked, well-defined crystals of epidote are present, locally disturbed at the sides, while small identically oriented grains of epidote lie in the cavities. These grains, however, must be connected with the main crystal, outside the plane the thin section has struck. It is therefore obvious that we are concerned with an originally complete and afterwards corroded epidote crystal: for the outposts of epidote do not push forward outside the space that would be taken up by the epidote crystal if it were quite completely developed. In this connection we may mention that Adams (see note 3 p. 192), discusses an analogous relation between muscovite and epidote on the one side and quartz on the other; the "loose" grains which lie around the first two minerals in the quartz, he thinks, conflict with the explanation that quartz is of later origin and that the cavities filled with quartz are caused by corrosion; for these loose grains would certainly be transferred and therefore would not remain identically oriented with the main crystal (l.c. p. 355). Since, as we have already said, the "loose" grains are to be regarded as being connected with the main crystal, outside the face struck by the thin section, this objection is removed. That we have to regard the channels and cavities in the epidote as a phenomenon of corrosion and not as intergrowth is clear from other facts. As has been mentioned above, the contact between biotite and epidote is of another type than that between epidote and the colourless minerals. Only when the latter two join each other, do cavities appear, and the phenomenon therefore is "synantetic" in the sense of Sederholm. When an epidote-crystal is partly enclosed in biotite, and partly projects from it between colourless minerals, we clearly observe the contrast between the idiomorphism of the crystal portion, encompassed by biotite, in contrast with the side which is turned to the colourless minerals; the latter side is perforated with cavities and channels, and, what is still more remarkable, it may to a large extent be dissolved: the undisturbed epidote in that case terminates just at the point where biotite, epidote, and colourless mineral touch each other simultaneously. Plate 31 fig. 5 shows a section of an epidote undisturbed on three sides where it is in contact with biotite, but considerably perforated on the fourth side, turned towards quartz, which penetrates into the channels. Fig. 38 shows another epidote, partly idiomorphic where it is surrounded by biotite, but has disappeared to a large extent where plagioclase and epidote touch each other (in gneissic quartz mica diorite from the Moesemba-prati-fall, Suriname river). Similar instances more or less well-defined are frequently met with in the epidote-bearing rocks. It is most probable therefore, that biotite in these cases has protected the epidote against a magmatic corrosion process that took place after the crystallization of biotite and epidote, but prior to that of the colourless minerals which filled the corrosion cavities. The phenomenon may at the same time be regarded as a proof of the primary nature of epidote.

Fig. 38. Primary epidote, idiomorphic as far as surrounded by biotite, corroded where bordering on colourless minerals. × 75 (Y. 25).

As we shall see, when dealing with the mineral orthite, grains of orthite are met with in the epidote and still more frequently isotropic remnants of that mineral, with cracks radiating from it (see p. 196). Similar growth of epidote around orthite has repeatedly been described, e.g. by Blomstrand [1]), Cross and Iddings [2]), Törnebohm [3]),

[1]) C. W. Blomstrand. Oefvers. af. akad. Förhandl. IX. 1854. p. 296. Ref. Journ. f. prakt. Chem. LXVI. 1855. p. 156.
[2]) J. P. Iddings and W. Cross. On the widespread occurrence of allanite as an accessory constituent of many rocks. Amer. Journ. Science. (III). XXX. 1885. p. 108.
[3]) A. E. Törnebohm. Mikroskopiska bergartsstudier. XIII. Epidotgneiss. Geol. För. Stockholm. Förhandl. IV. 1882. p. 189.

Hobbs [1]), Lacroix [2]), Adams [3]), Williams [4]), Grimsley [5]), Weinschenk [6]) and Flett [7]). Only in four cases, viz.: those described by Adams, Lacroix [2b]), Williams and Flett, does the epidote show the same corrosion phenomenon as treated above. (Lacroix speaks of "structure vermiculée", Flett mentions micropegmatitic intergrowths of epidote and quartz). Adams, Weinschenk, Lacroix and Flett express their opinion as to whether epidote is secondary or primary. Adams adheres to the first and Weinschenk, Lacroix and Flett to the second opinion. Adams assumes that the epidote has deposited itself around the primary mineral orthite after the crystallization of the quartz and has superseded the quartz. This opinion does not hold good, at any rate for the Surinam rocks, for epidote behaves idiomorphically in respect to biotite, appears as inclusions in that mineral and is therefore older, while at the same time, quartz sometimes fills up the cavities in biotite, too, and so the quartz must be decidedly of a later age than the epidote. Weinschenk, however, regards epidote, together with the minerals zoizite, orthite, chlorite and calcite, as primary constituents of the Gross-Venediger-granite, partly because this granite shows no secondary changes, which might account for the origin of these minerals, partly because of their appearance in the form of inclusions and mutual intergrowth making primary character probable.

Pöhlmann [8]), mentions primary epidote, sometimes idiomorphic, in biotite-gneisses from SW. Matto-Grosso, and Paraguay. Epidote is an important constituent of these gneisses and approaches biotite in quantity. Epidote with fine idiomorphism and at the same time showing corrosion, without enclosed orthite, is described by Williams of a mica diorite from the "Cortlandt-series", Hudson river near Peekshill, N.Y. [9]). From the illustration given (l.c. page 445) it is obvious that we are concerned with an analogous case and indeed this epidote is regarded by Williams as primary. The same corrosion is also visible in Grimsley's illustration (l.c. fig. 94) of epidote surrounding orthite crystals.

Harrison mentions the appearance of primary epidote in hornblende granite-gneiss from Br. Guiana: "the aggregates of biotite and hornblende are in places accompanied by apparently original crystals of epidote" [10]); and in epidote-

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1) W. H. Hobbs. On the Paragenesis of Allanite and Epidote as Rock-forming Minerals. Amer. Journ. Science. XXXVII. 1889. p. 223. Do. Tscherm. Miner. Petrogr. Mitt. XI. 1890. p. 1.

2a) A. Lacroix. Contributions à l'étude des gneiss à pyroxène et des roches à wernerite. Bull. Soc. franç. Minér. XII. 1899. p. 157.

2b) idem. Les granites des Pyrénées et ses phénomènes de contact (première mémoire). Les contact de la haute Ariège. Bull. Serv. Carte géol. France. Nr. 64. X. 1898—1899. p. 31.

3) F. D. Adams. On some Granites of British Columbia and the adjacent parts of Alaska and the Yukon District. Canadian Record of Science. 1891. p. 34.

4) G H. Williams. Notes sur les caractères microscopiques de certain roches du district minier du Sudbury, Canada. Comm. de Géologie du Canada. Rapport Annuel. V. 1890—91. p. 65. F.

5) G. P. Grimsley. The Granites of Cecil County in North Eastern Maryland. Journ. Cincinnati. Soc. Nat. Hist. XVII. 1894. p. 93—94.

6) E. Weinschenk. Beiträge zur Petrographie der östlichen Centralalpen speciell des Gross-Venedigerstockes. Abh. Königl. Bayer. Akad. Wissensch. XVIII. 1895. p. 733.

7) J. S. Flett. Vide: B. N. Peach and J. Horne. Chapters on the Geology of Scotland. London. 1930. p. 54.

8) R. Pöhlmann. Gesteine aus Paraguay. Neues Jahrb. Miner. 1886. I. p. 245.

9) G. H. Williams, Gabbros and Diorites of the "Cortlandt-series", on the Hudson River near Peekshill, N. Y., Amer. Journ. Science. XXXV. 1889. p. 438.

10) J. B. Harrison. **68.** p. 34.

granite-gneiss: "a noticeable feature in several of the specimens of the gneiss is the occurrence of epidote in the form of small prisms in some of the feldspars, and also as small plates surrounded by hornblende or biotite, in such a manner as to indicate that the mineral is an original product of the solidification of the magma" [1]).

Epidote intergrown with vermiform quartz and appearing between microcline and calcite, in a contact rock of granite and limestone is regarded by Sederholm as being synantetic between the minerals mentioned [2]). The rock was collected by P. Eskola in the Boikie-district. The illustration of the phenomenon shows some resemblance with the intergrowth in the Surinam rocks.

Epidote idiomorphic toward biotite is also mentioned by Heikki Väyrynen [3]). There are other phenomena which make the primary nature of epidote probable. It is a remarkable fact that sometimes we observe how a colourless mineral-grain penetrates biotite, hornblende and epidote, so that it is evident that the corrosion of all these minerals took place synchronically, from which follows again the primary character of epidote and crystallization prior to or synchronical with the colourless minerals. Plate 31 fig. 3 shows such a group: biotite, hornblende and epidote, in a quartz mica hornblende diorite from the Suriname river, below Mankwi creek. A large hornblende crystal (1) and biotite and epidote crystals of smaller dimensions (2 and 3) show no idiomorphism; on the contrary they are irregular, forming numerous bays, which penetrate deeply into them so that they are perforated in quite a number of places. The adjacent colourless minerals fill the cavities: they contain quartz marked (A), plagioclase marked (B). The smallest channels, too fine to be indicated by letters, are filled with these minerals. Especially in the epidote there are cavities and channels running most irregularly, in part too fine to be visible on the photograph. One and the same cavity penetrates both epidote and biotite, or epidote and hornblende so that there is not a single reason to presume that epidote is of later date.

As a primary mineral epidote often joins the groups of dark minerals: biotite and hornblende, together with apatite, ore, and titanite, etc. which crystallized earlier than the colourless minerals. Probably Bergt's mention of epidote in biotite hornblende granites of the Coppename also refers to this relation: „Der reichlich vorhandene Epidot is zum Teil derart mit Hornblende und Biotit vereinigt, dass man für ihn ursprüngliche Bildung annehmen muss". [4]) From other quotations, too, it appears that the remarkable character of epidote has not escaped former petrographers investigating Surinam rocks. Much epidote, partly with good crystal-shape towards biotite, is recorded by the mining-engineer Thie, in cataclastic biotite granite from the Tapanahony about 2 km. above the Jai creek mouth [5]). Idem: „epidoot komt voor als verweerings-

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[1]) J. B. Harrison. **68.** p. 35.
[2]) J. J. Sederholm. On Synantetic Minerals. Bull. Comm. géol. de Finlande. Nr. 48. 1918. p. 60; do Pl. III, fig. 13.
[3]) Heikki Väyrynen. Petrologische Untersuchungen der granito-dioritischen Gesteine Süd-Ostbothniens. Bull. Comm. géol. de Finlande. Nr. 57. 1923. p. 13.
[4]) W. Bergt. **45.** p. 137.
[5]) A. Thie. **57.** p. 149.

product, maar ook primair in zuilvormige kristallen"[1]) in a rock rich in topaz investigated by the mining-engineer Duyfjes from Akwitiki-soela near the Litani-Marowini junction[2]). Even as far back as 1885 Vélain[3]) recorded primary epidote from "amphibolites" from the Kou creek, source of the Yari.

Epidote stands in sequence of crystallization between biotite and the older minerals zircon, apatite, titanite and ore. Biotite is, as has already been remarked, often impeded by epidote, or the two minerals impede each other mutually or biotite even surrounds epidote (Pl. 31 fig. 1); so epidote is older or partly synchronic with that mineral. With regard to hornblende, the relation is seldom clear, but even in that case epidote appears to be the older. Titanite, zircon, and apatite are sometimes enclosed, while epidote sometimes has grown around ore. The colourless main components are invariably of later age.

Let us now once more resume the arguments which speak in favour of the primary character of the epidote:

1) Idiomorphism is common; especially in respect to biotite; it even appears as inclusions in the latter.

2) The presence of corrosion cavities, filled with the adjacent colourless minerals, quartz and feldspars, while biotite has frequently preserved epidote from corrosion.

3) The appearance in some cases of corrosion in all coloured minerals together; the cavities in that case being again filled with quartz and feldspar, and epidote behaving quite the same as biotite and hornblende.

4) The distribution of epidote which is comparable with that of the other coloured minerals, now evenly throughout the rock, now forming basic groups with the coloured constituents.

5) The fact of epidote not being connected with secondary minerals or processes; on the contrary, epidote is a normal primary constituent in granites, diorites, and corresponding ortho-gneisses and may belong to the most important minerals of these rocks.

Now we shall have to mention one more epidote-type. It is abundant in a few quartz hornblende diorite-gneisses especially from the Suriname river. Instead of independent, idiomorphic crystals, we observe irregular masses of epidote amidst and around the other minerals, and particularly so around hornblende. Now they take the form of narrow rims which surround the hornblende crystals which are not idiomorphic either; now again the masses of epidote extend in breadth. If the hornblende crystals in that case lie close together, epidote uninterruptedly fringes the cavities remaining among these minerals. This epidote generally appears between hornblende on the one side

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1) l. c. p. 169.
2) H. N. Duyfjes. **58.** p. 169.
3) M. Ch. Vélain. **22.** p. 490.

and plagioclase and sparse quartz on the other; so that epidote might be called "synantetic" between these minerals. At times, however, the cavities are quite closed up with epidote (Pl. 32 fig. 1). These typical rims of epidote around hornblende, sometimes also around ore, bear the character of "reaction rims", like those known around other minerals, particularly in basic rocks. What is remarkable here are the numerous fine and curved channels in epidote, so that the latter is perforated like a sponge (Plate 31 fig. 2). The diameter of these channels is very small but in some favourable sections we get the impression that plagioclase penetrates into the channels. Such sponge-like structure frequently appears in minerals forming reaction-rims. It is questionable whether this epidote is of a primary or of a secondary nature; and the same problem applies to the reaction-rims in general, the opinions of petrographers being divided. Mostly, however, the rims are interpreted as primary or deuteric: see the full discussion in Sederholm's summary. [1])

Orthite.

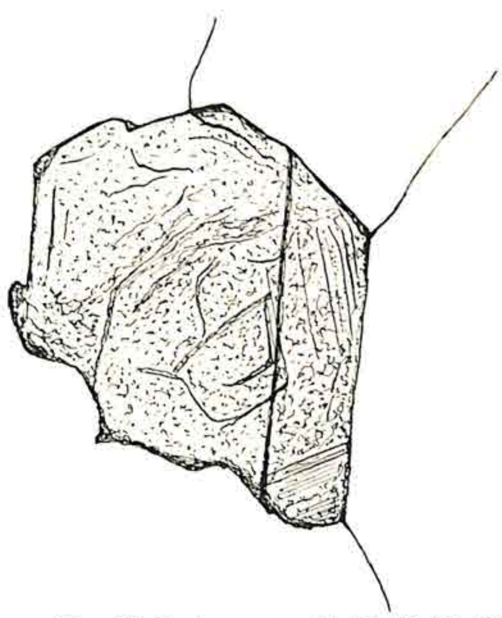

Fig. 39. Orthite-twin. × 95 (Y. 93 C).

Orthite occurs in a great many granitodiorites and ortho-gneisses without being a quantitatively important constituent. Orthite belongs to the oldest crystallization-products and is, on that account, mostly idiomorphic, although the crystals not always show finely developed faces. Perfectly fresh orthite is rare [2]) Fig. 39 shows a fresh crystal with some well-developed faces in biotite granite from Awadam, Gran-rio. It borders on quartz and plagioclase. The colour is brown with an olive-green tint and weak pleochroism. Between crossed nicols it appears to be twinned.

The crystal has been adjusted on the Federow-stage in such a manner that we look parallel to the intergrowth-plane of the twin. There are no optical axes visible in the two attainable planes of optical symmetry; the optical axes therefore lie in a plane, standing approximately perpendicular to the axis of the microscope. The angles measured are only approximately accurate as the crystal does not polarize quite homogeneously. Some cleavage is to be seen, viz. base-cleavage, which forms an angle of 61° with the intergrowth-plane. It is a twin according to (100), indistinctly developed according the c axis or a cross-section of a crystal developed according to the orthodomatic zone; in any case, the optical axes lie in the clinopinacoid. The measurement of the axial plane in another slide (from Y. 119) yielded 55° around n_α, therefore optically negative character.

[1]) J. J. Sederholm, On Synantetic Minerals. Bull. Comm. géol. de Finlande. Nr. 48, 1918.

[2]) Fresh orthite mostly enclosed in epidote or surrounded by an epidote-rim occurs in V. 142, 474, 871, 1078, 1129, 1132, 1135, 1136, 1137, 1246, 1285, 1680; Y. 7 B, 15, 16, 17, 29, 42, 60, 73, 83, 93 C, 119, 130, 315. — The grains in the numbers quoted are often very small.

The relatively coarse orthite crystal in a biotite granite from the Afitimaboe fall, Saramacca river, is beautifully developed (Pl. 32 fig. 2). It is twinned to (100), developed according to c and cut according to (010). The colour is a pale yellowish-green, with a trace of pleochroism. Although the crystal is not quite fresh, we still find an extinction angle $c - n\alpha$ of 30°, for both twins.

Smaller well-developed grains without a pronounced main zone, often enclosed in coloured minerals, may be twinned, or not [1]). They are hexagonal, about isodiametric. In some other slides coarse, also fresh but ill-defined crystals were met with. In that case the colour is brown or yellowish-brown, frequently with an olive-green tint and some pleochroism. The cleavage is rarely visible. Here and there appear pleochroitic haloes around orthite-grains in the biotite. More frequently orthite is surrounded by a rim of primary epidote or enclosed within a large crystal of epidote, so that epidote seems preferably to grow around orthite, when the latter is present. The orthite is clearly older and finely shaped. In many rocks rich in primary epidote, a grain of orthite generally of slight dimensions forms the core of most of the crystals.

As has already been remarked fresh orthite is present in inferior quantities. In by far most cases a secondary change appears; the colour fades, and the refraction diminishes, the crystal becomes more or less dimmed, accompanied by a considerable decrease in double-refraction until at length an isotropic remnant or pseudomorph is left. These remnants are pretty well devoid of colour, or show scattered rust-brown yellowish or orange-red tinted specks. Similar isotropic masses are very common in the granites etc. [2]) Now they appear independently, but more frequently enclosed in epidote. The process ending in isotropism is accompanied by an increase in volume, for around the remnants of orthite there appear radiating cracks (Pl. 32 fig. 3); these cracks may radiate far into the adjoining rock. Suchlike cracks are never observed around fresh orthite. On being polished the relics of orthite often fall out of the slides but star-shaped cracks prove that the mineral has been present.[3]).

The mineral is of later date than apatite [4]). It appears as an inclusion in the coloured minerals. Its relation to the other accessories is nowhere to be clearly observed.

Very coarse orthite crystals in an eye-gneiss from the Werekitto falls, Upper Courantyne deserve special mention. The orthite is to be recognized even macroscopically in this rock [5]), in the form of grains as large as 6 mm. having at pitchy lustre and which are locally numerous; it forms a contrast with the white plagioclase-eyes. In so far as there is any question of these coarse grains having a crystal form, they are developed according to the c-axis.

The mineral orthite did not escape the attention of earlier petrographers

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1) See e.g. V. 1479.

2) e.g. V. 200, 371, 382, 384, 393, 438, 466, 467, 564, 652, 659, 850, 932, 961, 962, 1092, 1108, 1112, 1131, 1132, 1175, 1182, 1278, 1340, 1419, 1420, 1421, 1423, 1529, 1676; Y. 12, 30, 31, 32, 33, 35, 40, 106, 252, 320.

3) e.g. V. 365, 388, 389, 865, 961, 1092, 1108, 1139, 1143; Y. 12.

4) Y. 252.

5) Y. 297.

studying the Surinam granites and quartz mica diorites, although it has never been correctly interpreted. The erroneous identification of the orthite-relics has even caused the mentioning of augite granites from the Suriname river. In the granites collected along the Suriname river between Koffikamp and Toledo augite of importance is present, according to Kloos. There is, however, according to the thin sections at Delft, no augite present in these rocks either. A confusion, partly with epidote, partly with the orthite-remains enclosed in it, must have taken place. The corroded epidote is obviously interpreted as yellow pleochroitic "augite", [1]) which „in vielen angenagten Resten in den Schliffen zu sehen ist", for on page 178 l.c. the intergrowth of "augite" with feldspar is mentioned. Also (page 177 l.c.) epidote is stated to be a secondary product of augite, the former surrounding the latter, but from the thin sections we see that we are concerned with epidote enveloping orthite and remains of orthite. The same applies to an orthite-twin in biotite granite of the Saramacca (Pl. 32 fig. 2) which has been identified as augite [2]).

Titanite.

Titanite is a common mineral in the Surinam granites, the diorites and ortho-gneisses. Sometimes we may recognize it macroscopically in the samples. In the sample the crystals are invariably idiomorphic, black-brown with a brilliant lustre; the form is that which always appears in granites: the face (123) and the corresponding ones are most strongly developed; and further (001), (101), (201) and (011) have been observed in titanite of the size of a few mm. from coarse-grained biotite granite of the Cutari (Y. 321 [3])). We meet with similar faces again in the titanite in other samples.

Microscopically titanite sometimes shows fine idiomorphism, too. [4]) Sections approximately perpendicular to the zone [123] are in that case diamond-shaped; sometimes having the (110)-cleavage [5]) which does not run parallel to the boundary of the sections. In these sections we also fairly often see pressure lamination [6]). Simple twins are found nowhere. Irregularly shaped titanite is more common [7]). Two illustrations may show this. Pl. 32 fig. 5 shows a piece of titanite in a biotite hornblende granite from the Pikien-rio. The colour is brown; many rough cracks are present. The mineral borders on dusty microcline and dusty quartz, plagioclase, hornblende and irregular ore. The form in respect to hornblende is rectilinear. Its relation to quartz and microcline is different. The boundary-line with respect to microcline runs irregularly, and even more so with respect tot quartz and untwinned plagioclase. Especially with regard to the latter it runs most irregularly, we observe cavities near

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1) Kloos. **28**. p. 176—179.
2) C. Moerman. **54**. p. 287, Nr. 15.
3) do. in G. 265. 1923; V. 1183.
4) Y. 3, 5, 7, 7 B, 13, 42, 57 B, 242, 285, 327, 341.
5) Y. 7 B, 327.
6) Y. 42, V. 376, 467, 960, 1078, 1087, 1092, 1097.
7) Y. 16, 31, 38, 39, 40, 49, 73, 75, 82, 93, 209, 252, 302, 314, 316; and many from other collections.

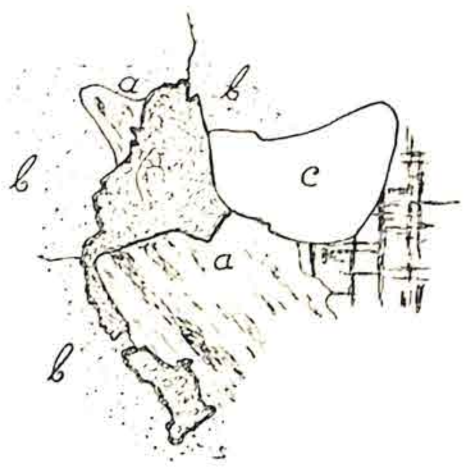

Fig. 40. Corroded (?) titanite × 100 (Y. 75).

(A) in the titanite, filled with plagioclase; near (B) with microcline. With regard to quartz we see the same near (C).

Another irregular titanite (fig. 40) occuring in a fine-grained biotite granite of the Pikien-rio, is bounded by plagioclase (b), clear quartz (c) and vaguely laminated microcline (a). Similarly shaped titanite is by far the commonest. Now we see a single or a few idiomorphic crystals in the same slide by the side of those which have wavy boundaries and only here and there an idiomorphic face, now all are devoid of any sign of idiomorphism.

This behaviour is therefore contrary to the general rule: excellent idiomorphism.

It is the question therefore, whether the mineral belongs to the first segregations, or crystallized simultaneously with the minerals in respect to which mutual impedement appears: plagioclase, quartz, and potash feldspar. In many cases indeed the latter seems to be the case, at any rate, with the borders of the titanite. What is striking, however, is, that cavities deeply penetrating the titanite and filled with the colourless minerals mentioned, commonly occur. This is probably due to corrosion-phenomena, implying that titanite, at any rate in these cases, is older than the minerals filling the cavities. It is even not impossible that all the irregular pieces of titanite, are the result of corrosion, and in my opinion this is more probable. It is a well-known fact that the sequence of crystallization and also the form of various minerals in a rock will sometimes change with changing quantities in which the minerals are found, e.g.: minerals such as titanite, zircon, [1]) and apatite [2]), nearly always present in slight quantities, and crystallizing first, will sometimes, when they occur in extraordinary quantities, lose their characteristic idiomorphism, or enclose other minerals, in very divergent types of rocks. Especially titanite in that case crystallizes considerably later than usually and conforms entirely to feldspar, pyroxene and nepheline. The defective idiomorphism in our case, however, is not accompanied by abnormally large quantities of titanite. It may be that a few rocks are exceedingly rich in this mineral [3]), but as the phenomenon likewise occurs in the other titanite-bearing rocks, a direct connection between the quantity of titanite and the defective form cannot be ascertained.

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1) c.f. J. Morozewicz, Tscherm. Miner. Petrogr. Mitt. XXI. 1902. p. 246.
S. J. Shand. Trans. Geol. Soc. S. Africa. XXIV. 1921. p. 121, 123.
2) M. A. Lacroix Nouvelles Archives Mus. d'Hist. Nat. Paris. (IV). IV. 1902. p. 11, and Pl. VI, fig. 4.
K. van Chrustchoff. Tscherm. Min. Petrogr. Mitt. VII. 1888. p. 488.
J. P. Iddings. Bull. Phil. Soc. Washington. 1889. p. 85.
W. S. Bayley. U.S. Geol. Survey. Bull. 109. 1893. p. 47.
P. A. Wagner. The Diamond Fields of Southern Africa. 1914.
3) V. 1181.

There still remains to be mentioned that now and again true skeletons of titanite occur, lying in and among other minerals and so finely elaborated, that only the polarization indicates that we are concerned with one crystal.

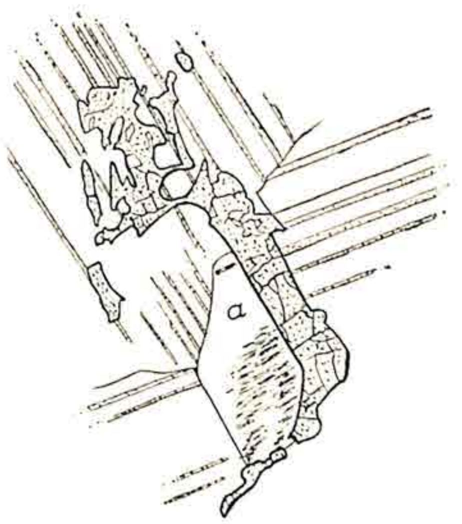

Fig. 41. Titanite skeleton. × 75 (Y. 91).

Fig. 41 shows a skeleton surrounded by twinned plagioclase and in part by microcline (a). The question remains, whether we are concerned here with an exceedingly far advanced corrosion form or a primary crystal skeleton. The illustration has been taken from a biotite granite from the Gran-rio. Another finely frayed skeleton we find enclosed in microcline, in biotite granite collected near the Upper-Lucie river (V. 1899).

Titanite varies considerably, ranging from being pretty well colourless to different tints of brown, reddish-brown, cinnamon-brown etc., which variation possibly corresponds, with a considerable change in its chemical composition. The mineral is frequently found in groups together with coloured ones. If it borders on biotite insignificant pleochroitic rims sometimes appear in the latter [1]). Rims of titanite appear fairly often around ore [2]), the ore often being irregular in shape and to some extent distributed in the titanite in the form of dust; in this case we are probably concerned with a demixture of titanomagnetite. In other cases again the ore is idiomorphic.

In the sequence of crystallization titanite comes after apatite [3]), zircon, and ore [4]) which appear in it as inclusions, but before the coloured minerals. Its relation to orthite has nowhere been observed.

Ore.

As usual, ore is always present in the granitodiorites and ortho-gneisses. A few granites and quartz mica diorites, however, are ore-free. Judging from its octahedral form, this ore is either magnetite or titanomagnetite; crystal-skeletons are wanting; also well-defined twins. By the side of the octahedral form there occur irregularly rounded off or irregularly angular forms. Here and there ore of an other type was found. Pl. 32 fig. 6 shows a piece of ore in acid diorite-gneiss from the Miengotiri falls, Suriname river. It has a magnetite-lustre and is surrounded by plagioclase (oligoclase or oligoclase-andesine) and quartz. The piece bends round an adjacent plagioclase (A) and besides this sends out an apophysis (B) between the latter and a piece of quartz (C). This behaviour causes us to suppose that the crystallization of ore went on for a very long

[1]) Y. 7, 341.
[2]) Y. 20, 28, 33, 36, 80, 91, 209, 252.
[3]) Y. 57 B, 209; V. 1087, 1092.
[4]) Y. 209; V. 1092.

time. Ore shows another deviating phenomenon in a biotite granite of Orohosso soela, Pikien rio (Pl. 32 fig. 4). Plagioclase (oligoclase-andesine) (A) and quartz (B) fill rounded-off cavities in the ore, which shows wavy contours against the colourless minerals. It is not improbable that this ore is ilmenite. [1])

Part of the octahedrons is, undoubtedly, titanomagnetite, since titanite-rims appear around them; [2]) the ore is often frayed at the edges or lies spread as irregular remains in the titanite.

In so far as octahedrons are developed, ore belongs to the oldest segregations, but has been formed later than apatite [3]) and zircon, and is older than titanite. [4]) Its relation with regard to orthite is unknown.

Pyrite.

Of the sulphurous ores pyrite only has been found, which is fairly common and frequently to be recognized by its lustre in the sample. It has a good form or is irregularly intergrown with magnetite; in the latter case it is certainly of a primary nature. This ore, too, belongs to the oldest segregations and is, sometimes even enclosed in titanite.

Apatite.

As in all the granitic and dioritic rocks, apatite is a wide-spread constituent. In some quartz mica diorites and a few granites rich in biotite and hornblende, apatite is conspicuous by its abundance, [5]) while in a few acid granites of the Central Wilhelmina mountains [6]) only after a long search some apatite was found, so that practically speaking it is absent.

Short, well-defined minute hexagonal columns are common; in other cases irregular ones and coarse pieces [7]). The mineral is invariably colourless, except in a few cases where black dust [8]) or extremely fine brown dust [9]) is found enclosed. In the latter case there are also oblong cavities filled with gas or liquid trending parallel to the prism-zone. In a single coarse apatite-crystal there are liquid-inclusions with a vibritale bubble to be seen [10]). Traces of corrosion in apatite occur fairly frequently. The characteristic cross-fractures are fairly common. Pleochroitic haloes appear fairly often in rocks rich in apatite around that mineral. In biotite in that case we observe dark rims around the crystals, which never show such distinct zonal structure, however, as the haloes round zircon. On account of its idiomorphism in respect to other minerals apatite belongs to the oldest segregations, older than titanite [11]), ore [12]), pyrite [13]), and

1) Y. 15, 72, 80, 92, 182; V. 1200, 1202, 1290, 1419, 1422, 1680.
2) Y. 16, 20, 21, 24, 28 etc.
3) Y. 15, 53, 85.
4) Y. 209.
5) V. 1876.
6) Y. 196, 198, 199, 201.
7) Y. 32 C.
8) Y. 145.
9) Y. 62.
10) Y. 71.
11) Y. 23; V. 1092.
12) Y. 15, 53, 85, 175.
13) Y. 175, 175 B.

orthite [1]) in which it repeatedly occurs as inclusions, while it is also met with enclosed in monazite [2]). Its relation to zircon is unknown.

Zircon.

One of the most generally distributed minerals, although never quantitatively of importance, is zircon.

Various types of this mineral occur. Zircons that show a rough surface relief in the slides are commonest. Their shape is prismatic, either longer or shorter, and almost invariably without well-defined terminal faces, instead of which there are curved planes. It is possible that the latter are the result of simultaneous appearance of pyramid planes with various indices. If, besides this, the prism-zone is very short, the crystals are rounded-oblong. The size observed in slides is mostly smaller than 0.20 mm., while the largest measurements found are 0.41 mm. (V. 1209). Still larger crystals were observed in the heavy concentrations from crushed granite samples. On the whole this zircon is relatively coarse and therefore soon catches the eye.

Often this type of zircon has a well-defined zonal structure [3]). It does not betray itself in the least by a disturbance of the polarization-colours, but only by dark concentrical lines which follow the crystalcontours (Pl. 33 fig. 1). Zircons of this type form pleochroitic haloes especially in biotite and rarely in hornblende. Another type, also of wide distribution, is formed by very fine crystals, which by their brilliant lustre attract attention. They show a prism-zone which is either long or short, with terminal pyramids, mostly several together. Similar crystals are found in the majority of rocks, when closely examined, and enclosed in all clear and coloured minerals, except in apatite, orthite, and titanite. It is especially these fine crystals that cause the general distribution of small haloes in biotite, and the rarer ones in hornblende and muscovite etc.; at any rate, it is probable that in this case we are concerned with zircon.

Occasionally the same glittering and sharply defined crystals occur in a longer shape: needle-shaped: 0.015—0.030 mm. long [4]); probably they are also zircon.

Zircon is the first mineral that crystallized, with the exception of apatite, in respect to which the relation is unknown. It is older than ore, orthite, monazite, titanite and any other mineral.

Monazite.

Monazite is nowhere recorded in the Surinam literature. It seems to be a fairly common but quantitatively insignificant constituent of the granito diorites. In most cases it is anything but easy to recognize the mineral in the thin sections both on account of its small size and its likeness to zircon. Any-

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1) Y. 252.
2) V. 1195.
3) Y. 28, 30 B, 141; V. 1088, 1184, 1189, 1196, 1227.
4) Y. 80.

one intending to examine the monazite in slides will be well-advised to begin with the rock-numbers mentioned at foot in which comparatively coarse monazite occurs.

The mineral shows no distinct crystal-shape. We see rounded-off pieces of different shapes. Some crystals are oblong and developed according to the c-axis; mostly, however, they are sub-isodiametric. In that case we see diamond-shaped sections with rounded-off angles in the slides (Pl. 33 fig. 2). So the Surinam monazite does not show the typical idiomorphism which is generally emphasized in petrographical literature. Indistinct cleavage is frequent.

The mineral is colourless in the thin sections. In concentrations from crushed rock-samples it is yellow or yellowish-brown and shows some pleochroism. It is biaxial and positive and has a very small axial-angle so that the cross only just opens if one turns the stage of the microscope [1]). Indistinct pleochroitic haloes occur locally in biotite if it borders on monazite.

By the side of fresh monazite we sometimes see a transformation constantly moving on inward and contrasting with the fresh centre. In that case we observe a brownish, but slightly transparent rim [2]), often an oval or a circle corresponding to the rounded-off shape of the grains (Pl. 33 fig. 3). Similar rims on being more highly magnified (V. 1200) turn out not to be isotropic, but to consist of a radially built, fibrous and doubly-refracting material. Although zircon may in the same way pass into isotropic substance, (the so-called malacon), this was never seen in the Surinam zircon and so this phenomenon may serve here as a means of recognizing monazite.

The largest sizes found in slides are 0.45 mm. (V. 1220) and 0.36 mm. (V. 1198).

In sequence of crystallization, monazite ranges after zircon and apatite, for these minerals are met with as inclusions (Pl. 33 fig. 4).

We often see both zircon and monazite in the same rock. In that case it is the zircon with the zonal structure, mentioned on page 201. This is, however, not a constant association, for the minerals occur separately also.

To distinguish monazite in slides from zircon may be very difficult when the crystals are small, the crystal-form of zircon is wanting, and the monazite does not show the transformation at the border. When both minerals occur in the same rock as rounded-off small grains, it is impossible to tell, which is which, and the surest way is crushing the rock sample and examining the heavy mineral-crop, in the same way as has been discussed for monazite from the latest deposits (see p. 40).

Garnet.

The granitodiorites and ortho-gneisses under consideration rarely contain garnet. It occurs as insignificant grains, only to be recognized microscopically,

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[1]) A convincing interference figure is seen in thin section D.D. 1041 (V. 1200) and in D.D. 1031 (V. 1189), at the border of the slide.

[2]) Y. 71, 89, 99; V. 2345.

either pale red or pretty well colourless. The crystal form is indistinct or entirely wanting. The crystals sometimes enclose irregular grains of quartz.

Accidental components.

In connection with the previously mentioned minerals we may still record a few which are not of secondary origin in the granitodiorites, but are rather to be regarded as derived from insignificant enclosed and recrystallized material; these minerals do not belong to the characteristic mineral combinations either. We refer to *sillimanite, cordierite,* and *andalusite.*

Sillimanite appears fairly often in the form of very insignificant needles with the well-known pseudo-square cross-sections, or as entangled tufts of hair (fibrolite). Both types occur enclosed in muscovite crystals, in rocks whose ortho-nature, for the rest, does not admit of doubt.

Cordierite. Very occasionally isolated pseudomorphs of cordierite are met with.

Andalusite. The combination of bundles of sillimanite-needles, together with some pale rose pleochroitic andalusite crystals, prismatically developed, and a single cordierite pseudomorph in a gneissic granite (V. 1241) from the Tapanahony, is noteworthy.

II. THE GRANITES AND ORTHO-GNEISSES OF THE GRAN-RIO MASSIF.

INTRODUCTION.

The Gran-rio granites occupy an extensive region in the centre and South-East of the Colony. In the North-East and North of this region, the granites alternate locally with acid diorites (the so-called diorite facies) and all form together the "Gran-rio massif".

The Gran-rio granite in its most typical form is biotite or biotite hornblende granite, mostly without pyroxene. Besides these there are quite a number of other types: sparse forms containing hornblende exclusively as coloured mineral (hornblende granites), a few bearing an abnormal quantity of pyroxene (pyroxene granites) and many with primary muscovite by the side of biotite (bi-mica granites). Others on account of a decrease of the coloured minerals approach aplites, others, through an increase of the coloured minerals are more basic, others again by an increase of plagioclase and decrease of potash feldspar become granodiorites, while a still further decrease of potash feldspar locally yields quartz mica and quartz mica hornblende diorites.

By the side of mineralogical variations important structural differences occur: we know a small number of gneissic granites, as well as granite-gneisses in the massif. In this chapter the granitic rocks and the corresponding ortho-gneisses of the massif will exclusively occupy our attention. We will first describe the typical Gran-rio granite and next the more important types of the related ortho-gneisses. Then we shall treat the granitic core of the massif in view of its geographical extension. In doing so, we shall get an idea of the variability of the granites and of the relation between them and the acid diorites and ortho-gneisses which occur together in the massif.

So the scheme will be:

1) Description of the typical Gran-rio granite.

2) Description of the corresponding ortho-gneisses.

3) Geographical distribution of the different types.

DESCRIPTION OF THE TYPICAL GRAN-RIO GRANITE.

Typical representatives of the Gran-rio granites are either with or without coarse phenocrysts of microcline lying in a normally-grained variegated ground-mass, which, on closer inspection turns out to consist of quartz, microcline, plagioclase and biotite, often accompanied by green hornblende, with granular massive texture; so the mineral combination is that of biotite or biotite hornblende granites, with typical granitic texture. As was observed during our expedition porphyritic and non-porphyritic granites alternate locally with each other; now there are many phenocrysts, now few or none at all. Consequently it is rational to treat both the porphyritic and the non-porphyritic facies at the same time, the more so, as many samples, collected by other expeditions, are very small; so that the lack of phenocrysts does not at all prove that the sample comes from a region where no phenocrysts are present. See for the coarse microcline phenocrysts p. 174. Microcline also invariably occurs in the groundmass (see p. 175).

Plagioclase, in the typical rocks, has the composition of oligoclase-andesine, (or deviates a little from it, in which case it is mostly somewhat more acid); or that of oligoclase and rarely of albite-oligoclase. The twinning structure is always clearly developed, in by far most cases there is twinning according to the Albite law. Traces of zonal structure are very rare. Some antiperthite is often visible (see p. 180). Inclusions of various sorts, all described on page 179 have a fairly wide distribution in the typical form of the Gran-rio granite. Myrmekite between plagioclase and the adjacent potash feldspar often occurs.[1]) Quartz calls for little comment. It often shows strings of liquid inclusions with vibritale bubbles.

The quartz rarely has a milk-blue colour (e.g. locally on the Upper Gran-rio) instead of the common gray one.

The quantitative relation of quartz, microcline, and plagioclase is such that plagioclase invariably belongs to the essential components and in the typical Gran-rio granites is mostly approximately equal to the quantity of microcline; in this respect, however, there is rather much variation, but on the whole we may say that typical rocks possess an over-measure of plagioclase with regard to microcline rather than the reserve; this goes so far that sometimes we meet with but a few pieces of microcline in the groundmass [2]) per thin section. It is but seldom that plagioclase is decidedly inferior in respect to microcline. The sample in that case mostly has a more aplitic appearance on account of the diminution of the coloured minerals.

Apart from porphyritic microcline the rocks are mostly normal-grained. [4])

The sequence of crystallization is relatively little developed. On the whole we meet with no pronounced idiomorphism of plagioclase. The commonest is a plagioclase with a few idiomorphic faces and angles towards microcline and quartz, hence partially idiomorphic. Exceptions, in the form of well-defined idiomorphic plagioclases, occur, however, pretty often. Besides this, the small plagioclases, enclosed in the microcline phenocrysts, show idiomorphism. In many typical Gran-rio granites, however, indications of earlier crystallization of plagioclase are mostly insignificant. This applies even more to microcline and quartz mutually. Microcline is very rarely idiomorphic towards quartz, the two mutually hindering each other. This does not apply to the phenocrysts. These are idiomorphic, but at the sides often enclose pieces of colourless and coloured minerals which points to the fact that the growth of the phenocrysts had not

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1) e.g. V. 961, 962, 963, 1093, 1230, 1235, 1247, 1291, 1369.
do Y. 40, 89, 168.
2) e.g. V. 1087, 1088; do Y. 54, 73, 73 B, 93 C.
3) Y. 61.
4) > 5 mm. is taken for coarse grain.
< 5 and > 1 mm. for normal grain.
< 1 mm. for fine grain.

yet come to an end when the groundmass crystallized. Clear crystallization sequence: plagioclase, microcline, quartz, rarely occurs. [1]).

Biotite, with or without hornblende, forms the coloured main constituent of the typical granite; sometimes an important percentage of diopside is found with it, while hypersthene rarely occurs. They never show distinct idiomorphism: deep cavities often appear, of such a nature, that they were probably caused by magmatic corrosion (see p. 181 tot 182). Biotite of a greenish-brown tint is most common; often, too, brown [2]) or green tints [3]), occur all of them in the position of strongest absorption. Pleochroitic haloes, around zircon, apatite, and orthite are frequently met with.

Green hornblende shows great difference in size. In some typical Gran-rio granites, by the side of microcline-phenocrysts, coarse hornblende skeletons of the type illustrated and discussed on page 186, occur. In the typical granites, however, hornblende is nearly always restricted to the groundmass. Neither is hornblende idiomorphic in that case, with the occasional exception of the prismatic zone.

Most typical Gran-rio granites appear to be biotite granites. Next to these, however, there are a good number, containing some hornblende [4]) as well, and many which bear about as much biotite as hornblende, hence they are biotite hornblende granites. [5]) Green diopside is of little significance in the typical granite. It appears by the side of biotite [6]), more frequently by the side of biotite and hornblende [7]) and sometimes by the side of biotite and hypersthene [8]). It is occasionally present in such quantities as to form half of the coloured minerals. [9]) Hypersthene is of little significance.

Of the accessory minerals, two are interesting, namely primary epidote and orthite. They are widely distributed in the Gran-rio granites, both in the typical and in the divergently developed rocks, although not always present, and quantitively insignificant.

The behaviour of and the arguments for the primary nature of this epidote have been discussed in detail on p. 188 [10]). Orthite frequently accompanies primary epidote, as a more or less idiomorphic nucleus in the latter. By the side of it we also see the mineral alone (see for details p. 195).

The other accessories of the typical Gran-rio granites are ore, apatite, zircon, monazite and titanite. Ore is always present, now clearly octahedral, now irregular in form. The latter is especially the case in the coarser pieces (ilmenite?). Sometimes a titanite-rim appears around the ore, which suggests a demixture of titano-magnetite. This is sometimes the case both with the

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1) V. 1247.
2) among others: V. 1230, 1235; Y. 72, 73, 73 B.
3) V. 1269, 1270.
4) e.g. V. 960, 962, 1258; Y. 57 B, 73, 73 B, 86, 89, 91, 168, 169.
5) e.g. V. 1093, 1247; Y. 40, 42, 53, 59, 71, 72, 74.
6) Y. 69, 79, 88, 109; V. 1234.
7) Y. 53, 57, 71, 72, 73, 73 B, 74; V. 1201, 1202.
8) Y. 107 B.
9) Y. 73.
10) The fairly wide distribution of primary epidote in the granites of the Gran-rio massif, taken as a whole, is evident from the quantity of numbers: V. 226, 293, 294, 295, 299, 300, 365, 372, 376, 379, 747, 767, 953, 954, 955, 956, 961, 963, 1081, 1087, 1088, 1157, 1182, 1237 1242, 1337, 1744, 1746; do Y. 40, 48, 93 B; do C. 85.

octahedral and the irregularly shaped ore. Apatite is always present, prismatic or in irregular grains and sometimes in relatively large quantities; it is always easily recognizable in connection with the fairly significant size of the grains in these rocks. The latter is also true for the accessory zircon. Here we see the coarse zircon with occasional zonal-structure mentioned on page 201 and although not always present yet this zircon is a typical constituent of the Gran-rio granites. [1]) Monazite is very characteristic in several typical Gran-rio granites, but is generally difficult to identify (see page 201). Titanite, too, is widely distributed but not always present in the typical Gran-rio granites. Sometimes it is beautifully idiomorphic [2]), sometimes irregular in shape [3]). Brown titanite is the commonest, now occurring in coarse pieces [4]), now in smaller ones mostly varying with the size of the grains of the rock itself. In some samples the mineral may be recognized by its size and beautiful shape (Y. 42, 42 B). In the typical Gran-rio granites the accessories muscovite and pyrite are of very little importance. Some muscovite is regarded as being of a primary nature, when it has systematically intergrown with biotite according to the base. Sulphidic ore excelling by its idiomorphism is met with here and there. [5])

If we arrange the sequence of crystallization for the Gran-rio granites we find: the accessories (zircon, apatite, monazite, orthite, ore, pyrite, titanite), then the coloured minerals (primary epidote, biotite, hornblende, monoclinic and orthorhombic pyroxene and muscovite), lastly the colourless constituents (plagioclase, now clearly earlier, now less clearly so than microcline and quartz, and sometimes contemporaneous with them; the same varying relation holds for microcline and quartz together). The sequence of crystallization corresponds to the summary given, taking the following into consideration. The sequence of zircon and apatite is nowhere observed; both, however, occur as inclusions in monazite. We know that orthite is of later age than apatite, but the relation of this mineral in respect to the other accessories has nowhere been clearly made out. Ore is, in its turn of later age than apatite and zircon and this also applies to pyrite in so far as it occurs intergrown with ore. Titanite is of later age than apatite, zircon, orthite (?), and pyrite: this not only applies to the irregularly shaped titanite, but has also been observed with regard to a few idiomorphic sections. Possibly the growth of the coarser pieces has continued into the period of the coloured minerals. Primary epidote especially with regard to biotite is earlier, the relation in respect to hornblende is less clear. The rest of the coloured minerals seem to be contemporaneous; at any rate, they are found intergrown. They are partly earlier than the colourless minerals which is shown now by idiomorphism, now by corrosion-structures.

The texture is massive. Only in a few samples do we see equal trend of the microcline-phenocrysts: the faces (010) are more or less equally directed

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[1]) e.g. V. 961, 962, 1087, 1088, 1093, 1097, 1098, 1182, 1227, 1230, 1235, 1247, 1258, 1265, 1314; Y. 40, 53, 54, 57 B, 72, 88, 89, 93 C, 130, 141, 168.

[2]) e.g. V. 1087, 1092, 1258; Y. 40, 42.

[3]) V. 961, 1088, 1182, 1234, 1235, 1247, 1265, 1269, 1270; Y. 40, 53, 57 B, 59, 73, 73 B, 91, 93 C, 129.

[4]) e.g. V. 1087, 1092.

[5]) V. 1092, 1182, 1227, 1234.

in that case. This texture is more frequently visible in the field; some parallel trend is also shown sometimes by biotite. The size of the grains in the groundmass varies from 1 to 4 mm. but also rocks of coarser grain (5 mm. and more). appear locally. In types having grains smaller than 1½ mm. the phenocrysts also disappear: no rock is fine-grained and porphyritic at the same time.

DESCRIPTION OF THE ORTHO-GNEISSES OF THE GRAN-RIO MASSIF.

Representatives of the ortho-gneiss facies of the Gran-rio granites are mineralogically identical with the granites. Structurally they have typical gneiss-characteristics, however. Porphyritic forms are lacking. Texturally they are massive, or show more or less distinctly parallel texture.

A few typical representatives are described here:

a. *Massive types.*

Judging from the massive sample which is from medium to fine-grained, a series of rocks collected close together between the Lawa and the Tapanahony, might be taken to be normal biotite granites (V. 86, 115, 117, 118, 821). The microscope shows us a combination of quartz, acid plagioclase, microcline and biotite; whilst the accessories are primary epidote, ore, apatite and a very small quantity of zircon; traces of isotropic orthite-remnants may also occur. There is no idiomorphism of the main components. The boundaries of the colourless minerals are now undulating, now angular; the general impression is that they are highly irregular. On the other hand, because locally some idiomorphic faces may be seen in some of the rocks mentioned, it may be said that they are related to the normal granites structurally. Holding to the fact that the absence of sequence of crystallization is characteristic of gneiss-structure, these rocks are ortho-gneisses (Pl. 33 fig. 5).

Another specimen was collected West of the Marowyne creek (V. 1676). It is medium-grained, without any parallel texture and looks like biotite granite poor in biotite. The microscope shows that is consists of much microcline and quartz, less plagioclase (oligoclase), little biotite, and some muscovite. The accessories are octahedral ore, zircon, and a pretty large number of orthite-crystals which have completely changed into an isotropic substance. The three colourless minerals are separated from each other by irregularly curved lines and penetrate each other frequently with patchy shapes. On the one hand we have typical gneiss structure here. On the other hand we are again reminded of granite-structure by the plagioclases, which show a tendency towards idiomorphism.

b. *Types with parallel texture.*

An excellent specimen is a granite-gneiss of the Paloemeu river, found three km. below the Weliok fall (V. 1196). The fine-grained sample shows indistinct parallel texture in consequence of the equal orientation of the biotite-leaves. The microscope shows that it contains nearly equal quantities of plagioclase, quartz and microcline. There is a good quantity of biotite; the accessories are ore and zircon, while no apatite has been found. The plagioclase (approximately oligoclase-andesine) has normal twinning and is strikingly bright. In those places where it is found side by side with potash feldspar it is here and there surrounded by myrmekite. The quartz does not show any pecularities. The microcline has splendid grating-structure. Disturbances by pressure are practically absent. The colourless minerals show no sequence of crystallization. On the contrary the boundaries are irregular, partly angular, partly undulating (Pl. 33 fig. 6). Rounded-off grains of relatively large size (quartz and microcline) often occur enclosed in the non-corresponding minerals. Only a few biotites show the basal face, by far the greater part are patchy with rounded perforations through which the colourless minerals are visible. Here and there the ore shows octahedra, but more commonly it is irregular in shape. Zircon occurs in rounded-off grains.

Another type of granite-gneiss, which is also related to the Gran-rio granites, occurs at the foot of the great fall above Kaboeba dam, Gran-rio (Y. 123). It is a fine-grained rock, showing distinct parallel texture, the dark minerals, which are found in pretty small quantities, being oriented in the same way and lying in the same planes, along which the sample breaks. The microscope shows much microcline and quartz, very little plagioclase (oligoclase), biotite and a little muscovite. Ore is scarce, pyrite however more frequent. The texture is not only caused by the parallelly oriented biotite leaves, but also the colourless minerals are not quite isodiametric, showing the same orientation as the biotite. The colourless minerals show no trace of idiomorphism, the boundary lines being either undulating or angular, whilst the grains differ but little in size, so there is a typical ortho-gneiss structure.

The quartz betrays some disturbance caused by pressure.

The next gneiss is found on the Bata falls, Suriname river (Y. 35). In the sample which is from normal to fine-grained, some parallel texture is visible. The small quantity of biotite shows parallelly oriented leaves (Pl. 34 fig. 2). The parallel texture is also seen in the whole rock-mass in the field, the trend being about N-S, dipping 70° W.

The microscope shows that the rock is composed of microcline, quartz and plagioclase in nearly equal quantities; the coloured minerals are some biotite and epidote; the accessories are some ore, apatite and zircon. The plagioclase (about oligoclase) shows vague lamellae, sometimes there is no twinning at all. The quartz shows strings of fine inclusions. The three main components do not show any sequence of crystallization, the boundary lines having an undulating or angular course. Besides, the size of the grains varies considerably. Very often small irregular or rounded-off grains of one mineral are found in another (Pl. 34 fig. 1). The basal face of the biotite is pretty often developed. The parallel orientation of the biotite chiefly causes the parallel texture in the slides; the colourless minerals take no part in it. Primary epidote and orthite form the well-known combination. Orthite-grains are enclosed, in epidote, partly as isotropic remnants. The epidote may show idiomorphism against biotite. It also shows corrosion forms; in a word all the characteristics described on page 188. There are only slight traces of ore; besides these there are a few rounded-off grains of apatite and zircon. Signs of pressure are limited to slight undulose extinction in quartz.

SOME CHEMICAL DATA ON THE GRAN-RIO GRANITES.

The subjoined table gives the chemical composition of some Gran-rio granites. The Niggli values have been added.

The first three columns of the first table concern typical Gran-rio granites, partly porphyritic. Chemically the rocks are to be classed with the granites in a wider sense. On comparison with Niggli's magma-types the first rock is found to agree with the yosemititic magma-type, the second and the third with the normal-granitic and with the granodioritic type. The last two magma-types are scarcely to be separated. The value mg of the granite Y. 73 is rather high owing to the occurence of hornblende and pyroxene. In the third rock the plagioclase is relatively rich in calcium (oligoclase-andesine), which appears from the c-value.

The last two rocks of the first table show a composition not typical of the Gran-rio granite, but they are derived from the Gran-rio massif. The rock V. 1285 belongs to the more acid type which inter alia finds a large distribution along the Saramacca river. The low c-value corresponds with the highly acid composition of the plagioclase, and the high k-value with the large potash feldspar percentage of the rock. It is the engadinitic magma-type of Niggli.

The last rock of the table is a granite-gneiss from the area between Tapanahony and Gonini (V. 391). It is an anomalous type, characterized by a great abundance of quartz. Nevertheless the c-value, and more especially the fm-value are higher than those found in typical aplitic granites.

GEOGRAPHICAL DISTRIBUTION OF THE DIFFERENT TYPES; LOCAL FACIES-DIFFERENCES IN THE GRAN-RIO MASSIF.

The Gran-rio granite is the most important igneous rock in the Colony. The centre and East of the Colony are occupied by an enormous massif, the Gran-rio granite massif. This massif is traversed by no fewer than five important rivers with their tributaries: the Coppename, the Saramacca, the Suriname river, the Tapanahony, and the Litanie-Lawa. As the rivers yield the best exposures and as they are the customary means of communication we meet with most data along their courses.

TABLE 21.

	Biotite granite (indistinctly porphyritic) Y. 52 [1])	Biotite granite Y. 106 [1])	Biotite granite (porphyritic) Y. 73	Biotite granite V. 1285	Granite-gneiss silicic V. 391
SiO_2	70.92	66.97	65.24	74.04	75.80
Al_2O_3	16.82	15.71	14.86	13.62	12.31
Fe_2O_3	1.09	2.06	0.92	1.22	3.40
FeO	0.97	1.88	2.78	0.32	0.10
MnO	0.07	0.14	0.06	—	—
MgO	0.57	1.24	2.02	0.64	0.10
CaO	2.78	2.44	3.88	1.72	1.65
Na_2O	2.89	3.20	4.25	2.27	2.20
K_2O	2.88	4.60	4.37	4.87	2.45
H_2O+	} 0.40	} 0.25	0.52	0.04	0.19
H_2O-			0.02	0.00	0.28
TiO_2	0.26	0.70	0.64	1.26	1.52
P_2O_5	0.08	0.17	0.52	—	0.00
	99.73	99.36	100.08	100.—	100.—
	1) 0.03 SO_3	1) 0.07 SO_3			
Anal.	Koning & Bienfait, Amsterdam	Koning & Bienfait, Amsterdam	Dr. S. Parker Zurich	Dr. K. Brauer Cassel	Dr. K. Brauer Cassel

	si	al	fm	c	alk	k	mg	Section
Y. 52	355	49.5	13	14.5	23	0.40	0.34	6
Y. 106	291	40	22.5	11	26.5	0.48	0.37	4
Y. 73	254	34	23.5	16	26.5	0.41	0.50	5
V. 1285	430	46.5	12.5	10.5	30.5	0.59	0.45	5
V. 391	487	46.5	18	11.5	24	0.42	0.05	4

Y. 52, Suriname river, Feroelassi falls.
Y. 106, Gran-rio, Tetakosi fall.
Y. 73, Pikien-rio.
V. 1285, Saramacca river.
V. 391, Area between Tapanahony- and Gonini-rivers.

The Suriname river.

Let us begin with the Suriname river, which traverses the massif from the South-West to the North-East in its full breadth. During our expedition I had an opportunity of investigating the whole length of this section. It appears that along a stretch of not less than 150 km. (as the crow flies) from the Bakrabote fall to the Gran-rio-springs we find this granite, only being cut here and there by dykes of diabase, and lamprophyre, and with a few masses of enclosed schists, all quantitively of small importance. While we are impressed by the monotony on one hand, local facies-differences are present on the other to a large degree. Going up the Suriname river, from the low-lands, we already meet with granites on the lower part of the river, which may be considered to belong to the Gran-rio-type, but they are only very locally exposed and we had best begin the discussion at lat. 4° 30′ N., where we find the Bakrabote fall between the Bushnegro-villages of Doewatra and Wittikamba. Here we meet with the granite in its most typical facies for the first time, forming part of the uninterrupted granite-region upstream. Coarse, twinned microcline phenocrysts are present in a normal-grained groundmass; the latter, besides copious biotite and hornblende, also containing a good percentage of primary epidote, with traces of orthite and copious coarse titanite (Y. 40). A parallel trend of the phenocrysts is to be observed. This latter phenomenon we see more distinctly in the field, particularly conspicuous where the phenocrysts are visible in consequence of weathering: among other places near the Koesikamba falls, farther upstream, where red phenocrysts attain to a size of 4 cm. Titanite in the sample is to be recognized macroscopically there; some orthite only microscopically (Y. 42, 42 B). Quite another facies is exposed at the extremity of the island of Kordonsanti going upstream. Here we meet with fine to normal-grained non-porphyritic rock, with a relatively slight percentage of biotite besides a small quantity of primary epidote (Y. 45). In agreement with the slighter percentage of coloured minerals it is rich in microcline, and contains acid plagioclase (oligoclase) of relatively good crystal-structure. On the left bank opposite the island mentioned, we see a sharply delineated dark zone in the granite, of amphibolitic composition, the petrographic description of which appears on page 232 (Y. 46). Having thus far met with exposures in abundance in the numerous rapids and among the islands, we now come to a wide, open stretch of river, with large bends, at low water, revealing extensive sandbanks. Exposures of non-porphyritic Gran-rio granite are sparse. The same rock appears with others near the landing-place of the village of Abene-stone; it is again fine-grained, relatively rich in microcline and shows the same acid plagioclase with a tendency to idiomorphism, epidote, chlorite and some muscovite of doubtful origin (Y. 48). Both at five or six km. below Abene ston (Y. 47) and upstream in the Jau jau soela (Y. 49) the Gran-rio-granite shows quite another facies. In the first locality the rock is partly normal, partly fine-grained, with equally distributed, copious biotite. Microscopically it appears that potash feldspar is wanting, plagioclase (oligoclase to oligoclase-andesine) and quartz being the only colourless minerals, with a bad sequence of crystallization. Here, too, some primary epidote, and some muscovite possibly of a primary nature, are present. In the Jau-jau falls there is a normal-grained rock, conspicuous by its clear white colour which forms a contrast with the black biotite leaves. The white colour is caused by the abundance of plagioclase. It shows a poor sequence of crystallization in respect to quartz; potash feldspar is wanting. As accessories there are some primary epidote and titanite. Here then, we have two cases in which Gran-rio granite, on account of the disappearance of potash feldspar, almost assumes a diorite facies, viz., quartz mica diorite.

In the Feroelassi falls again there are true Gran-rio granites, normal-grained, some with a few poorly developed phenocrysts, others without them (Y. 50, 50 B, 50 C, 52). In one of these (Y. 50) the potash feldspar is merely represented by poorly developed phenocrysts. We shall find this relation again in other localities. A fine-grained type the plagioclase of which shows relatively good idiomorphism against quartz and microcline, was also collected here. On the group of islands in these falls, granite is exposed in abundance.

Further upstream we do not pass a single fall of any importance, till we get to the junction of the Gran- and Pikien-rio. Yet rounded granite-rocks of the normal type are visible at quite a number of places in this stretch, either porphyritic or not. Normal-grained porphyritic ones we see near Nieuw Goejaba (Y. 53) near Aurora (Y. 54), on the Biahatti rapid (Y. 57 and 57 B), between the Asomboto and Kitti creek (Y. 59 and 59 B), near the landing of Semoisi (Y. 60), near Dahomey (Y. 61 and 63) and in quite a number of other spots, alternating locally with the non-porphyritic facies. Hornblende (Y. 57 B) as well as titanite (Y. 53, 59) appear here locally, sometimes diopside is met with (Y. 59). The granite in this stretch represents the Gran-rio type "par excellence" by its normal, often almost coarse grain, and porphyritic facies, while deviating forms seem to be of little importance. It is worthy of notice that in the numbers just quoted, primary epidote and orthite do not occur, an illustration of how these minerals are in no sense a constant component of the Gran-rio granite.

Porphyritic granite, whose groundmass has almost entirely been replaced by quartz was collected near Semoisi (Y. 60) (see p. 328). Gran-rio granite "par excellence" is also developed in the Pikien-rio, source river of the Suriname river. I visited this as far as the Moelai soela. Porphyritic forms were collected at Damanallé (Y. 71), at Orohosso soela (Y. 72), some km. farther upstream (Y. 73), at Dekweh soela (Y. 74) and at the Koemboe fall (Y. 79), and seen at numbers of points lying between, alternating locally with phenocryst-free forms.

In the last five numbers a considerable quantity of green diopside appears by the side of biotite and hornblende. Sometimes titanite occurs too. The rock from Koemboe fall is remarkable because of the potash feldspar being restricted to some microcline as antiperthite, so that we are again concerned here with an almost dioritic facies. A mylonite from the porphyritic Gran-rio granite was collected between Adjokko- and Santi creek, which will be found described on page 337 (Y. 76).

From above the Moelai falls we have the samples collected by Eilerts de Haan (Suriname Expedition 1908). From these it appears that the same granite-region must extend up to the source (although there are a few sillimanite gneisses among the material) and also along the trail that was cut by this expedition to the Ananas mountain. They are rocks mostly somewhat smaller of grain and poorer in coloured minerals than the previous ones from the same river, and therefore less typical Gran-rio granites, partly even aplitic because of copious microcline and little biotite (V. 1839). Hornblende appears sporadically, and there is an insignificant diopside percentage (in V. 1833 and 1840). Traces of orthite are to be found here and there. Sparse phenocrysts occur in the small samples from the Lawakau fall (V. 1832), from Komopratti soela (V. 1833) and from Kapoesa dam (V. 1842),while others have no phenocrysts (V. 1839, 1841, 1843). The same granite apparently occurs along the trail to the Ananas mountain (V. 1824), the low summit of which consists of granite (V. 1845).

Let us now return to the Gran-rio, the other source-river of the Suriname river. At the junction we find the same facies as downstream; a porphyritic granite, which, near Goddo, has some diopside in a groundmass poor in microcline and rich in plagioclase (Y. 68, 69). The granite forms a powerful weir here, the Tappawatra dam, shutting off the Gran-rio. The granite, itself, shows nothing new, but is intersected by a few very insignificant veins of non-porphyritic granite (Y. 68; V. 1847). We find similar veins in the samples from the Komopratti falls, (V. 1833) and from the Lawakau fall (V. 1832) both in the Pikien-rio. Mineralogically they are of the same type as the rock through which they have broken. Sometimes they bear traces of isotropic orthite and diopside too, differing only by being fine-grained and by their geological appearance. They are somewhat prepared out, with respect to their surroundings. We cannot but regard them as contemporaneous veins.

Other falls of importance soon follow, of which the Gran dam is the largest (Pl. 14 fig. 1). In the whole complex of falls the rock is, as a rule, non-porphyritic (Y. 82, 83, 85) only locally porphyritic (Y. 86). Higher up the porphyritic facies preponderates (Y. 88, 89), as far as to the neighbourhood of Awa dam, sometimes with hornblende occuring by the side of biotite. There is but one facies-difference to be mentioned in this region: the appearance of a normal- to fine-grained rock, not far from the Bushnegro-village of Deboe (V. 1850) having as colourless constituents only plagioclase (oligoclase or oligoclase-andesine) and quartz, hence it has a quartz mica diorite facies.

We meet again with a pronounced change within a short distance, in the rapids and fall of the Awa dam. Here we find a normal-grained rock containing plagioclase and quartz as colourless minerals in which the plagioclase (an exceptional case) forms phenocrysts (oligoclase-andesine), hence diorite facies; the groundmass is rich in biotite and ore and shows some hornblende too (Y. 92 and 93 D). Next to this appear forms with only phenocrysts of potash feldspar, while this mineral is wanting in the groundmass (Y. 93 C), others with traces of free potash feldspar in the groundmass (93 B) and non-porphyritic. Briefly: a pronounced local variation. Another pronounced local change but of another nature occurs near the Tetakosi dam and environment. When we approach these rapids and falls, we first notice a local change from porphyritic to nonporphyritic facies; a little more upstream the porphyritic rock shows a somewhat different mineralogical composition. Some rocks are very rich in hornblende (Y. 96) and show typical skeletons of this mineral (Pl. 30 fig. 4) others contain biotite and hornblende (Y. 79), or biotite only (Y. 99, 99 B, 106). Here, again, on account of the lack of potash feldspar, we have a diorite facies (Y. 105). Various of these types contain titanite, and a few show traces of orthite-remnants. Other varieties appear near Sintia fall. In part they are biotite granite with a few microcline phenocrysts and some plagioclase-phenocrysts measuring ¾ cm. (Y. 107 B), containing, by the side of biotite, a considerable percentage of diopside and hypersthene while the groundmass is practically free of potash feldspar. Others (Y. 107 C) have less diopside and no hypersthene. One rock (Y. 107) is abnormally rich in myrmekite. Others agains, have approximately as much microcline as plagioclase in the groundmass (V. 1855—1856). All these rocks are from the same fall, collected within a few hundred metres distance from each other.

About 3 km. below the mouth of the Riomau or Seisoe creek, a rock was collected that shows quite another structure (Y. 111). It is normal-grained granite-gneiss relatively poor in biotite, showing lack of crystallization-sequence. The boundary lines have an undulating course, to that the minerals fit into each other (ortho-gneiss).

Above the mouth of the Riomau we meet with porphyritic biotite granite once more, which, however, is replaced by other rocks when we approach the important obstructions of the Maupe-, Maripa-, and Kaboeba dam. At about 1½ km. before these falls microcline phenocrysts are wanting (Y. 114, 116). Microcline is present in smaller quantities than plagioclase (oligoclase-andesine), This latter is as usual only partially idiomorphic. Hornblende, some diopside (in Y. 114), and primary epidote (in Y. 116) are present. Local differences follow each other in quick succession in these falls. In the first rapids we see a rock with the mineral

Plate 14.

Fig. 1. Gran dam fall (biotite granite) near Goddo, Gran-rio. February 1926.

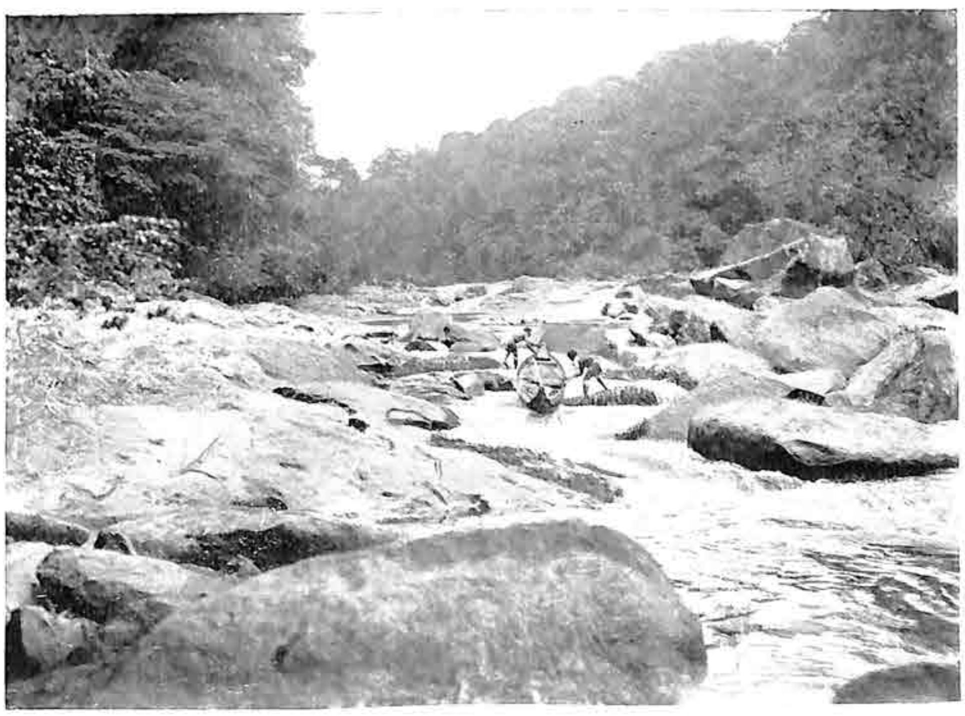


Fig. 2. Exposures of biotite granite near Kaboeba dam, Upper Gran-rio, during abnormal drought, February 1926. Bush-negroes with "korjaal" in the foreground.

combination of biotite hornblende granite (Y. 118) with some primary epidote, showing a few idiomorphic plagioclases, but with preponderant undulating boundary-lines between the minerals: it is an ortho-gneiss. In the Maupe- and Kaboeba falls the rocks are still without phenocrysts: they contain some orthite. Some parallel texture is visible in the samples. The sequence of crystallization is indistinct, the colourless minerals fitting occasionally into each other (Y. 119). Others rocks again are without any trend and with some crystallization-sequence (Y. 122). The same is to be seen in a rock from the large fall next to the Kaboeba fall (Y. 124). The latter rock only bears traces of microcline. How little these differences count appears from the fact that at a few metres distance in the same fall some hornblende and microcline are again present (Y. 125). Besides, the latter rock has an unmistakable gneiss-habitus in the sample, which is even more strongly pronounced in V. 1866 from the same spot. The copious biotite is evenly directed and moreover more or less concentrated on faces lying close together. In the field the parallel texture generally runs from East to West, dipping 60—80° N., while diaclases cut it at a small angle (dipping 50° towards the North). Microscopically the parallel texture is visible as streaks of biotite decidedly flattened according to the base, winding through patches richer in colourless minerals (Pl. 34 fig. 3). Besides this the biotite individually also shows a slightly bent and curved cleavage. This trend and bending seems to be of primary nature, at any rate, they are not to be attributed to pressure, in view of the moderately cataclastic quartz. Although the sequence of crystallization of plagioclase and quartz is indistinct, it is not altogether wanting in this gneiss. At the foot of the same fall again, within about 40 or 50 m. distance, we observe a fine-grained gneiss rich in microcline (Y. 123). It is a typical ortho-gneiss which has been discussed more fully on page 208. As if all these changes were not yet sufficient we must still mention that at a couple of places bi-mica granite was met with. Although collected at a relatively great distance from each other (Y. 117 and 120) both are pretty well analogous. The sample is normal to fine-grained. Macroscopically we observe pale-rose feldspar, gray quartz, a moderate percentage of biotite and muscovite. In Y. 120 we see black grains, which are to be recognized as strongly pleochroitic tourmaline. Microscopically the rocks appear to possess a very confused aplite-like structure. Very acid finely-twinned plagioclase (albite or albite-oligoclase) microcline and quartz are present in grains of varying sizes, only showing a trace of idiomorphism and penetrating each other. The microcline shows, as usual, some microperthite while in the plagioclase some fine sericite is present. Biotite and frayed muscovite are partly so much intergrown that the muscovite is probably of primary origin. The accessories apatite and ore are of very little significance, while in Y. 120 grains of garnet appear. Pressure has cracked the quartz locally and bent the plagioclase. Although we shall meet later on with more bi-mica granites as facies of the Gran-rio granites, it is doubtful in my opinion, whether this is the case here and whether we might not be concerned with more recent granite veins here. If this is true the veins ought to be some m. broad.

The typical peak, too, East of the river, the Franssen Herderschee peak, visited by De Haan's expedition, consists of Gran-rio granite. The rocks collected along the trail to this mountain have yielded nothing but pieces of quartz etc. From near the summit, however, we have five samples (V. 1870—1874), partly porphyritic, normal to fine-grained, acid granite, rich in microcline, and containing very acid plagioclase (almost albite), partly with orthite relics and insignificant hornblende (V. 1870). Hence here we are dealing with a relatively fine-grained acid facies of the Gran-rio granite.

Above these last-discussed falls there is a change from normal and fine-grained granite, sometimes showing parallel texture, but no samples were collected, until we got to about 3 km. farther upstream where the typical massive Gran-rio granite, often porphyritic, makes its appearance again, and, as preponderating rock keeps on to near the source of the river (Pl. 14 fig. 2). The Gran-rio granite here forms two large falls and also the important rock-obstruction, the "Ston-portoe" (stone-gate). Phenocrysts of a few cm. in size, appear sparsely in a groundmass approaching coarse-grain. In the vicinity of the "Ston-portoe" we see milk-blue quartz in the granite, which gives the rock a peculiar appearance (Y. 129 and 130). The plagioclase shows relatively good idiomorphism towards quartz; white microcline is sparse in the groundmass. In the same region, locally, I saw also normal- and fine-grained granites (Y. 132, 133), which by the side of biotite, contain sufficient muscovite probably of primary nature to call them bi-mica granite. It is probably a facies of Gran-rio granite. The same porphyritic granite with the milk-blue quartz continues in the great fall above Ston-portoe (V. 1885), here pretty well devoid of potash feldspar in the groundmass. The quartzes resume their normal colour again somewhat higher up (V. 1888, 1889). These latter two rocks unlike most granites in this region, show considerable pressure by the fact that the quartzes, besides showing undulose extinction, are partially crushed, while the biotite in both rocks is sometimes considerably bent. Undulose quartz has also developed in the vicinity of the "Ston-portoe". All these granites contain insignificant traces of orthite. Plagioclase with more distinct idiomorphism than usual is met with in a porphyritic Gran-rio granite (Y. 140). The same granite also forms the triangulation-point (470 m.) marked on the map (V. 1891).

In the same latitude, but more to the West, in the watershed between the Gran-rio- and Lucie rivers, we come across Gran-rio granites, but of greatly varying types. Material was collected at quite a number of places along the trail of Eilerts de Haan, and by our expedition on a reconnoitring trail, followed by us over a distance of about 8 km. in a South-Westerly direction. The low watershed is formed by hilly-country the highest points of which attain to about 500 m. above sea-level. Although the laterite-cover is strongly developed, yet quite a number of exposures of rock appear in creeks, on slopes and here and there also on the ridges, showing that the core of by far the greater part of the hills consists of granitodiorites. Gran-rio granite in its most typical form is found in V. 1892, Y. 147 and 168, with twinned microcline phenocrysts. V. 1892 and Y. 147 are normal-grained biotite granites. Y. 168 is biotite hornblende granite. Orthite-remnants appear in V. 1892. In Y. 168 the sequence of crystallization is slight, the structure of the groundmass approaching that of the ortho-gneisses. This applies even more to Y. 167 which is an ill-defined porphyritic rock by a few small, oblong, rounded microcline phenocrysts. In this rock the colourless minerals, plagioclase, microcline and quartz seldom show any idiomorphism, hence it is a gneissic granite.

Of the normal-grained granites (Y. 146, 148, 149) one is a biotite hornblende granite (Y. 148). Y. 146 contains some hornblende and has isotropic orthite-remnants. Y. 145 shows a new structure: the fine-grained sample shows a number of gray quartzes and feldspars more than a mm. in size, together with irregular biotite and hornblende. The sample, therefore, has indistinct porphyritic habitus. Microscopically no true porphyritic structure is to be seen, oligoclase, microcline and quartz vary in size. The feldspars are without idiomorphism. These minerals, large and small, completely enclose numbers of small quartz-crystals showing bi-pyramidal-structure, the "quartz-granulitique" of Michel Lévy (Plate 28 fig. 4). The larger feldspars are impeded at the edges by idiomorphic quartz. Some crystals are poikilitically studded with quartzes as far as the centre. The bi-pyramids are invariably smaller than 0.25 mm. Green hornblende and biotite show considerably perforated forms through which the smaller quartzes are likewise visible. Octahedral ore and apatite appear as accessories.

The bi-mica granites, which especially appear on the trail of our expedition, are of quite another type. A few km. from the Gran-rio we meet with a region that seems to consist exclusively of these granites. In the creeks intersected by our trail and on the slopes appear blocks of this granite and here and there the solid rock is exposed. Masses of blocks also appear on the slopes of the steep hills on both sides of the trail over about 1 km. distance. They are normal to fine-grained massive rocks. The normal-grained ones show muscovite leaves in great number in the sample by the side of biotite (Y. 151 and 152). Because of the slight percentage of coloured minerals the sample has a grayish tint. Microscopically they consist of much microcline and quartz, a varying percentage of acid plagioclase (albite-oligoclase), muscovite, little or no biotite and an insignificant percentage of accessories. Orthite and primary epidote are not found here either, only some zircon, and more often some octahedral ore. The latter is sometimes as good as wanting: the same applies to apatite. The structure of the colourless minerals varies. Plagioclase, microcline and quartz may be irregular in form with little crystallization-sequence (Y. 142, 151); in other samples the structure is quite confused, the minerals penetrating each other frequently (Y. 155). The muscovite here and there shows the base, more often, however, its edges are frayed and perforated; or the muscovite is rosette-shaped, or spongy. Of the secondary minerals we must especially mention sericite in the plagioclase, some chlorite, and epidote. Some disturbances caused by pressure may occur.

As these granites differ from the surrounding granites only on account of their muscovite and as besides this we saw that in the preceding rocks primary muscovite may also be present these bi-mica granites are regarded as a facies of the Gran-rio granite. The more so, since, as we shall see later on, (on the Saramacca) an extensive bi-mica granite-region connected with the Gran-rio granites by transition. We have indicated these numbers by means of a separate signature on map VI.

From the description, given above, it is clear, that the Gran-rio granites may possess a very varying nature, both in mineral-combination and structure. Now regions extending over a number of km. show apparently no change, now we find numbers of varieties often within a few dozen m. In view of this experience we may now discuss the "loose-samples", from other regions too, which were gathered by non-geologists, so that no geological data are available.

The Tapanahony river.

Let us begin with the Tapanahony, a tributary of the Marowyne river. From the lower river we have quite a number of samples. Among these there are Gran-rio granites, but we shall refer to them more in detail later on.

In the neighbourhood of Granbori the Gran-rio granites seem to appear more constantly; to begin with there is a normal-grained non-porphyritic rock (V. 1179), followed by a form in which potash feldspar is very rare, only occurring in rims of granophyre, a phenomenon rare in Gran-rio granites (V. 1180). Then follows a fine-grained Gran-rio granite (V. 1181) non-porphyritic, with about as much microcline as plagioclase (albite-oligoclase), and abnormally rich in titanite. A porphyritic form, however, was collected at the same place (V. 1182), also having a good percentage of microcline in the normal-grained groundmass, together with primary epidote, some three-coloured hornblende and orthite-remnants. Next, at the corner near Bobbi creek, a porphyritic form follows with coarse, idiomorphic titanite-crystals recognizable in the sample, while plagioclase possesses a relatively large degree of idiomorphism towards quartz (V. 1183). At this point a trail cut by the Government Mining-Exploration, and connecting the Wilhelmina river (tributary of the Gonini) with the Tapanahony, joins the river. Over a distance of at least 25 km. in an Eastward direction along this trail the same granite, be it in non-porphyritic facies, seems to be the predominating rock according to the samples and the annotations on the map of the aforesaid Exploration. This granite appears to be normal to fine-grained, having a percentage of microcline almost equalling that of plagioclase; the latter sometimes shows relatively good idiomorphism towards microcline (V. 767), but also the latter mineral shows a tendency towards idiomorphism (in V. 776). For the rest the sequence of crystallization of the colourless minerals in these rocks is indistinct. Sometimes primary epidote appears (V. 767), or orthite-remnants (V. 767, 769, 770, 776), once or twice also titanite. The same Gran-rio granites, non-porphyritic, normal- and sometimes fine-grained, we meet in the neighbourhood of the place where the trail reaches the Wilhelmina river (V. 747, 750, 761, 762, 765). A few contain hornblende and primary epidote (V. 747). A region of typical Gran-rio granites is found along the Tapanahony where it trends East-West and also farther upstream to where the division into two tributary rivers, the Paloemeu and the Upper Tapanahony proper, takes place. Granite here is preponderantly porphyritic and coarse-grained (the grains on an average attaining to 4 mm.). Microscopically these rocks once more show all the features of the typical Gran-rio granites. In parts they contain three-coloured hornblende (V. 1184, 1185, 1188) showing skeleton-like forms, in coarse pieces, with rounded-off cavities, filled with the colourless minerals. The relatively coarse biotite too, often shows irregular forms entirely agreeing with the type described on page 181. Pieces of brown titanite without idiomorphism are frequent here (V. 1184, 1185, 1187, 1188, 1189) and many of these rocks yield conspicuous zircon, which corresponding to the coarse grain of the rock, also assumes larger dimensions and reveals some concentric structure. In V. 1194 some primary epidote seems to be present. A trace of diopside appears in V. 1189. The plagioclase has, in parts, a tendency to well-defined idiomorphism towards quartz (V. 1188, 1189); this is, however, never the case between the microcline of the groundmass and quartz. One of the rocks (V. 1189) shows some microcline phenocrysts, but practically no potash feldspar in the groundmass, a phenomenon we met with several times before. The latter rock was collected by the Tapanahony Expedition on one of the remarkable monadnocks, lying near the river, the "Magneetrots". Of another rockdome in the shape of a truncated cone, the Teboe, there is no material available, but, on climbing it, it also appeared to consist of granite and the same also undoubtedly applies to the other masses of rock showing bare surfaces and domes, observed by the expedition mentioned, but not visited by it, inter alia the Rosevelt peak.

Following the Upper Tapanahony above the mouth of the Paloemeu we come across a long series of the same granites, the samples here lying relatively close to each other. Various divergent types come into consideration for discussion, e.g. the remarkable hypersthene granite (V. 1224), a normal-grained non-porphyritic massive rock. In the thin section it is partly a granite with about as much microcline as plagioclase, of the normal Gran-rio-type, containing some biotite, coarse zircon and myrmekite. Parts of it, however, bear only plagioclase (oligoclase-andesine) and quartz as colourless minerals, while it is abnormally rich in hypersthene which is pretty well colourless. The structure of the hypersthene is skeleton-like, it is quite of the same type and shows the same secondary change as is mentioned on page 188. Here, the abnormal distribution of the colourless minerals combined with the pyroxene would lead us to think of an inclusion; there is no reason to suppose that this hypersthene granite is connected with gabbroid rocks, as may be the case outside of Suriname (charnockites).

Then follows a variety, bearing practically only plagioclase as feldspar (V. 1225), while V. 1220 is a mylonised granite of the type discussed on page 337. The rocks mentioned so far from the Tapanahony, show, however, slight traces of pressure.

Then follow again alternating porphyritic and non-porphyritic rocks upstream in the Tapanahony and in the left side-creek. A quartz mica diorite facies is represented in V. 1229 characterized by a very slight sequence of crystallization of the colourless minerals, so that the structure approaches that of the ortho-gneisses. Another type (V. 1231) shows well-defined parallel texture in the sample, in the thin section the coloured minerals and partly also the colourless ones having their maximum length parallelly directed; this rock however is no gneiss, for the colourless minerals show crystallization sequence. The sample V. 1232, is locally developed as a normal granite with microcline phenocrysts, and locally shows fine-grained spots rich in biotite, which microscopically are very rich in plagioclase (approximately oligoclase-andesine) and poor in quartz. We find the same, without microcline phenocrysts and with little potash feldspar in the groundmass of V. 1233.

The same granites keep on to near the source of the Tapanahony, though with much change in mineral combination and structure. Some diopside is present in V. 1234, three-coloured hornblende in V. 1238, 1244, 1246, 1247, 1249. Titanite invariably brown and of irregular structure in V. 1237, 1238, 1240, 1246, 1247. Now and then we see titanite around ore, which shows no idiomorphism and is distributed in the titanite in such a manner as to give the impression that the latter, partly at any rate, was formed from the ore (V. 1244, 1246, 1247). An orthite-remnant still recognizable as a twin we see in V. 1246. In V. 1237 primary epidote and orthite-remnants appear, the former mineral in considerable quantities. Among the relatively coarse accessories in these rocks the sometimes concentrically built zircon strikes us in particular. The rocks are now porphyritic, now non-porphyritic. A strange mineral-combination is present in the gneissose granite V. 1241. Besides biotite we observe locally accumulated andalusite, sillimanite, muscovite, and a trace of cordierite, which, together, are regarded as recrystallized inclusion-material (see p. 203). V. 1242 gives us a new microscopic structure owing to the great difference in the size of the grains: coarse pieces of microcline lying without order in a fine filling consisting of pieces of microcline, quartz and very little acid plagioclase, which filling shows confused structure and has partially developed into granophyre. V. 1243 is also of quite a different type, fine-grained with distinct parallel texture in the sample, and partially also in the thin section, because of the parallel trend of the very copious biotite. Moreover it bears abnormally large quantities of primary epidote sometimes enclosing traces of orthite. V. 1245 shows a similar phenomenon but has less distinct parallel texture, while epidote reveals fewer arguments for its primary nature. The plagioclase in V. 1249 shows good idiomorphism. All these rocks again have been little influenced by pressure, with the exception of the rock V. 1236, which shows crushed quartz.

Let us now turn to the other tributary of the Tapanahony, the Paloemeu. The data are much sparser here. First of all we meet with a typical porphyritic Gran-rio granite, containing microcline-phenocrysts, but no potash feldspar in the groundmass, with an abundance of accessories (apatite, zircon, monazite) (V. 1195). Next to this occurs a fine-grained granite-gneiss, as a typical instance of how gneiss-structure may sometimes be present among the Gran-rio granites (V. 1196). A detailed description is given on page 208. Then follows a fine-grained gneissose quartz mica diorite V. 1197. The sample shows distinct and constant parallel texture. Microscopically it appears to consist of well-defined laminated plagioclase (oligoclase-andesine), a fair quantity of greenish-brown biotite, and a considerable quantity of ore, apatite, zircon, and a single piece of orthite. The plagioclases sometimes show by their general form and still more by their size, no indication of crystallization-sequence in relation to quartz: irregular and in some parts true undulating lines of demarcation between these two minerals rather point to an ortho-gneiss, so that we might classify the rock with the gneissose diorites. It seems to be a facies of the Gran-rio granites. V. 1198 once more is a typical porphyritic representative. The same granite, which judging from the sample is non-porphyritic, forms the most remarkable monadnock, the Kassikassima, near the river (V. 1200). The samples V. 1200 and 1201 were collected at its foot and at the river. Microscopically V. 1201 besides biotite appears to contain green hornblende and some diopside. The latter mineral is also present in the next typical Gran-rio granite (V. 1202) intergrown with hornblende. After this follow normal biotite granites (V. 1203, 1204, 1206).

Normal-grained Gran-rio granite was collected in the right hand side creek: the Makroetoe creek (V. 1217) and next to it, a fine-grained sample (V. 1215, 1216); the last rock contains rather much secondary muscovite. On the Paloemeu itself follows a normal-grained type, rich in microcline (V. 1208). From the Tapaje creek we have a normal-grained granite (V. 1214) with muscovite showing such a relation to biotite, that primary nature is probable; in which case this rock might consequently be regarded as a bi-mica granite facies of the Gran-rio granite. The intensely pressed V. 1212 is remarkable for its contrast with the insignificant pressure which the granites of this region generally show. A normal- to fine-grained type, containing secondary (?) muscovite (V. 1213) from the springs of the Paloemeu, concludes the series.

Rocks were collected by the Tapanahony Expedition along an Indian trail, which leads to the Paroe (branch-river of the Amazon).

There are two non-porphyritic samples (V. 1223 and 1222) from the trail. In V. 1223 muscovite is distributed in scales in such a manner that its secondary origin is obvious and the plagioclases, here, have at the same time, partially been replaced by opal. The quartz in the acid rock, poor in biotite, is divided into mosaic-like fields. The second number (V. 1222) also contains muscovite, but it is intergrown with biotite in such a manner that we cannot but conclude that it is of primary nature, the rock being a bi-mica granite-facies of the Gran-rio granite. Next follows a type with a few phenocrysts, decidedly cataclastic in structure. The quartz disintegrates into oblong, undulating fields, the biotite is bent between feldspars (microcline), which are still intact (V. 1221). V. 1220 shows a few phenocrysts and coarse microcline-crystals in the groundmass lying in a confused mass of potash feldspar, quartz, and acid plagioclase with some traces of pressure. All these rocks are poor in plagioclase and rich in microcline, and the ill-defined porphyritic ones are consequently not typical Gran-rio granites. Typical, however, is a rock collected at one of the sources of the Paroe (V. 1219); here coarse phenocrysts appear.

The Litanie river, and the area between the Lawa- and Tananahony rivers.

Let us now turn to the extreme South-East corner of the Colony, where the Litanie takes its rise, which river, further downstream, under the name of Lawa, unites with the Tapanahony and forms the Marowyne river.

Here, too, and until far downstream, Gran-rio granites appear to be present, judging from the sample-material. The most Southern samples at our disposal on the Dutch side are three granites from the Piton Vidal or Knopaiamoi, a dome 510 m. high, the highest point of which was reached for the first time by the Gonini Expedition. The rounded-off rock-surface of the summit and its surroundings consists of normal-grained porphyritic, typical Gran-rio granite (V. 1096, 1097, 1098). The same applies to V. 1100, taken from the top of a small mountain, on the left bank of the river: it contains coarse titanite. A similar, but non-porphyritic granite appears close by in the river; it is rich in epidote-grains and sericite which have nestled themselves in the acid plagioclases, coarse pieces of epidote of unknown origin also being present. This rock is almost a quartz mica diorite, on account of its trifling percentage of potash feldspar V. 1095). Next follows non-porphyritic Gran-rio granite (V. 1094) and another kind, containing an abundance of hornblende and some titanite, which surrounds ore as if it were formed from it (V. 1093). Then again near the Indianvillage of Panapie, a porphyritic form, rich in brown, partially idiomorphic titanite appears (V. 1092). Also porphyritic is V. 1091. According to the sample we find a non-porphyritic form with some hornblende in V. 1090. A porphyritic one from Kroboi soela shows coarse titanite and probably primary epidote (V. 1089). After this follow non-porphyritic types (V. 1088, 1087), the former with hornblende, titanite and some primary epidote; the latter with idiomorphic titanite and also primary epidote. The latter is at again a type in which the plagioclase is pretty well the only feldspar in the groundmass, while microcline is restricted to the coarse phenocrysts. Next follow other rocks of varying composition, namely a hornblende granite-gneiss, described in detail on page 284 (V. 1086). After this we come to a banded sample consisting partly of a gneissose quartz mica diorite, containing primary epidote, and partly of a biotite-gneiss zone likewise rich in epidote (see page 239). This rock and the next biotite gneiss (V. 1083) and a biotite hornblende gneiss (V. 1080) are once more petrographically very closely allied to the Gran-rio granites as discussed in the chapter on the Diorite facies. Alternating with these we meet with a few Gran-rio granites again (V. 1081, 1079, 1077, 1073), among which we see a fine-grained, non-porphyritic form (V. 1081) with primary epidote and orthite-remnants; this rock has undergone considerable pressure, at least, the quartz has been transformed into a mosaic of undulose fields, unlike the previously mentioned Gran-rio granites of the Litanie, which have been very little influenced by pressure. Among these there is also an aplitic form (V. 1079).

While the data are meagre and varying in this part of the river, we meet with a fine series of Gran-rio granites again, on the important tributary-creek, the Oelemari; these were collected by the Government Mining-Exploration. The samples lie close together here; sometimes they are porphyritic, but mostly without phenocrysts. It is again the typical form, although the quantities of microcline and plagioclase are variable, and the structure of the plagioclase, too, diverges. By the side of biotite some hornblende occasionally appears together with diopside (V. 962), while one single rock (V. 960) is very rich in hornblende. Primary epidote is common (V. 953, 954, 955, 956, 961, 963). Remnants of orthite (V. 953, 961, 962) are sometimes coarse. Sometimes still fresh orthites occur (V. 954). The rock V. 959 seems to be a coarse aplite with predominating microcline. Hence there are also Gran-rio granites, some typical, some less typical, on the Litanie.

We have many granite-samples collected North and East from the "De Goeje" mountains and very locally in the mountain-range itself. These granites, are not at all to be separated from the Gran-rio granites, even though they may yield local peculiarities (e.g. copious appearance of Baveno-twins of microcline etc.); they occasionally contain orthite or primary epidote again.

Now follow the Gran-rio granites collected by the Government Mining-Exploration on the trail which penetrates to the West of the "De Goeje" mountains over a distance of some 25 km. and on the line connecting the Assisi creek to the West of the Emma river. These Gran-rio granites apparently link up in the field with those of the Oelemari, but are, unlike these, non-porphyritic. They very much resemble the types collected along the trail connecting the Tapanahony with the Wilhelmina river by their normal and often somewhat fine grain. They are almost exclusively biotite granites. Only V. 377 and 371 are biotite hornblende granites, while some hornblende also occurs in V. 397. The relation of microcline and plagioclase is changeable again. The numbers V. 380, 386 and 388 are pretty well without microcline, consequently they may be called granodiorites. Of the accessories primary epidote is of frequent occurrence (V. 293, 294, 295 (much), 299, 300, 365, 372, 376, 379, 382, 386, 388, 392, 393, 394, 397). We also frequently observe orthite-relics (V. 293, 365, 371, 373, 376, 382, 384, 388, 389, 392, 393). Some titanite occurs, inter alia in V. 365, 371, 376, 379, 382, 384, 386, 388, 389, 393. Some muscovite possibly of primary nature is to be seen in V. 299, 300 and 393. Structural change to an important degree takes place among the colourless minerals. The plagioclase is occasionally distinctly idiomorphic towards quartz and microcline or the sequence is less clearly defined, while rocks with an ill-defined sequence sometimes pass over into types showing an irregular and partly undulating structure not differing from that of the ortho-gneisses (V. 391). This rock has more or less aplitic composition. With the exception of some chlorite, some secondary epidote and some sericite in the plagioclase, these rocks have not been changed to any degree; the signs of pressure are slight and restricted to undulose or slightly cracked quartz.

On the extreme upper course of the Wilhelmina and Emma rivers and on the trail of the Government Mining-Exploration which links up both, Gran-rio granites also occur. They are normal to fine-grained rocks (V. 1157), containing primary epidote and at the same time the rare Baveno-twins of microcline. V. 756 and 765 contain muscovite. V. 759 is a biotite hornblende granite. In V. 1161 there is some parallel texture and a very insignificant sequence of crystallization. V. 762 has perfect gneiss-structure; it is a fine-grained ortho-gneiss with perfect massive texture.

Hence in this region of the Wilhelmina- and Emma rivers, the Gran-rio granites are conformable to those we met with along the trail running in a Westerly direction to the Tapanahony. It is therefore an established fact, and the Government Mining-Exploration has already come to the conclusion, that between the Litanie and the Tapanahony there is a connected and vast region of granite.

The Saramacca river.

Let us now turn to the Saramacca, on the NW. side of the region discussed. The same granites also occur there over an extensive area. A few granites of this type occur even in the vicinity of the Mamma dam and the mouth of the Lesser Saramacca, but these we shall leave undiscussed for the time being and begin with the data collected by the Saramacca Expedition (1903). It appears that the Gran-rio granites on the Saramacca in general are more acid than the typical forms on the Gran-rio, Suriname river etc. In the sample it strikes us that biotite is sparse, but especially of smaller dimensions. Corresponding to this, hornblende is much rarer and pyroxene is entirely wanting. Quartz is generally present in larger quantities than feldspar. The percentages of microcline and plagioclase are subject to considerable change. The accessories are mostly of less importance and vary in a less degree. Some muscovite more often occurs. Although secondary phenomena, the chloritization of biotite and the forming of secondary epidote on a slight scale are present in by far most Saramacca rocks, this is no reason to regard muscovite as secondary.

The first sample is from the Jan Basi Gado, a granite-mountain on the left bank. It is a normal to fine-grained granite, acid on account of little biotite, much microcline and very acid plagioclase. Epidote, however, which is partly looked upon as primary, is present; also an insignificant isotropic orthite-grain is to be seen (V. 1272). The rocks 1273 and 1275 occurring on the river near the mountain are of the same nature, containing even fewer coloured minerals; they are aplitic. A coarse-grained aplite comes from this place too, forming a vein, and consisting of microcline, plagioclase and insignificant garnet-grains (V. 1274). Near Pakka pakka, in the neighbourhood, a normal-grained biotite granite with much microcline, very acid plagioclase, and some primary epidote, sometimes enclosing orthite-remnants, is present. This rock has experienced pressure, witness the bent plagioclases and disintegrated quartz (V. 1276). A couple of biotite granites, normal-grained, were collected 5 km. farther upstream (V. 1277 and 1278), the latter of which contains a good deal of muscovite. Its appearance causes us to presume that is is a primary rather than a secondary muscovite, and if this be correct, we should be concerned with bi-mica granite. The same mineral occurs in trifling quantities in the rocks already mentioned. Besides this there is from the same place a rock of quartz mica dioritic composition, containing a good deal of primary epidote, which encloses small orthite-remnants; indistinct parallel texture and the poorly developed crystallization-sequence of the colourless minerals show that the rock belongs to a type intermediate between rocks with normal structure and ortho-gneisses. It is probably a facies of the granites. Somewhat farther upstream, we come across a granite (V. 1279), followed by a gneissose quartz mica hornblende diorite, rich in coloured minerals, especially hornblende, with primary epidote and orthite-remnants. The sequence of crystallization of the plagioclase and quartz mutually is also very slight here, partly with undulating course of the boundary-lines between the minerals, just as we see this in gneisses. Next comes an aplitic granite again (V. 1280) and from the same place a granite rock very much enriched with secondary epidote and other minerals (V. 1281). Judging from the samples other types occur in the Brokoboto fall near to each other. To begin with, a rock of the Gran-rio type with a few phenocrysts, the groundmass being rich in quartz (V. 1284). We also have an aplitic granite enriched secondarily with quartz and epidote (V. 1283), while besides this there is a sample present showing a mylonised quartz mass, penetrated to a very large extent by secondary epidote (V. 1282). From the immediately following Afitimaboe fall there are again two normal-grained Gran-rio granites with trifling biotite-percentage, one of which bears the large and twinned orthite figured in Plate 32 fig. 2 (V. 1285, 1286). The two Gran-rio granites from the Kaja Mongga fall (V. 1287, 1288) are copiously provided with secondary sericite, muscovite, and epidote which is certainly in part secondary. The latter of these two rocks contains a few small microcline phenocrysts. Probably too, the fine-grained rose granite (V. 1289) with some muscovite of primary nature may be brought in here.

If porphyritic forms have been scarce up to now, they get commoner farther upstream. As such we must mention three from the Grasi fall (V. 1290, 1291 and 1293) with normal-grained groundmass. They have a good quantity of biotite. A couple of other rocks (V. 1292, 1294) from the same place are, however again fine to normal-grained rose biotite granites, non-porphyritic, almost aplitic; some muscovite of primary nature occurs in them. The coarse microcline, twinned partly according to the Carlsbad-law, and collected by the Saramacca Expedition at this fall (V. 1296, 1297, 1298) may attain to a size of 5 cm. The same porphyritic Gran-rio granite seems to extend over a vast area upstream, judging at least from the widely scattered samples collected: at the Wittiston fall (V. 1304, 1305), a non-porphyritic sample from Granman-kondre (V. 1309) and again a porphyritic one from Biniwatra (V. 1310, 1311) and once more three porphyritics from the junction of the Saramacca with the small tributary the Toekoemoetoe (V. 1114, 1115, 1116). All these rocks are relatively poor in coloured minerals and are accordingly less variegated than the same granite in its typical form from the Gran-rio, etc. Chloritization of the biotite occurs in all of them and secondary epidote too, which makes it difficult to distinguish primary epidote. Some muscovite of primary nature occurs here and there also.

In agreement with these are the rocks collected by the Saramacca Expedition along a trail from the Bushnegro-village of Mombabasoe on that river to the Ebba top, one of the highest peaks of the Van Asch van Wyck mountains. First a couple of normal-grained aplitic types (V. 1366, 1368), rich in microcline; then again two porphyritic types (V. 1369, 1370), with biotite as the only coloured mineral which is present in comparatively small quantities. It is probable again that the Ebba top itself consists of the same granite, although gabbro has been collected on the summit.

Let us now turn to the few data along the tributary of the Saramacca, the Toekoemoetoe. Here too, but not until far upstream, we meet with a couple of granites, non-porphyritic, of the same type (V. 1318, 1319). At the point, where the Saramacca Expedition cut a trail to the Hendrik top, we come across granites of the same composition, but which bear some primary muscovite (V. 1320, 1321): hence we might just as well call them bi-mica granite.

This brings us to a region where the rock instead of being developed as biotite granite, almost invariably contains primary muscovite and has the composition of bi-mica granite. Bi-mica granites are found along the source-river of the Toekoemoetoe, at the beginning of the above-mentioned trail to the Hendrik top, and on the Saramacca itself above the confluence with the Toekoemoetoe as far as the source. Is is obvious that these granites are likewise a facies of the Gran-rio granites; apart from muscovite and lack of porphyritic representatives, they resemble them in details and besides this, we repeatedly observe on the Saramacca itself, that next to biotite some primary muscovite occurs, corresponding to the more acid type there. As long as no geological observations point to superposition we shall have to regard them as a facies of the Gran-rio granite. These granites appear to be the predominant rock over an extensive region (on the upper course of the Saramacca over a distance of 40—50 km) and I have marked them just as the bi-mica granites on the trail Gran-rio-Lucie river, with a different signature on Map VI.

The bi-mica granites on the trail to the Hendrik top yield nothing new; they show the same secondary phenomena as the Gran-rio granites on the Saramacca: chloritization of the biotite, traces of sericite in the acid plagioclase and signs of pressure of very little importance (V. 1327, 1328, 1329, 1331). In V. 1329 occur traces of tourmaline. From the source of the Toekoemoetoe we have at our disposal three acid granites bearing muscovite, two of which are poor in biotite and aplitic; they possess a large percentage of acid plagioclase (albite-oligoclase). Possibly on account of the latter they have been called diorite-aplites in a provisional description [1]). In one of the samples, however, some coarse white microcline-crystals occur (V. 1323). We might just as well consider these rocks as aplites of the bi-mica granites as of the Gran-rio granites. V. 1325 to conclude with, is again a typical normal-grained bi-mica granite.

On the upper course of the Saramacca itself the first bi-mica granite appears at a good 5 km. distance above its confluence with the Toekoemoetoe, rich in microcline and quartz, with less acid plagioclase (albite-oligoclase) the latter having a tendency to idiomorphism. As coloured minerals some chloritized biotite occurs; further some patchy muscovite, and some octahedral ore. It is an acid granite. The muscovite percentage increases in significance on the Governor Lely fall (V. 1350). Here we find once more a normal-grained, non-porphyritic, and normal-grained rock, consisting of much quartz and microcline, very little acid plagioclase (albite-oligoclase), and about as much chloritized biotite and muscovite. These micas are scattered about without any order; the muscovite is irregularly patchy without any idiomorphism. It is remarkable that besides a porphyritic rock was collected on the Governor Lely fall (V. 1349), which we might call a Gran-rio granite, but which also contains some primary muscovite, so that it may once more serve as an argument for the connection between both types of granites. It has a normal biotite percentage, and much plagioclase (approximately oligoclase), with ore, apatite and zircon as accessories. Then follows a series of bi-mica granites, up to the source of the river, where they also form the triangulation-point, the "De Kockberg". They are normal or almost fine-grained, all massive, non-porphyritic, now with as much biotite as muscovite, now with less muscovite (V. 1357, 1358). In the normal-grained ones muscovite, by the side of biotite, often may be clearly recognized even in the samples. They are again characterized by the combination quartz-microcline and a varying percentage of plagioclase (oligoclase-andesine) and few accessories. In short: the "Granit" (bi-mica granite) of Rosenbusch. Corresponding to the acid composition primary epidote, orthite, monazite and titanite have not been identified with certainty. The secondary changes here are also general chloritization of biotite, and the forming of some secondary epidote and sometimes of some sericite in the plagioclase, beginning of opalization in the latter and insignificant signs of pressure. The rock V. 1352 only, deviates considerably from this group on account of its mineral-combination. It is a quartz biotite hornblende diorite, with very much hornblende and plagioclase (approximately oligoclase-andesine), showing well-defined idiomorphism towards quartz. The rock shows titanite of the same brown type as we often see in the Gran-rio granites. Where and how it occurs is unknown. A few Gran-rio granites from tne basin of the Saramacca, along a trail to the Hendrik top are still to be discussed. At about 13 km. distance from the Toekoemoetoe we come across this granite. First come three, not

[1]) C. Moerman. 54.

pronouncedly porphyritic, but coarse-grained samples (grains about 5 mm.) (V. 1332, 1333, 1334), which by the side of biotite, may contain some hornblende (V. 1332) and titanite (V. 1334). Then follows a series of six samples which belong to a ridge reaching to the Hendrik top, all normal-grained, though on the coarse side (V. 1335, 1336, 1337, 1338, 1339, 1340). Some contain hornblende (V. 1338). A coarse isotropic orthite-remnant is found in V. 1340. Most of them show coarse granophyre of quartz and potash feldspar (V. 1336, 1337, 1338, 1339, 1340). Two granites of the same coarse type belong to the Hendrik top itself (V. 1341, 1342). Both again bear some granophyre, and the last rock contains hornblende. All these coarse granites excel by the large dimensions of the accessories, especially zircon and apatite. Hence, including the bi-mica granite facies, we are, on the Upper Saramacca up to the source over a distance of more than 100 km. in an apparently connected granite-region, exclusively consisting of Gran-rio granites.

The Coppename river.

To the West, on the Coppename, there are still more Gran-rio granites of importance. To begin with, in the neighbourhood of the Voltz mountain. This typical monadnock, and also the neighbouring Van Stockum mountain dominate the vicinity as rounded-off granite-domes, in a landscape that in its turn also consists of granites itself. The Gran-rio granite of the typical porphyritic form is represented by samples from the summit of the Voltz mountain (G. 1923, 267), from the neighbourhood (G. 1923, 269), and from the Raleigh falls (C. 1). Other samples from the same region appear, macroscopically, to be non-porphyritic (G. 1923, 265, 268, 271; C. 3, 4, 5, 6, 7; B. 13, 16, 17). These granites agree microscopically with the normal-grained Gran-rio granites. G. 1923, 265 is a biotite hornblende granite, rich in coloured minerals, with macroscopically recognizable, idiomorphic titanite and beautifully idiomorphic plagioclase (oligoclase to oligoclase-andesine). G. 1923, 272 is a bi-mica granite. Concerning C. 3 we may still mention that the sequence of crystallization of the colourless minerals is very distinct, even microcline has a tendency to idiomorphism, so that the order plagioclase, microcline, quartz occurs in the groundmass. C. 6 and B. 16 (= V. 1462) have traces of primary epidote. The three rocks marked "B." have already been described by Bergt [1]). In all these three the acid plagioclase is idiomorphic. The rocks are of the same nature as the preceding ones. Signs of pressure are more or less distinctly present in all the rocks, but confined to undulose and slightly crushed quartz; Bergt, on the contrary, speaks of intense pressure; he regards the microcline-structure as a result of pressure, an opinion I cannot share (see page 333). Moreover for B. 16 he gives "Porphyrartige Trümmerstruktur". Possibly the very thick slide Bergt had at his disposal was the reason of this interpretation: in a better section of the same rock (see DD 1286) we see that only coarse plagioclases and abnormally coarse quartzes are present, which lie in a somewhat finer groundmass of the same minerals together with much microcline without well-defined porphyritic structure. It is true, the quartzes are pronouncedly undulose, yet there is no reason to suppose that the heterogeneous grain is a result of partial crushing. Number C. 7 bearing very richly fine-grained microcline and biotite is remarkable, most of the isometric grains measuring about 0.2 mm. It is possible that we are concerned here with a fine-grained vein-granite. C. 8 is an aplitic form of these granites. Then follow sparser samples of diorites of which we shall see in the chapter in question that they are mineralogically closely allied to the Gran-rio granites. Only at the first step of the Langa soela do we meet with the Gran-rio granites again (C. 21 and 22) as biotite granite poor in microcline, non-porphyritic; the plagioclase there shows in parts remarkably undulating boundary-lines against quartz, a feature reminding us of the gneisses, although the plagioclase by its size seems to be older than the quartz. Next follow a number of biotite granites, non-porphyritic (C. 24, 26, 31, 35, 36, 37, 38), of which there are no thin sections available. They alternate with others, of which we have some thin sections. C. 25 appears to be a biotite granite, with a significant percentage of muscovite showing considerable signs of pressure. C. 27 and 28 are again two Gran-rio granites, non-porphyritic, one of which (C. 27) has so much muscovite of primary nature (being sometimes intergrown with biotite) that we are concerned with a bi-mica granite facies. An isotropic orthite-remnant occurs in this rock. Then follow a couple of ortho-gneisses of dioritic composition. The next granite-sample, from the left bank of the Coppename is again a non-porphyritic Gran-rio granite (C. 42). Much farther upstream again a rock of the quartz mica dioritic composition (C. 46), probably as a facies of the same granites, occurs; C. 47 is a type diverging structurally; macroscopically we see by the side of porphyritic feldspars of some mm. also a number of rounded-off quartzes of this size; microscopically it appears that the feldspar phenocrysts consist of idiomorphic microcline; next to them there is some acid plagioclase; the latter encloses pieces of quartz at the sides. The quartzes, on the contrary, lack all idiomorphism. The colourless components of the groundmass are again the same three, but more irregular in shape. For the rest the rock corresponds to the preceding ones. On the Upper Coppename there are three more Gran-rio granites, one of which is porphyritic (C. 50), another normal-grained with a well-defined sequence of crystallization of plagioclase

[1]) W. Bergt. **45.**

and quartz (C. 49), while the last number (C. 51) is an aplitic form. Further C. 53 is worthy of mention. The sample is red and fine-grained, and almost aplitic because of its very small biotite-percentage. Microscopically it appears that very much microcline and quartz are present, the size of the grains being 0.15 to 0.25 mm., almost invariably isodiametric; besides the quartz has a distinct inclination to bi-pyramidal structure ("quartz granulitique"). Octahedral ore and traces of epidote and titanite occur as accessories. The normal grained granites C. 54 and 55 call for no comment. C. 56 is a Gran-rio granite of aplitic form. A set of three normal-grained granites (C. 59, 61, 63) the last of which is aplitic, and a single one, which is porphyritic, conclude the series on the left hand Coppename. From the right hand Coppename we also have at our disposal a number of Gran-rio granites. C. 83 is porphyritic, C. 84 normal-grained. C. 90 and 91 are bi-mica granites, the former of which, by the side of primary muscovite, also has some primary epidote. C. 85 is rich in orthite-remnants. A non-porphyritic rock (C. 89) closes the series along this river.

The Gran-rio granites in the area of the "Diorite facies".

Next we will treat those granites which agree petrographically with the Gran-rio granites and which locally alternate with the rocks of the "Dioritic facies", in a broad zone to the NE. and N. of the core proper of the Gran-rio massif. In all the rivers with regard to which we have discussed the Gran-rio granites in the massif we find these allied diorites and granites again, with the exception of the Coppename.

Let us begin on the East-side. On the Lawa near Awara soela there are a few granites; whereas many are found below the Bushnegro-village of Cottica, as far as the junction with the Tapanahony. They are all normal-grained, sometimes almost fine-grained Gran-rio granites, and never porphyritic. Several are closely related to the acid diorites of the same region, by only a slight percentage of microcline. A number show beautiful idiomorphic plagioclase (V. 459, 461, 462, 472, 479), but these again are also related by transitions to granites with ill-defined sequence of crystallization. Only V. 461 and 462 contain hornblende. Primary epidote we find in V. 471, 472, 473, 477, 479, 481; orthite remnants in V. 462, 473, 481. Some primary muscovite is present in V. 471 and 477. All the rocks are massive, except V. 481. They show slight signs of pressure. V. 810, however, is intensely crushed. In a number the plagioclase has, to a great extent, been replaced by grains of epidote and sericite. To the West there are a number of Gran-rio granites on the Emma- and Wilhelmina rivers; they show more variety than the preceding ones. They are again normal-grained, non-porphyritic. V. 748 is poor in microcline and with a tendency to gneissose structure and parallel texture. V. 743 betrays intense pressure. The fine-grained rock shows a distinct parallel texture, while biotite and much secondary (?) muscovite thread themselves around the coarser grains in winding strings. It is not impossible that the parallel texture and ill-defined sequence of crystallization have been considerably influenced by pressure. We see indistinct crystallization-sequence in V. 1130, which is very rich in hornblende; while perfect gneiss-structure with true parallel texture is present in V. 1150, which at the same time on account of its large percentage of hornblende is a hornblende gneiss.

Along the trails of the Government Mining-Exploration in the Grutterink mountains and on the trail running from there to the South we find normal-grained Gran-rio granites once more. Concerning these rocks it is said on page 208 that they are, for the most part, ortho-gneisses according to the structure, but without parallel texture. A few, however, (e.g. V. 818) show normal granite-structure once more. Neither is primary epidote wanting here.

We are still further acquainted with a few granites on the Tapanahony near Affivisiti and Drietabbetje and with some collected by the Government Mining-Exploration to the North-West of it. The rocks again are invariably non-porphyritic. All bear some primary epidote, although often very little, and are poor in potash feldspar. The very fine-grained V. 1686, shows practically no sequence of crystallization, and has aplitic structure.

From the Gran creek, the side-creek of the Marowyne river we have a couple of these granites (V. 2407, 2410). They are very rich in quartz (especially the first number). The acid plagioclase shows a good structure, but is often bent by pressure. In agreement with this the quartz is broken up into fields, showing aggregate polarization. The rocks have been altered very much by sericite and epidote-grains in the plagioclase, while coarse secondary epidote, chlorite and some muscovite are present.

We possess a few data concerning these granites in the basins of the Sara creek and the Marowyne creek, small tributaries of the Suriname river. Here are again normal-grained rocks. V. 1674 is a biotite hornblende granite with very much hornblende. V. 1676 is discussed on page 208 as an ortho-gneiss without parallel texture in the sample. Primary epidote is sporadically present in V. 1596, orthite remnants in V. 1596, 1674, and 1675; abnormally coarse remnants appear in V. 1674. Irregular structure which, to a large extent, is to be set down to quartz-potash feldspar-granophyre is met with in V. 1566 and 1567. V. 1573 is a biotite hornblende granite, which unlike all the preceding granites from this zone, shows many coarse microcline-phenocrysts in the sample. The idiomorphism of plagioclase and titanite is conspicuous in the groundmass rich in quartz, while the hornblende which exeeds the biotite in quantity, unlike the more frequent state, shows idiomorphic structure of the prism zone. V. 863 consists of quartz, microcline and epidotized plagioclase by the side of abnormal quantities of green hornblende.

From the side-creeks of the Sara creek (the Locus and Tompi creeks) and on the Suriname river between Gansee and Koffikamp we have a few more Gran-rio granites. These, too, are again non-porphyritic. The fine-grained V. 1645 shows microscopically a pseudo-porphyritic structure because of the very acid plagioclase being but slightly idiomorphic and also because of larger quartzes lying in an irregular granophyric mass of quartz and potash feldspar. The plagioclases in the granite poor in potash feldspar (V. 1398), show well-defined idiomorphism. The rocks V. 1398, 1408, 1412, and Y. 8 show sericite in the plagioclase and frequently conspicuous idiomorphic epidote-grains, of the same nature as we find them in the acid diorites of this area. V. 1589 from the Sara creek has a divergent mineral combination. The normal-grained rock is massive, rich in hornblende, and has a dioritic habitus. Microscopically, however, we see colourless quartz, very acid plagioclase (approximately albite) and some microcline. The plagioclase and quartz appear here and there to be granophyrically intergrown, which is nowhere else to be seen in the Surinam granitodiorites. The green hornblende excels in idiomorphism and is very often twinned. The mineral combination is abnormal, because of the large percentage of hornblende combined with the very acid feldspar; hence it is probable that this rock is not a hornblende granite, but rather an abnormal part in the granites or in acid diorites. In any case it is not a diorite rich in hornblende as Du Bois has called it [1]). It is not marked on the map. A typical ortho-gneiss of granitic composition has been collected much higher upstream on the Suriname river (Y. 35); see the description on page 209.

We have a number of granites from the Saramacca river near the mouth of the Lesser Saramacca, only two of which could be marked on the map. Of the rest, the exact locality is unknown (V. 2297, 2300, 2301, 2304, 2308, 2309, 2319, 2327). They are all normal-grained rocks. They are nearly all characterized by idiomorphism of the acid plagioclase and a slight percentage of microcline. So V. 2308, 2309 and 2327 for instance may just as well be called granodiorites or, even quartz mica diorites. V. 1746, 2304, 2319 are, however, richer in microcline again. V. 2304 has confused, aplitic structure. Primary epidote may be recognized in V. 1744, and 1746; an orthite remnant is found in V. 2301, a coarse titanite-grain in V. 1746. Nearly all the rocks (V. 1744—46, 2297, 2300, 2301, 2304, 2319, 2327) show abundant sericite in the plagioclase mostly together with conspicuous epidote-grains.

SUMMARY OF THE GEOGRAPHIC DISTRIBUTION OF THE ROCKS OF THE GRAN-RIO MASSIF.

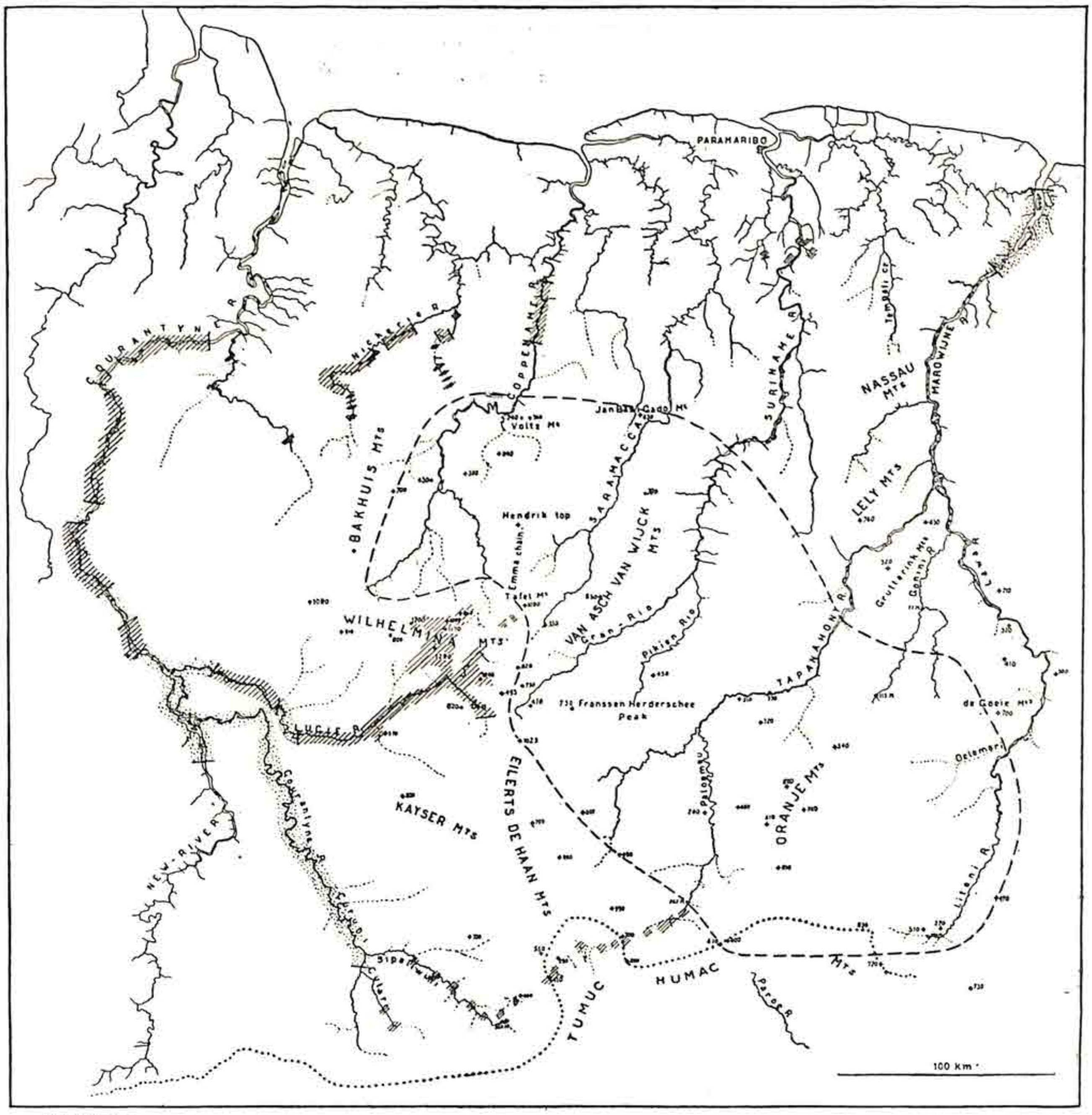
From the many local details that have been given above, the following may be inferred. The data which have led to the construction of the Gran-rio massif are the observations in the field and the material collected by our expedition along the Suriname river. From these it appears that along the river approximately upstream from 4° 30′ lat. N. and also along the Gran-rio we are concerned with a connected region of granite. Along the greater part of the stretch we pass from one exposure to another. It is true that it is not absolutely impossible that softer rocks, possibly schists, lie concealed from the eye in the open river, but should this be so, they cannot be quantitatively very important after all. This last fact also applies to the intrusive diabases and lamprophyres, which, as is stated in the chapters concerned, occur locally in this region but invariably form comparatively insignificant dykes. Anyone who has travelled along this stretch once, cannot but come to the conclusion that he is in a mighty granite-area, which has developed as an uninterrupted mass.

By the side of the local variations in the composition of the granite, in the different dark main components present, and in the porphyritic and non-porphyritic forms, we saw many other rock-types, in the first place those differing from the typical granite mineralogically. In some granites the potash feldspar is limited to the phenocrysts and wanting in the groundmass. In other rocks these phenocrysts are lacking too, they are quartz mica and quartz mica hornblende diorites. Such rocks were found in the middle course of the river and rather frequently on the Gran-rio. It is clear that these rocks, in several places

[1]) G. C. Du Bois. **40.** p. 19.

at least, are connected in the field with the granites, and do not differ in age from the latter.

Fig. 42.



Chiefly Granitodiorites. Chiefly Ortho-gneisses.

Area of Gran-rio — granites and allied rocks.

Of several bi-mica granites (Grain-rio) it is doubtful whether they are a special type of the Gran-rio granite. Some bi-mica granites, however, namely those occuring on the watershed Gran-rio—Lucie river, which comprise an area of several km^2. certainly belong to the Gran-rio granites.

But also important differences in structure and texture were found in rocks, sometimes of normal, sometimes of deviating mineral combination: gneissic types, especially granite-gneisses, quartz mica diorite- and quartz mica hornblende diorite-gneisses, all on the Gran-rio. It is clear from fieldobservations that several of these gneisses are undoubtly connected with rocks of normal crystallization-sequence; again they do not differ from the latter in age.

These observations show that the granites locally give rise to many other rocks, differing from them both mineralogically and structurally, which all of them are but different facies of the same igneous mass.

Seeing that the granite-massif along the stretch mentioned, has a length of at least 150 km., (as the crow flies), it is obvious that the dimensions in other directions must be considerable too. We meet the typical granites again among the material collected by others in the main rivers: Tapanahony, Litanie, Saramacca, Coppename and in the areas between them. The occurrence there of other rocks between the typical granites is not astonishing, after what we have seen on the Suriname river. Indeed, these other rocks are generally of the same types as the facies varieties on the Suriname river. It appears that granites in the typical form are largely distributed along the Tapanahony, South-East of the region of Suriname river and Gran-rio, some data along the Pikien-rio linking up both areas. Accordingly the region is regarded as the core of the Gran-rio granite area. We are not venturing too much by assuming, in view of what was ascertained on the Suriname river, that this core consists almost exclusively of the same rocks and is not interrupted by vast regions of schists or basic igneous rocks of another age (See fig. 42).

It is difficult with our present knowledge of things to judge with absolute certainty in how far other regions of granitic composition, are also connected with this core-massif, in the sense that the same granite and granite-facies invariably occur in the intermediate territiories even while the landscape-forms, as has been discussed render it probable that at least the intervening mountains to a large extent consist of granites (see p. 23), or that separate areas of granite are present outside of the core-massif. While the findspots lie close to each other, in the core-region, at any rate in the cross-sections discussed, the state of affairs in the other regions is generally otherwise. In the first place some regions lie at a great distance from the core, and further, the places where the data were collected are, in each of these regions, often wide apart. We find an instance of the former in the region on the Litanie, lying at a great distance from the rest, although in the North-West it is connected with the granites on the Tapanahony. We have found an example of relative scarcity of samples on the Coppename river. Besides in other regions the percentage of typical rocks may be small and that of deviating types may predominate, as will be clear from the following summary:

Along the Tapanahony upstream from Granbori, along the Upper Tapanahony, along the Paloemeu, and their tributaries, at the watershed with the Amazon and also here and there in the adjoining areas, the typical granites call for no remarks. They also constitute mountains (Teboe, "Magneet-rots", Rosevelt peak, Kassikassima). Of other types granite-gneisses, bi-mica granites, a single hypersthene granite and quartz mica diorites are to be mentioned, all but of small importance.

At the Litanie river the typical granites occur but data are sparser here. Between the Lawa and Tapanahony river especially non porphyritic, otherwise typical granites, occur. These granites may build-up mountains (Piton Vidal = Knopaiamoi mountain, and Northern group of the Oranje mountains). Among the deviating rocks hornblende granite-gneiss should be mentioned. On the Saramacca river we sometimes find granite of the type met with on the Gran-rio, which may constitute mountains too (e.g. part of the Emma chain). Generally they are more acid, biotite being scarcer and quartz more abundant, while among the coloured minerals hornblende is rare. Muscovite is not unfrequently of primary origin, and this type changes gradually to bi-mica granite, which dominates over a distance of 40—50 km. along the Upper Saramacca, up to the source. These granites are linked up in such way with the type already mentioned that they must be regarded as a different facies of the same massif. Among the deviating rocks several aplitic granites and some quartz mica hornblende diorites should be mentioned. Ortho-gneisses are not known to occur at the Saramacca.

At the Coppename river, too, the granites are less typical, except in the neighbourhood of the Raleigh falls, where they also constitute the Voltz mountain and the Van Stockum mountain. Upstream the rocks are less constant. Some bi-mica granites and aplitic forms occur, and a single quartz mica diorite. Granite-gneisses related to the Gran-rio granites are not known to occur at the Coppename.

In all these regions some signs of pressure may be found; some mylonitic granites (Pikien-rio, Upper Tapanahony) indicate great pressure.

From these data it is clear that especially the rocks from the Saramacca and Coppename are less constant or less typical. *Taking this fact into consideration, together with what was said above about the far distance at which other regions are lying, all the areas discussed may, however, be looked upon, at any rate provisionally, as belonging to one enormous massif, with a more homogeneous core.* The area occupied by this massif is shown by fig. 42.

Moreover it appears that in an extensive zone NE. and North of the massif, granites of the Gran-rio type, which are seldom porphyritic, alternate with related acid diorites, of which the latter will be discussed later on. These granites are exposed in all the rivers cutting the massif, except in the Coppename. These granites call for few remarks.

Granite-gneisses occur locally on the Suriname river in the area of the Marowyne creek, and East of the Tapanahony in the neighbourhood of the Grutterink mountains; in the last-mentioned locality they furnish once more good evidence of the direct connection between the granites and the corresponding gneisses.

TABLE 22.

			I Quartz mica diorites and Ortho-gneisses	II Quartz mica hornblende diorites and Ortho-gneisses	III Quartz-hornblende and hornblende diorites; and Ortho-gneisses	IV Aplitic diorites
Normal Diorites	A.	a. distinct crystallization sequence; massive texture.	V. 70, 465, 466, 1078, 1166, 1167, 1399, 1678, 1748, 2313, 2316.	V. 462, 463, 1679.	V. 32, 212, 232, 412, 1352	V. 81, 122, 359, 407, 413, 464, 485, 587, 805, 840, 897, 966, 1574, 1585, 1622, 1631, 1687, 1688, 1689, 1690, 1745, 1750, 2298, 2299; Y. 2.
		b. do; parallel texture.				V. 182, 458, 588, 1403.
	B.	a. crystallization sequence less distinct; massive texture.	V. 13, 125, 457, 468, 588, 738, 741, 842, 851, 865, 871, 1111, 1112, 1143, 1151, 1156, 1175, 1403, 1416, 1417, 1420, 1561, 1562, 1568, 1575, 1586, 1680, 1681, 1747, 1755, 2310; Y. 13B, 17, 20, 26, 343; C. 13, 18.	V. 8, 486, 1418, 1419, 1587, 1588; Y. 16, 21.	V. 10, 21, 207, 213, 216, 225, 228, 297, 298, 356, 552, 560, 678, 715, 859, 1071, 1558.	V. 14, 80, 139, 142, 200, 201, 313, 476, 478, 482, 591, 592, 764, 771, 824, 829, 831, 837, 841, 852, 862, 870, 995, 996, 1401, 1410, 1411, 1413, 1555, 1560, 1564, 1571, 1572, 1623, 1627, 1632, 1635, 1639, 1667, 2311, 2312; Y. 1, 3, 7, 7B, 344, 345.
		b. do; parallel texture.	V. 130, 474, 484, 991, 1551, 1664, 2465; Y. 9, 11, 11B, 13, 13B.	V. 467, 469, 480, 1556; Y. 26.		V. 30, 35, 78, 79, 475, 593, 594, 839, 1058, 1557, 1565, 1633, 1668.
Gneissose Diorites	C.	a. crystallization sequence indistinct; massive texture.	V. 136, 1113, 1129, 1148, 1429, 1529, 1671, 1677.	V. 1422; Y. 14.		
		b. do; parallel texture.	V. 1133, 1134, 1176, 1424, 1657, 1658, 2408, 2409; Y. 10, 12, 25.	V. 1131.	V. 1425; Y. 32B.	
Ortho-gneisses	D.	a. crystallization sequence lacking; massive texture.	V. 1421.	Y. 15, 33, 36, 37.		
		b. do; parallel texture.	V. 483, 742, 1083, 1108, 1132, 1135, 1136, 1423, 1427, 1428; Y. 23, 29, 30; C. 30, 32.	V. 740, 744, 746, 773, 1072, 1080, 1137, 1138, 1139; Y. 24, 30B; C. 14, 15.	V. 1563, 1825; Y. 28, 28B, 32, 32C, 39, 46.	

III. THE DIORITE-FACIES OF THE GRAN-RIO MASSIF.

In this chapter the diorites and allied rocks, found to the North and N.East of the core of the Gran-rio massif will be discussed. As has already been stated, the diorites are regarded as a facies of the granites and alternate with them locally. The petrographical description of these diorites will be given first, next their distribution in the field and their relation to the granites.

The diorites may be classified into the following groups:

I. Quartz mica diorites and ortho-gneisses.
II. Quartz mica hornblende diorites and ortho-gneisses.
III. Quartz-free and quartz-bearing hornblende diorites and ortho-gneisses.
IV. Aplitic quartz mica diorites.

Mineralogically these groups are connected by transitions. In the opposite scheme the numbers of the rock-samples are given as they are distributed over the four groups. According as the rocks show a typical sequence of crystallization, or possess a gneissose structure, or exhibit typical ortho-gneiss features, they have been subdivided into a second classification, intersecting the first groups horizontally (respectively A + B, C and D). Besides another classification has been introduced according as the parallel texture is wanting, or is more or less clearly developed (A, a and b; B, a and b. etc.).

I. *The quartz mica diorites and ortho-gneisses.*

This group is characterized by the mineral-combination plagioclase, quartz and biotite. The following applies to the group in general. Quartz is mostly present in somewhat smaller or in about the same quantities as plagioclase; frequently considerably smaller than the latter. The percentage of biotite varies within bounds that may be directly compared with the percentages of biotite of biotite granites. In the samples the rocks are variegated by white plagioclase and gray quartz, contrasting strongly with the dark biotite. These rocks are normal or fine-grained, non-porphyritic. [1]) In as far as there is no pronounced parallel texture, we might, judging from the sample, mistake them for biotite granites.

The plagioclase varies in composition from oligoclase to oligoclase-andesine (approximately 15 to 35 % An.), rarely andesine. Twinning is never entirely wanting, and in general, is moderately well-developed according to the Albite-law, sometimes combined with the Pericline-law, also, but rarely according to the Carlsbad-law (e.g. V. 1131). In a few rocks twinning is very indistinct. Zonal structure is practically wanting. The plagioclase shows few inclusions. Anti-perthite of potash feldspar is common. Quartz shows nothing worth mentioning. The biotite is almost invariably the same, with greenish-brown or brown tints. The development of the base varies, while prism-faces are always wanting. Once or twice forms occur suggesting magmatic corrosion: the

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[1]) Coarse-grained: > 5 mm.
Normal-grained: < 5 and > 1 mm.
Fine-grained: < 1 mm.

crystal showing very deep holes, or being traversed by vermiform channels (see p. 181—182). Primary epidote is almost always present by the side of biotite. Hornblende is not very common in this group. The mineral orthite is common but never occurs in considerable quantities. Titanite is also common. The mineral is now beautifully idiomorphic, now irregular in shape, probably owing to corrosion. Ore is practically never wanting. It often exhibits an octahedral shape (in the case of the smaller crystals) or is irregular in shape (in the case of the larger ones). It is mostly magnetite, sometimes also titano-magnetite, judging from a rim of titanite that sometimes surrounds the mineral. In that case demixture seems to have taken place. Further, apatite is common. Zircon is usually idiomorphic, sometimes with a zonal structure. Free potash feldspar is rare. It has invariably microcline structure. It often occurs as anti-perthite. Pyrite and muscovite rarely appear as primary minerals.

The mineral combination answers to the preceding on the whole, the following is of importance locally. Here and there traces of non-idiomorphic microcline appear (V. 70, 468, 1078, 1112, 1129, 1133, 1134, 1143, 1151, 1529, 1658, 1664). Primary epidote, practically present in all of the rocks, will, in a few rocks amount to about half of the biotite, and in some cases may be equal to it in quantity (V. 466, 871, 1664). Although undulose quartz is common, pressure is negligible.

In column I of the table 22 we find under "A" those rocks which are characterized by a very well-developed sequence of crystallization of plagioclase and quartz. The plagioclase shows chiefly idiomorphic faces and angles, and a short thick-tabular form. The quartz conforms to it and obviously crystallized later (Pl. 34 fig. 4). All these rocks show a complete massive texture, both in the sample and microscopically (Group I, A, a).

Following the structure-series in the same group, we come to the division B. The rock-samples here given, agree mineralogically with the preceding ones. The difference is only a structural one; as a rule plagioclase shows one or a few idiomorphic angles and also one or a few idiomorphic faces towards quartz (Pl. 34 fig. 5). Now this is the case with all the plagioclases, now we observe a few wholly idiomorphic plagioclases next to partially idiomorphic ones; now again all are only partially idiomorphic. In short, it is a varying relation, as we usually meet it in granites and diorites. Quantitatively these types are well represented.

Next to rocks having a massive texture, there are some showing a more or less parallel-texture (I, B, b). The latter finds expression microscopically because of the biotite running parallel while most of the colourless minerals, too, run more or less parallel. Types, however, with such a decided parallel texture that they resemble gneisses in the sample, are wanting.

Going on with the sub-division of group I, we come to rocks with the same mineral-combination but considerably less sequence of crystallization of the colourless minerals (I, C.) The shape of the plagioclase is practically entirely irregular, whether patchy or angular and pretty well devoid of recognizable faces. Hence the adjoining quartz does not at all give the impression of residual crystallization; but plagioclase and quartz impede each other mutually (Pl. 35 fig. 1). Part of the edge of a plagioclase may be undulating and works into the adjoining quartz and the reverse. This phenomenon, however, is mostly of little importance in this group. Another structural feature, however, reminds us strongly of the rocks already discussed. The plagioclase shows a tendency towards idiomorphism, which comes into prominence all the more, when the plagioclase is larger than the quartz. Here and there, an idiomorphic face or angle of the plagioclase appears, so that the partial idiomorphism reminds us of the preceding group. These rocks combine features of normal crystallization with gneiss-features. The term "gneissose diorites" has been adopted for them. In the sample and in the thin section these rocks now show massive texture (C, a), now more or less parallel texture (C. b). The latter finds expression again in the parallel direction of the biotite usually combined with that of the colourless minerals. A few of these rocks have, on account of the strictly parallel direction of copious biotite gneiss-habitus in the sample.

The next and at the same time the last sub-division of group I, is formed by rocks of perfect gneiss-structure (I. D). Crystallization sequence in the colourless minerals is entirely wanting. Quartz and plagioclase impede each other mutually as if they had crystallized contemporaneously, each striving for space without either of them succeeding in being idiomorphic. The following structure types may be distinguished:

1). The boundary-lines have an irregularly curved and to some extent an irregularly angular course (see e.g. V. 483, 742, 1108, 1132, 1427, 1428; C. 30, 32) (Pl. 35 fig. 2).

2). The boundary-lines between the plagioclase and quartz are more or less undulating, so that the minerals work into each other with rounded-off projecting parts (V. 1421, 1423; Y. 23, 29, 30) (Pl. 35 fig. 4 and 5). [1]) It is but a special form of the preceding type, and transitions between the two are sometimes present in the same thin sections, so that the differences have little significance genetically.

The colourless minerals may be more or less oblong-shaped, and in that case they trend parallel (I, D, b); or there is no parallel texture (I, D, a). If parallel texture is developed, the sample may, macroscopically, have a typical gneiss-habitus.

II. *The quartz hornblende diorites and gneisses.*

On the whole this group is somewhat less silicic than the preceding one. It is characterized by the mineral-combination: quartz, plagioclase, biotite, and bears a considerable percentage of green hornblende; on an average hornblende is present about as much as the biotite. Apart from the percentage of hornblende the rocks correspond to the preceding ones, the more so, as occasionally some green hornblende appears in the latter.

The following applies to this group in general: The plagioclase is again oligoclase or oligoclase-andesine; the latter appears more often than in group I.

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[1]) The photos show diorite-gneisses of the next group (II); the structure-types, however, are the same in both rock-groups.

Quartz is invariably present in smaller quantities than plagioclase, sometimes considerably smaller; this variation seems to bear upon the percentage of coloured minerals: if hornblende and biotite are abundantly present we find less quartz, hence, the whole rock is more basic. In this respect there is more variation than in group I. Some rocks have a strong tendency to pass into group III.

The hornblende never shows idiomorphism, although occasionally the prism zone has some good faces. Cavities may affect it on all sides and magmatic corrosion is, in this case, not improbable. The colour passes from a pale yellowish green (according to n α) into an approximately grass-green shade (according to n β) and sometimes with a bluish-green tint (according to n γ).

The same structure and texture types as in the preceding rock group once more occur here. We may refer to p. 229 and to Pl. 35 fig. 3, 4 and 5.

A few rocks may be discussed separately here. Traces of microcline may be present (V. 1137, 1138, 1139, all ortho-gneisses). In the massive diorites V. 462 and 463, copious hornblende is present, exceding biotite in quantity and having a better shaped prism-zone than the hornblende of the other representatives of this group. It is the prismatic hornblende we come across so often in quartz free hornblende diorites. Titanite with a tendency towards idiomorphism is present in V. 463. The plagioclase, here, is almost entirely superseded by ziosite having very feeble double refraction and also by some sericite. The quartz is undulose. Primary epidote or orthite are not seen. The diorite V. 1556 has undergone much modification, the plagioclase has again been superseded by zoizite with very feeble double refraction and the biotite by chlorite. This rock, too, is comparatively rich in quartz. V. 1587 clearly shows two different parts in the sample; one is normal-grained and devoid of parallel-texture, with partial idiomorphism of the plagioclases; the other is fine-grained with a well-developed parallel-texture of the coloured minerals, while the colourless components show gneiss-structure. The gneiss Y. 37 is normal-grained and very rich in hornblende. It is traversed by white aplite veins. In the gneiss V. 740 the biotite and hornblende are not evenly distributed, but some narrow zones almost exclusively contain biotite, whereas others almost exclusively contain hornblende. The distribution of the biotite and hornblende in the gneiss V. 746 is something like this, but rather in the form of spots. In the gneiss V. 773 the hornblende is found in the form of larger, intensely perforated skeletons. Very much epidote which must be of a secondary nature appears in the gneiss V. 1080. It is found in veins, traversing the parallel-texture of the whole. The gneiss V. 1072 is traversed by an aplite vein. It is not impossible that the structure of the gneiss V. 744 has been materially affected by pressure-action. The colourless minerals are more or less oblong-shaped and rounded-off. The rock has copious frayed biotite and some hornblende. As the colourless components show traces of intense pressure-action and the frayed biotite is sometimes undulose and warped, and as besides this a gneiss formed by pressure occurs in the neighbourhood (V. 745: both rocks are from the Wilhelmina river), the structure may have been considerably affected by pressure. The gneisses V. 740 and 1072 show distinct parallel texture by equal orientation of the dark and colourless components.

III. *The quartz-free and the quartz-bearing hornblende diorites and ortho-gneisses.*

The most basic differentiations of the "diorite-facies" have been classified under this group. Whether all the rocks found in column III belong here is not quite certain. This applies especially to the diorites with sequence of crystallization (III A and B). On account of the appearance or secondary products, practically all these rocks have undergone modification. As they generally agree mineralogically with the other rocks of this group, they have been classified under the diorite-facies.

Of the gneissose diorites and gneisses (III, C and D) there are but few; they differ considerably both structurally and mineralogically. In connection with the great variation a detailed discussion of the rocks is desirable. Let us first turn to the diorites (III, A and B).

The quartz hornblende diorites are invariably massive, normal to fine-grained. The percentage of hornblende is large, often approaching the sum of the colourless minerals. Microscopically the mineral combination turns out to be: hornblende, plagioclase, a varying quantity of quartz, rarely biotite and diopside, with titanite, apatite, ore, zircon, and pyrite as accessories.

The hornblende is elongated according to the c-axis and it sometimes has a tendency towards idiomorphic shape of the prism-zone. The shape is more often irregular. The pleochroism passes from light-yellowish green (according to $n\alpha$), to green of different tints (according to $n\beta$ and $n\gamma$) and sometimes gradually into a bluish-green at the edges. In others again (V. 212, 213) the colour passes from a pale yellowish-green to a greenish-brown, the latter colour occupying the centre and passing into greener tints at the edges. The plagioclase behaves idiomorphically towards quartz (III, A); if it is not modified the composition is approximately oligoclase-andesine. The crystals are tabular or isodiametric. The forms are often less well-developed (III, B). In some rocks the quartz is intergrown with some potash feldspar to granophyre (V. 21). The granophyre will sometimes surround plagioclase with a rim. Biotite occurs sporadically. Pale diopside, feebly pleochroitic, appears scarcely. Of the accessories only titanite calls for attention. In V. 216 it is very common, with the same irregular shape as is often seen in the preceding groups, and with a brown tint, while apatite is often enclosed.

Of the secondary phenomena cataclasm is confined to undulose quartz. The new formation of all sorts of products, however, is very considerable. The plagioclase is obscured by crystalline material, pieces of epidote and sometimes also sericite. This goes on to such an extent that the plagioclases are completely superseded (see for instance V. 412). The appearance of these products is accompanied by a diminution of the index of refraction. Hornblende and especially biotite chloritize. Much secondary epidote in coarse pieces has been formed also outside the plagioclase.

Let us now turn to the gneissose forms of this group (III, C). The mineral combination is again plagioclase (mostly oligoclase-andesine), hornblende and quartz, the two latter in varying quantities.

We have types of gneissose structure from Mamma-dam, Suriname river. In the sample they are normal to fine-grained rocks with some parallel-texture. They show about as much green hornblende as white plagioclase (V. 1425; Y. 32 B). Microscopically we observe green hornblende devoid of idiomorphism, in parts also perforated. Plagioclase has curved and angular border-lines. In places, too, it has an idiomorphic angle or face towards quartz so that we may, according to the structure, classify the rock under sub-section C. The twinning is often poorly developed. Quartz is rare. A fair quantity of epidote forms "reaction-rims" around the dark minerals. It shows channels. The epidote may fill up the space among the hornblende crystals. As accessory minerals many pieces of titanite occur, for the greater part changed into leucoxene. Further there are traces of apatite and ore.

The rocks with gneiss-structure (III, D) vary with regard to the quantity of quartz, plagioclase, and hornblende they contain.

The rocks Y. 28, 28 B, and V. 1825 in the field belong to a complex in which zones of hornblende gneisses, alternate with zones of gneisses poor in hornblende, which otherwise have the same mineral-composition. They appear near the Madiengo falls, Suriname river (see further page 239 for their geology). Let us first confine ourselves to the gneiss zones rich in hornblende. The sample, fine-grained, shows approximately equal quantities of white plagioclase and hornblende. We might mistake the rock for an amphibolite. Microscopically it appears to consist of plagioclase, hornblende, and a slight quantity of quartz. The parallel-texture is well-developed (Pl. 35 fig. 6). The oblong-shaped pieces of hornblende are in no sense idiomorphic. The twinning of the plagioclase (oligoclase-andesine) is occasionally well-developed but usually with very few lamellae; oblong-shaped crystals impede each other, and, where they border on the quartz they are not idiomorphic, either. Altogether we are strongly reminded of some amphibolites. Of the accessories we must mention: rounded-off pieces of titanite. Apatite, octahedral ore, and pyrite are present in very meagre quantities.

In V. 1825, which was collected in the same falls, we find epidote again showing indications of vermiform or irregular cavities filled with plagioclase. It is the same primary epidote which often occurs in the granitodiorites. The samples Y. 28 and V. 1825 at the same time show the light-coloured bands poor in hornblende which, as has been stated, alternate repeatedly with the darker bands. The coloured material consists of grey plagioclase, quartz and sparse hornblende. The hornblende is more or less arranged in streaks, parallel to the dark and light bands of the rock. The size of the grain is somewhat coarser, on an average 1 to 3 mm. Microscopically we observe plagioclase (oligoclase-andesine) approximately as much quartz, green hornblende and primary epidote. The latter represents a considerable proportion of the coloured minerals. The sparse accessories are apatite and pyrite; while titanite forms rims around ore remnants; besides these, there is some octahedral ore. Here and there a coarse grain of zircon occurs. Apart from the percentages of minerals and some subtle differences, the amphibolitic and acid bands are closely related. It is clear that we are not concerned with basic veins in more acid rocks here.

Another hornblende diorite-gneiss with amphibolite habitus in the sample comes from Mamma-dam, Suriname river (Y. 32). The rock shows a great resemblance to the hornblende gneiss from the Madiengo fall. Here, too, it alternates with more acid bands, inter alia quartz mica hornblende diorite-gneisses (e.g. Y. 30 B); besides, gradual transitions occur towards rocks of coarser grain and quartz hornblende dioritic habitus. Plagioclase and hornblende are present in about equal quantities varying in the size of the grain from 0.5 to 2 mm. The parallel-texture is but moderately developed. Microscopically we find the same green hornblende, partly perforated. The twinned plagioclase (oligoclase-andesine) shows irregular, angular forms which are polygonal in places. Quartz seldom occurs. Epidote is present in abundance here, especially occurring between the hornblende and plagioclase as "reaction rims" around the former (Pl. 31 fig. 2; Pl. 32 fig. 1). As accessories, we must mention pieces of titanite and traces of ore, apatite, pyrite.

The hornblende gneiss from the Sara creek (V. 1563) is of quite the same type, the epidote only requiring further discussion. It is probable that we are concerned here with epidote of a different origin. On closer inspection there appear to be two types. The first shows comparatively coarse pieces, polarizing evenly. Curved channels, filled with feldspar, penetrate deeply into the specimens. A few faces are developed idiomorphically. It is very probable that we are concerned here with primary epidote, the more so as minute granules of orthite occur enclosed. By the side of this we observe grains and small crystals of epidote which are regarded as secondary. They occur on a large scale in the feldspar. If much epidote is enclosed, a diminution of the index of refraction of the feldspar is to be observed.

A hornblende gneiss from the Mamma-dam (Y. 30 C), is of special interest because of the percentage of primary epidote and of some orthite. In the massive sample we recognize hornblende, varying in size from 1—4 mm., in somewhat smaller quantities than plagioclase and quartz. The massive structure and the somewhat coarse grain give it the habitus of a hornblende diorite.

A couple of rocks of this group, also from the Suriname river, have the combination hornblende-plagioclase. Through the lack of quartz they form the equivalent of the hornblende diorites. Structurally and texturally both rocks are quite correspond with amphibolites and we might call them by this name. On account of the presumed relationship with the preceding rocks, the name of quartz-free hornblende gneiss is the best (Y. 39 and 46). The most beautiful example is Y. 46 from the left bank of the Suriname river, collected at the end of the island of Kordonsanti going downstream. In as far as the exposure allows of our judging the rock forms a steep zone in granite. The contact between the two is, at any rate on one side, marked. Here then, there is no direct connection with the diorite rocks, but the gneisses appear among the Gran-rio granite. It seems likely that we are concerned here with a still more advanced zonal differentiation than in the case of the Madiengo fall, and if this interpretation is right, we find the two extremes: a granite on the one hand and a rock of hornblende diorite composition, at the other hand. This relation is not so queer as it might look, if one takes the close relation existing between the Gran-rio granites and the diorite facies, into account. Microscopically the plagioclase (oligoclase-andesine) and hornblende appear to be present in equal quantities. The shape of the hornblende is, to a considerable extent, different from that of the preceding rocks. A few larger pieces are irregular in shape, but by far the most have a polygonal shape, with a tendency towards iso-diametry. The same form is shown by the plagioclase. The scarsely twinned specimens are chiefly iso-diametrical, with polygonal forms. The rocks shows "Pflasterstructur" (Pl. 36 fig. 1 and 2). At first sight we might take the non-twinned clear plagioclase for quartz. There are pale fragments of titanite, with a tendency towards idiomorphism. The second rock (Y. 39), Bakrabote fall, is of the same type; it contains some orthite.

IV. *The aplitic quartz mica diorites.*

The aplitic quartz mica diorites are characterized by the mineral combination: much quartz, acid or extremely acid plagioclase (approximately albite-oligoclase) and some biotite, which is sometimes practically wanting. They are, therefore, the more acid equivalents of group I; now they are approximately aplitic rocks; now they are truly aplitic; they are all classed under this name. The quantity of quartz is now somewhat less, now somewhat more than that of the plagioclase; hornblende is very rare; primary epidote is of little importance; some potash feldspar, however, is often found. The accessories are of less significance than in the preceding groups; ore and apatite are scarce; orthite rare; titanite, however, occurs occasionally.

Petrographically the rocks are not to be separated sharply from group I; transitions are frequent and we often have doubts as to the classification of these rocks. What has been stated concerning the minerals in group I, also applies here again. The rocks are normal or fine-grained, non-porphyritic.

Notwithstanding the large number of samples, the variation in structure is of much less significance than in the preceding groups. True gneisses and gneissose types are lacking. In the first structure-sub-section (A) the rocks are again characterized by idiomorphism of plagioclase, with massive- or parallel texture. The idiomorphism is shown very distinctly in those rich in quartz which contain so much of the last-mentioned mineral that the plagioclases touch each other less often (e.g. V. 81, 407, 413, 840). The quartz grains are, in this case usually much smaller than the plagioclase crystals. In these types fields occur consisting of a large number of quartz grains. These grains do not seem to have arisen from a larger quartz-grain by pressure (V. 407, 413, 805, 1631). Other rocks again, show a more poorly developed sequence of crystallization between plagioclase and quartz (IV, B).

The rocks of this group show a considerable percentage of secondary minerals: chlorite and epidote, but particularly sericite (Pl. 36 fig. 3). In many rocks the plagioclases have, to a very large extent, been substituted by sericite, often combined with epidote granules and dust, which latter partially seems to be zoisite. It appears that the presence of secondary epidote-granules, zoisite-dust etc. in plagioclase is accompanied by a diminution of the refraction, so that in a part of these rocks, the composition of the plagioclase was less acid, before these secondary minerals appeared. The question is more fully discussed on p. 327.

Occasionally some calcite or muscovite occur as new formations (V. 78, 592, 593, 594, 1058, 1565, etc.).

Practically all the rocks of this group have been affected by the changes mentioned, often so intensely that the original composition only becomes clear when we compare them with less modified types (see e.g. V. 870, 995, 1632, 1635).

Pressure is usually indicated by undulose and often crushed quartz, while in several rocks plagioclase with warped lamellae are found (V. 476, 478, 593, 862). Pressure-zones: crushed material along micro-faults occur in V. 852, 1565 and 1745. In some, intense pressure action is found together with secondary minerals to a considerable extent, rendering the partial idiomorphism of the plagioclase difficult of recognition (V. 78, 79). V. 30, 35, 139, 831, 837 and 839 are highly-crushed and mylonized rocks.

	Group IV	Group I				Group II			Group III
	Aplitic quartz mica diorite	Quartz mica diorite	Quartz mica diorite	Gneissose quartz mica diorite	Quartz mica diorite-gneiss	Quartz mica hornblende diorite	Gneissose quartz mica hornblende diorite	Quartz mica hornblende diorite-gneiss	Hornblende gneiss
	V. 80	V. 1167	Y. 17 [1]	V. 1176	V. 1421	Y. 16	Y. 14	Y. 15	Y. 28
SiO_2	71.70	69.44	68.47	68.80	69.47	62.79	66.62	67.92	49.81
Al_2O_3	12.90	12.92	16.87	10.40	14.40	16.22	17.29	16.89	18.03
Fe_2O_3	3.33	6.03	1.53	4.28	4.24	1.86	1.12	0.74	13.83
FeO	0.25	0.13	1.41	0.10	0.95	2.96	1.34	1.43	0.09
MnO	—	—	0.19	—	—	0.08	0.02	0.02	—
MgO	1.86	0.33	1.07	3.62	0.15	2.60	1.51	1.07	1.69
CaO	2.48	4.10	4.32	5.48	3.99	5.44	4.75	4.52	10.14
Na_2O	2.96	3.68	3.22	3.76	4.36	4.51	5.18	4.59	4.01
K_2O	1.19	2.33	2.45	2.03	1.00	1.87	1.07	1.32	1.50
H_2O+	0.03	—	} 0.10	0.01	0.19	0.61	0.39	0.30	0.00
H_2O-	0.32	0.01		0.00	0.20	0.02	0.03	0.02	0.06
TiO_2	2.14	0.93	0.41	1.52	1.05	1.01	0.95	0.95	0.84
P_2O_5	0.84	0.10	0.16	—	—	0.25	0.15	0.31	—
	100.—	100.10	100.20 [1]) 0.08 SO_3	100.—	100.—	100.22	100.42	100.08	100.—
Anal.	Dr. K. Brauer Cassel	Dr. K. Brauer Cassel	Koning & Bienfait Amsterdam	Dr. K. Brauer Cassel	Dr. K. Brauer Cassel	Dr. S. Parker Zürich	Dr. S. Parker Zürich	Dr. S. Parker Zürich	Dr. K. Brauer Cassel

TABLE 23.

Findspots:

V. 80: Lower Tapanahony, near Piketi.
V. 1167: mouth of the Gonini river.
Y. 17: rapids of the Miengotiri falls, Suriname river.
V. 1176: Tapanahony river, beneath Aloekoekondre.
V. 1421: Suriname river, near Kapua.
Y. 16: rapids of the Miengotiri falls, Suriname river.
Y. 14: Suriname river, beneath Mankwi creek.
Y. 15: Suriname river, Miengotiri falls.
Y. 28: Suriname river, Madiengo falls.

SOME CHEMICAL DATA ON THE ROCKS OF THE DIORITE-FACIES.

The annexed table gives the chemical composition of some typical rocks of the diorite-facies. The Niggli values have been added (Table 24). The analyses are arranged in accordance with the groups drawn up in the petrographical discussion. The analyses show a decreasing percentage of silicium, respectively in the groups IV, I, II, and III. The groups I, II and IV appear to be closely related chemically. The rock representing group III is much more basic. The latter forms part of the hornblende gneiss zones with amphibolitic habitus, which alternate in the field with highly acid zones (c.f. p. 232). As the first eight colums show typical representatives of the bulk of the diorite-facies, the latter appears to have a rather acid composition. If from the first eight analyses we calculate the average for si, al, fm, c, alk and k, we find severally 293,

	si	al	fm	c	alk	k	mg	Section
Aplitic quartz mica diorite V. 80	373	39.5	28.5	13.5	18.5	0.21	0.51	4
Quartz mica diorite V. 1167	315	34.5	23	20	22.5	0.29	0.10	5
Quartz mica diorite Y. 17	293	42.5	17.5	20	20	0.33	0.39	6
Gneissose quartz mica diorite V. 1176	270	24	34	23	19	0.26	0.62	5
Quartz mica diorite-gneiss V. 1421	320	39	19	20	22	0.13	0.05	6
Quartz mica hornblende diorite Y. 16	217	33	27	20.5	19.5	0.21	0.50	5
Gneissose quartz mica hornblende diorite Y. 14	265	40.5	17	20	22.5	0.12	0.54	6
Quartz mica hornblende diorite-gneiss Y. 15	290	42.5	14.5	20.5	22.5	0.16	0.48	6
Hornblende gneiss Y. 28	127	27	33	27.5	12.5	0.20	0.20	4

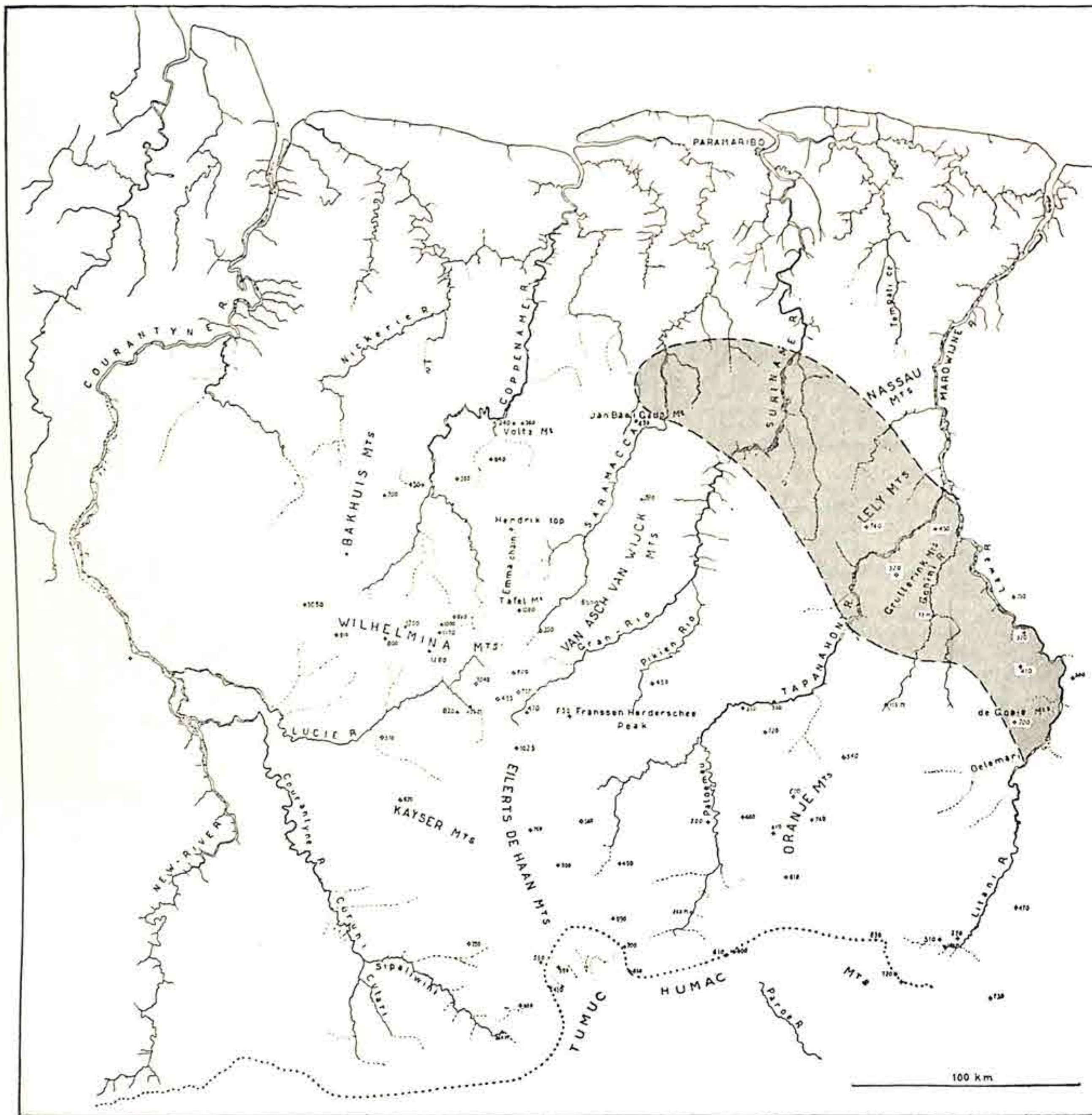
TABLE 24.

37, 22.5, 19.5, 21 and 0.21. These values agree with those of an acid dioritic magma and only differ from the granitic magma by lower k value. Among the diorites our average comes very near to the magma-type entitled as plagioclase-granitic by Niggli [1]). Mineralogically this appellation is not a very appropriate one in our case, as free potash feldspar is lacking in the rocks. Our average, because of the c value, (mostly abt. 20) inclines towards the quartz-dioritic magma-type. One single rock (Y. 16) quite agrees with the latter. Our aplitic diorite is in the same ratio to the others as Niggli's trondhjemitic magma-type is to that of the plagioclase-granitic one.

The hornblende gneiss of the last column does not join on the preceding ones and also deviates chemically from the basic diorites in general. The value for fm namely is strikingly low. If the large hornblende percentage of the rock is taken into consideration, as well as the fact that dioritic hornblende contains more than 10 % of MgO [2]), the MgO percentage in the analysis

[1]) P. Niggli. Gesteins- und Mineralprovinzen. Berlin. 1923. p. 120.
[2]) c.f. H. Rosenbusch. Elemente der Gesteinslehre. Stuttgart. 1910. p. 160, Nr. 5, 6, 7, 8, 9 and 10.

is abnormally low. Should the analysis be correct, we have to do here with a hornblende very poor in magnesium.



Area of the "Diorite-facies"

Fig. 43.

The gneissose diorites and gneisses are chemically the equivalents of the diorites, which again affords proof for their ortho-nature and relation (c.f. Y. 16, 14 and 15).

THE DISTRIBUTION AND GEOLOGICAL BEHAVIOUR OF THE DIORITE-FACIES. THE RELATION TO THE GRAN-RIO GRANITES.

The rocks of these facies chiefly occupy a region that from East to West, from the Lawa to the Saramacca, as a wide zone adjoins the granite region that we regard as the core of the Gran-rio massif (See fig. 43). In the East the zone extends along the Lawa between Awara fall and the mouth of the river. To the West, it comprises part of the course of the Emma river, Wilhelmina river and the Gonini. More to the West it comprises part of the Tapanahony, at any rate, between Granbori to Clementie, while the same rocks occur seldom on the Gran creek. Farther to the NW. there are many samples from the Sara- and Marowyne creeks. On the Suriname river the zone appears again between the place where 4° 30 N. lat. intersects this river and Koffikamp. Up to here it keeps to the N.East edge of the Gran-rio granite massif. It may be recognized again locally on the Saramacca, near the mouth of the Lesser Saramacca. The data which we possess of the Saramacca are too scanty, however, to judge about the distribution there. We are not acquainted with a continuation of the zone on the Coppename.

It must be emphasized here that the area marked on the sketch map is not taken up by the rocks of the diorite-facies only. Other rocks are also frequent there, especially granite of the Gran-rio type, and to a less extent schists etc.

If we look into the distribution of the different forms of the diorite-facies in the field, we see that none of the groups I—IV takes up a special area. The same applies to the distribution of normal rocks, gneissose types, and true gneisses. On the whole then, the various forms of the rocks of the diorite-facies are found mixed up and in geological connection, some areas excepted.

In the middle course of the Suriname river, namely, ortho-gneisses predominate over a considerable distance.

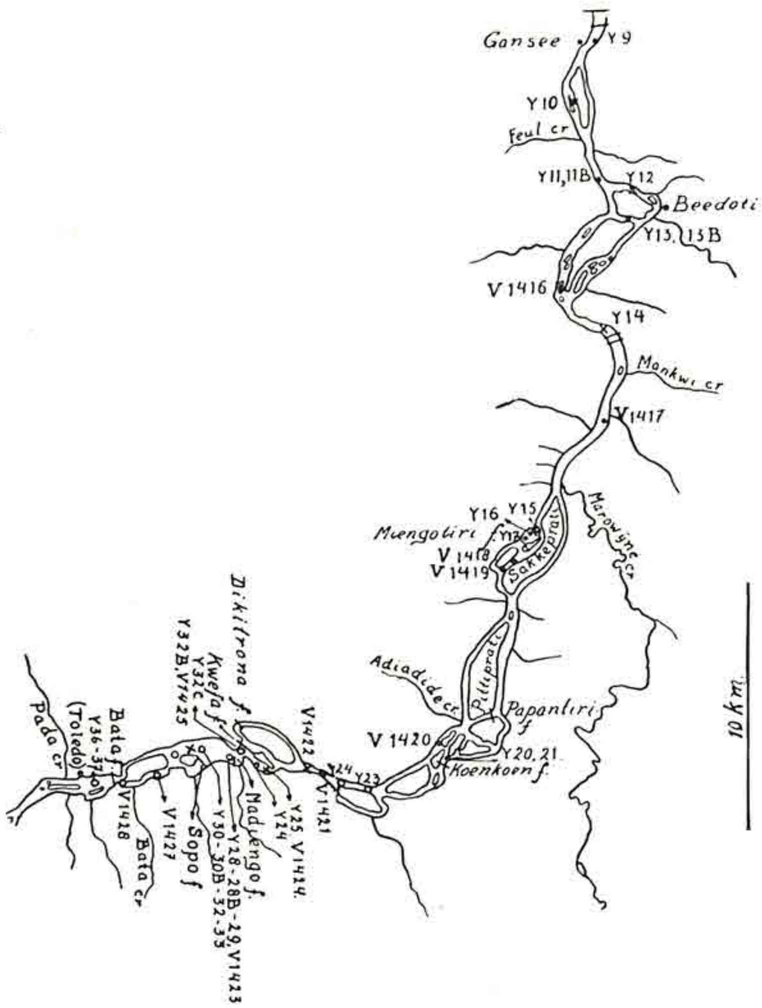
We will now sum up what is known about the geology of the rocks, especially from the Suriname river, where they are known best.

Starting from the East, many diorite-samples have been collected along the Lawa and Litanie, 16 of which represent the most acid type with normal structure. The same structure is also shown by 15 diorites, 10 of which are quartz mica diorites, 5 quartz mica hornblende diorites. Of gneissose diorites we find but two quartz mica diorites; ortho-gneisses 6. Two of the gneisses have the mineral combination of quartz mica diorite, three others also bear hornblende and one is a hornblende gneiss. We repeatedly see how rocks of different groups and structure occur next to each other. On the Lawa we repeatedly find quartz mica diorites with or without hornblende near the acid forms. A gneissose quartz mica diorite (V. 1113) by the side of two normal quartz mica diorites (V. 1112 and 1111) has been collected at the mouth of the Gonini. The few ortho-gneisses do not appear far away from the other structure-forms either; in the sample of V. 1083 from the Litanie we see both structures in different zones in the same sample. Gneisses of quartz mica- and quartz mica hornblende dioritic composition we see next to each other on the Litanie above the mouth of the Oelemarie (V. 1108 and 1072). In short: all these facts prove that besides the mineralogical. there is also a geological relation, and that all of them are but facies of the same type.

We find the same again on the tributaries of the Gonini-, the Emma- and Wilhelmina rivers, hence more to the West. There several ortho-gneisses (V. 740, 742, 744, 746) have been collected at no very great distance from the quartz mica diorites 741 and 738. The same applies to a gneissose diorite (V. 1148) and a rock of normal structure (V. 1151). On the Kotilolo fall, not far below the junction of the two tributary rivers of the Gonini, there occurs a whole series of gneissose rocks and ortho-gneisses next to each other.

Some diorites have been collected North of the De Goeje mountains and at the Gran creek. On the Tapanahony, more to the NW. we know the diorite-facies from the scanty samples below Granbori, while series of these rocks in the neighbourhood of the Tosso creek are present and also from near Drietabbetje. The most acid facies prevails here; locally, however, we also know quartz hornblende diorites and gneissose quartz mica diorites. We have many data at our disposal from the basin of the Sara creek and the Marowyne creek. In the basin of these creeks the most acid facies prevails, by the side of which diorites of varying composition, sometimes of gneissose structure, occur.

The geology of the diorites along the Suriname river is best known owing to Martin (1885) and because, during our expedition, there was an opportunity to study them again. Between Koffikamp and Gansee a few quartz mica diorites



● normal diorites ╳ gneissose diorites o diorite-gneisses

Fig. 44.

occur, the most acid facies, however, prevails. Above Gansee we find instead of these quartz mica and quartz hornblende diorites and gneisses. The accompanying sketch (Fig. 44) gives the distribution of the rocks at our disposal. The rocks are marked with different signs, according to the structures. From Gansee upstream we observe that rocks with normal structure alternate with those forming a structural transition to the gneisses, while the structure changes within a comparatively short distance (compare Y. 11, 12 and 13), and the mineralogical composition remains the same. This finds still better expression near the island of Sakkepratti, where a gneiss together with normal rocks has been collected. The alternations of structure in the neighbourhood of Kapua and near the islands situated farther upstream are still more frequent. All three structure types occur here, and were collected quite close to each other. Martin refers to the varying habitus of the rocks as follows: "Gneiss-artige Granite, welche von typischen grauen Gneissen in Handstücken nicht zu unterscheiden sind, nehmen unter anderen an der Zusammensetzung der ausgedehnten, concentrischschaligen Kuppeln von Kapua Theil" [1]).

In the bend in the river towards the West, the rocks vary from a quartz mica dioritic to a hornblende dioritic mineral-combination, ortho-gneisses predominating.

Zonal texture is developed locally in the rocks: there are bands very rich in hornblende and bands poor in hornblende. This phenomenon is visible on the Madiengo fall (the samples Y. 28, 28 B, 29, and V. 1825, are from there). The amphibole zones and the lighter ones vary from one cm. to a few dm. in breadth and run strictly parallel, so that trend and dip can be measured: N. 25° E. and very steep dip.

More or less well-developed zonal structure appears repeatedly still further upstream. Over a distance of 6 km. to not far past the Bata falls, we repeatedly observe coloured groups in the acid diorites and gneisses, now zonal, as near the Madiengo fall, now oval or in curved streaks varying from some dozens of m. in length to but a few dm, in which latter case, we had better regard them as inclusions. Their appearance has already been mentioned by Martin (l.c. p. 163, 164). Gneisses ranging from basic composition (group III) to acid types (group I) occur near Mammadam next to each other and showing zones, more often, however, connected by gradual transitions, so that we might collect a whole series of transitionary forms between the two extremes (the samples Y. 30, 30 B, 32, 32 C, 33 and V. 1428 are from here). Here the geological connection and contemporaneous origin are clear. The banded texture of the rocks must probably be regarded as a consequence of differentiation "in situ". The phenomena are the same as those described by Geikie and Teall [2]), Högbom [3]), Rogers [4]) and of banded ortho-gneisses of other regions. Harker [5]) assumed that we are concerned with a contemporaneous intrusion of two different magmas which have penetrated into each other without mixing before they intruded.

In this connection it may also be observed that among the sample-material from the Litanie (V. 1083) and from the Sara creek (V. 1587) there are diorite-rocks showing zonal texture i.e. groups with ortho-gneiss-structure, next to others with sequence of crystallization. It is not impossible that the same phenomena as those on the Madiengo fall occur there.

The rocks along the Suriname river mostly show rounded-off forms. On

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[1]) K. Martin. **26**. p. 162.

[2]) Archibald Geikie and J. J. H. Teall. On Banded Structure of Some Tertiary Gabbro on the Isle of Sky. Quart. Journ. Geol. Soc. L. 1894. p. 646.

[3]) A. G. Högbom. Zur Petrographie von Ornö Hufvud. Bull. Geol. Instit. Upsala X. p. 150.

[4]) G. S. Rogers. Original Gneissoid Structure in the Cortlandt Series. Amer. Journ. Science. (IV). XXXII. 1911. p. 125.

[5]) A. Harker. The Natural History of Igneous Rocks. London. 1909.

our examining them, they now appear to be massive rocks, now some trend appears to be present. Even rocks showing a fairly pronounced trend will sometimes show rounded-off weathering forms. If the trend is a decided one, it mostly finds expression, however, by the appearance of bench-like forms, the trend of which corresponds to the texture of the rock. We may also draw some conclusions concerning the trend of the rock-texture from the diaclases, for the latter appear to run, on the whole, parallel with it. It is striking that, especially in the stretch of river running East-west, the degree of parallel texture is subject to very local change. Martin has already referred to this as follows:

"Neigung zur Parallelstruktur by übrigens gleichbleibender Zusammensetzung wird sehr häufig beobachtet, der Art dass grössere und kleinere Partien gneissartiger Biotitgranite [1]) ganz allmählig in rein granitischkörnige Gesteine [1]) übergehen; vielfach lassen beide Abänderungen sich aus ein und demselben Blocke herausschlagen" (l.c. p. 162).

The trend and dip of the parallel texture has been measured roughly, from Kabelstation upstream, partly direct and partly from the course of the diaclases.

Place.	*Trend and Dip.*
A rapid near Witte creek	East-west, very steep dip.
Near the Jowakaai creek	Do, dip very steeply towards the South.
Below Lanti-ston	East-west, very steep dip.
Above Lanti-ston	East-west, dip very steeply towards the South.
Close to Gansee	East-west.
In front of the Feul creek	East-west, dip 80° N.
The rapid of Grantata bakhosoe	N. 25° E., steep dip.
To the left of the island of Jaboetabiti	East-west, dip steeply towards the North.
Close to the Katoeka creek	N. 70° W., dip North.
In the stretch of river running East-west	East-west.
Below the Nana rapid	N. 70° W., dip North.
Above the Marowyne creek	East-west, dip steeply towards the North.
The Miengotiri falls	N. 100° W.
Do	NE.—SW.
Above the island of Pittiprati	ESE.—WNW. dip steeply.
Near the Adiadedde creek	N. 15° W., dip steeply.
Near the island of Pogro	North-south, dip 70° W.
Near Kapua	North 20° W., dip steeply towards the West.
Do	North-south, dip steeply towards the West.
The Madiengo fall	N. 25° E., dip 65° W.
Do	N. 25° W., dip 60° W.
Mamma-dam	N. 10° W., dip 70° W.
The Bata falls	North-south, dip steeply towards the West.
Above the Bata falls	North-south, 70° W.
Near the Pada creek	North-south, dip 75° W.
Below Awaia-poea-dam	North-south, dip 60° W.
Do, somewhat higher up	N. 15° W., dip 75° W.
The Bakrabote fall	N. 35° W., dip steeply towards the West.
Do, in porphyritic granite	N. 35° W., dip steeply.
Do, do	N. 45° W., dip steeply.
In front of the Koesikam fall	N. 20° W., dip 55° E.
The Koesikam fall, in porphyritic granite	N. 10° W., dip 55° E.
Above the Koesikam fall, in porphyritic granite	N. 70° W.
Do, somewhat higher up	N. 70° W., dip 50° E.
On the tail of the island of Kordonsanti	N. 60° W., dip 45° N.
Below this island	N. 80° W., dip 80° N.

[1]) read: Diorite.

In the stretch of river above Kabelstation parallel texture is but locally developed, but gains in significance especially past Gansee. It appears that the texture upstream first takes an East-west and then a varying course to a prevailingly North-south one: then it changes gradually again to East-west. The dip in as far as their is any question of it, is always steep, greater than 45°. Instead of sudden turns in the dip and strike it changes gradually. A few of the data from further upstream have been taken from the region of the Gran-rio-granites; here, too, the strike may be very clear, because of the parallel trend of the phenocrysts etc. It appears that the "strike and dip" in these granites is of the same nature as that in the rocks downstream, so that both reveal the same (primary) "tectonics".

There is no sharp boundary between the diorite-facies on the one side and the Gran-rio-granites on the other: on the contrary, the two are only to be regarded as different facies of the same complex. At quite a number of places we see mineralogical transitions among members of both groups: especially among the granites and the acid members of the diorite-facies diorites of the groups I, II and IV. Since the potash feldspar percentage varies extremely in the Gran-rio-granites, it is not surprising that in quite a number of cases, the granites pass into acid diorites. We find free potash feldspar, now in the most acid diorites (group IV) now in the quartz mica diorites (group I), and sometimes also in the quartz mica hornblende-diorites (group II) and in all the structure forms of these groups, transitions from different groups directly to the Gran-rio granites are present. Also in the Gran-rio massif itself diorites occur locally which, as appears from the observations during our expedition, are again and again but local modifications of the Gran-rio granite proper.

We may conclude:

The Gran-rio granites and the diorites are facies of the same magma; they are linked up by direct transitions in the field, and are pretty well of the same age.

IV. THE GABBROS AND GRANITODIORITES OF THE DE GOEJE MOUNTAINS.

In this chapter there will be discussed a series of rocks of greatly varying composition which are to be regarded as magmatically closely related. They vary from basic gabbros to quartz gabbros, diorites and quartz diorites of varying acidity, and biotite granites. Their magmatic affinity is accepted because they may be arranged into a series comprising all the transitions between the two extremes of the rocks mentioned. Not only is the modification in the mineral combination gradual, but a few "local" minerals, not found elsewhere, may, to a greater or less extent, be traced through the whole series. Besides this all the rocks appear in the same region, and have often been collected closely together.

The De Goeje mountains form a low range in the SE. of the Colony on the left bank of the Lawa. The range comprises the De Goeje summit proper (700 m.) as the highest point of a ridge running NW.—SE. over about 10 km., with numerous side-ridges and foot-hills. The De Goeje mountains in a wider sense are bounded on the East by that part of the Lawa, which occurs between the mouth of the Marowini and the Bushnegro-village of Soemanjere, and extend to the West to the neighbourhood of the Emma river (source river of the Gonini, a left hand tributary of the Lawa). In all, the region comprises an area of about 1000 km^2. Part of the region was surveyed in detail during the prospecting for gold by the Government (in the years 1904—1905). Map III shows the prospecting-trails and the course of the principal creeks.

From the extensive collection of rock samples gathered here, it appears that the region has a very varied composition, sharply contrasting with the surrounding granite region. Besides the basic and acid igneous rocks mentioned, we also know metamorphic rocks, both basic and acid ones, some of sedimentary, others of igneous origin.

Data concerning the distribution of these rocks in the field and the influence they have on the surface-relief, and also speculations on their geological bearings have already been published by the leader of the Government Mining-Exploration. [1])

In this chapter we shall discuss the granitodiorites and gabbros of the region. They will be treated in groups, preceded by a description of the mineral-components. After this, the arguments proving their magmatic relation will be summarized. In conclusion a review of their geological behaviour reconstructed from the data of the Government Mining-Exploration will be given.

THE MINERALS OF THE GABBROS AND GRANITODIORITES.

The minerals met with in these rocks are: orthorhombic pyroxenes, monoclinic pyroxenes, olivine, hornblende, biotite, plagioclase, potash feldspar, quartz, ore, pyrite, apatite, zircon, orthite, garnet and tourmaline.

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[1]) See E. Middelberg. **64**.

Orthorhombic pyroxenes.

These pyroxenes in the majority of rocks belong to the essential components. Their optical features vary too much to use one single name for all. They invariably contain a small percentage of iron, judging from the rarely occurring pleochroism, which (in the thin sections) shows a maximum variation from pale rose red (according to $n\alpha = b$) to pretty well colourless in the other directions. Mostly, however, either slight variation of colour or none at all is visible. In addition to this the optical sign is now negative, now positive, sometimes in the same thin section, or the axial angle amounts to approximately 90°. All this together points to members of the hyperstene — bronzite — enstatite-series poor in iron. The red pleochroitic pyroxenes, and also the colourless ones, which are optically negative, must be called hypersthene; this turns out to be most frequently the case. Great dispersion of $\varrho > v$ may sometimes be seen. Distinctly negative pyroxene, but at the same time totally devoid of colour, occurs e.g. in norites (V. 334, 709 etc.) A peculiar hypersthene with a microscopically distinct, yellowish colour and very feeble pleochroism appears in a single quartz hypersthene hornblende diorite (V. 1060).

Completely or as good as completely colourless pyroxenes, showing positive, feeble birefringence, or a birefringence that defies closer definition are bronzite or enstatite. The name of bronzite has been chosen here. The refraction of these last mentioned pyroxenes is abt. 1,680. The distinction from the colourless hypersthene is often difficult on account of the not very characteristic behaviour of the latter.

The shape of the orthorhombic pyroxene varies very much. Hypersthene is usually irregular in shape, with a greater length in the direction of the prism-zone, or this zone is well developed without end-faces (e.g. V. 695, 701). Patchy crystals may be perforated (V. 621). Relatively large crystals apparently crystallized later than the adjacent plagioclases which cut the hypersthene into figures bound by broken lines; in that case this form is quite the same as we sometimes observe in the ophitic structure of diabases (see V. 399, 400, 516, 519, 650, 693). This shape also occurs in a few rocks with pyroxene which ought rather to be called bronzite (V. 517, 705).

The following cleavages occur: the (110) cleavage, often that according to (100), and sometimes also the irregular one according to (010). In prism-shaped pyroxene cross-fractures are common.

Pretty often we may observe that the extinction is not homogeneous. In sections approximately parallel to the prism-zone, between crossed nicols, we observe very fine and vague lamellae running parallel to this zone; we cannot trace them along the whole length of the section for they are fibrous. The well-known leaves of titanomagnetite sometimes occur in the laminated crystals (V. 399, 519, 611, 695). More often, however, they occur in normal hypersthene. They diminish in size to dust-particles and cause a brownish tint of the hypersthene (see V. 516, 400).

Monoclinic pyroxenes.

Augite is present in quite a number of rocks in different varieties. The only thing worth mentioning is the occasional appearance of a fine, strictly parallel base cleavage (V. 519, 648, 689).

Olivine.

This mineral is invariably irregular in shape. Kelyphitic zones between olivine and plagioclase are very characteristic (Pl. 36 fig. 4). At the contact with orthorhombic pyroxene, hornblende and biotite this rim is lacking. The zone is, without exception, double. Immediately around the olivine a colourless, extremely fine radial fibrous mineral is arranged, which owing to feebler refraction forms a strong contrast with the olivine. It is possibly tremolite. This zone is on an average 50 μ wide. It is generally surrounded by a somewhat or several times broader zone of pale green hornblende. The latter shows very fine vermiform structure of slightly curved bodies inserted radially on the former zone, and growing out into the adjacent basic plagioclase, as if they were partly replacing the latter. The structure looks like that of the quartz worms of quartz-plagioclase myrmekite; only it is much finer and much denser. Besides this, hypersthene, which borders on olivine at the place where the latter touches the plagioclase with a double zone, may locally intrude between the olivine and the green hornblende and form a colourless rim there. The optical orientation and cleavage point to the connection of the colourless rim and the adjacent hypersthene. The fibrous polarizing tremolite material predominates, however, by far. Occasionally some insignificant rims of brown biotite around olivine appear locally. In a rock very rich in olivine (troktolite V. 693), practically all olivine is surrounded by the double zone; in rocks bearing more pyroxene only part of it. The zone is synantetic according to Sederholm's idea [1]) (for distinct zones see V. 502, 512, 650, 691, 693, 705).

Hornblende.

Hornblende belongs to the essential components in a large number of rocks. Quite a number of varieties occur, among which there are some very characteristic ones. They are chiefly recognizable by the nature of the pleochroism.

Brown hornblende resembles basaltic hornblende, but is distinguished from it by slighter refraction, double-refraction and pleochroism. The pleochroism extends from chestnut-brown to nearly colourless. This hornblende seems to be a brown variety of the more common green hornblende as sometimes a greenish tint appears at the edges. Quantitatively this brown hornblende is usually negligible. We find it in norite (V. 701), in gabbro (V. 682, 713), in olivine gabbro (V. 691), or quartz gabbro rich in hornblende (V. 173).

A hornblende showing pleochroism from greenish-brown (according to n γ) to light yellow (according to n α) is widely distributed.

The intensity of the brownish tint may change, even in the same crystals,

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[1]) See the detailed summary of what is known of this phenomenon in J. J. Sederholm, On Synantetic Minerals. Bull. Comm. géol. de Finlande. Nr. 48. 1918, especially p. 34 and those following; and Pl. 1, fig. 4 and 5.

and in that case the edges are usually lighter than the centre. We find this variety in the larger part of the rock series viz. in norite, in gabbro (V. 519, 640), in olivine gabbro (V. 336), in gabbro rich in hornblende (V. 561, 712), in quartz gabbro (V. 611, 614, 632, 636), in quartz-bearing hypersthene diorite (V. 663), in the same when containing considerable hornblende percentage (V. 632) and in the more acid quartz diorites with but a few traces of pyroxene (V. 610, 618). In the very acid members, the quartz mica hornblende diorites free of pyroxene, it is practically absent.

The common green hornblende is also widely distributed and shows varieties of little importance. It is restricted to the quartz-bearing members of this rock-series. It appears in quartz diorites (e.g. V. 52, 354, 504, 673, 1062, 1064) and in pyroxene-free quartz mica hornblende diorites. In the latter it occurs in an intensely pleochroitic form, often with a more or less bluish-green tint according to n γ, which may also be restricted to the edges; the centre may exhibit something of a brownish tint. Some crystals on the other hand are of a striking bluish-green. All these are but insignificant varieties of the same green hornblende linked up by transitions (see V. 547, 564, 602, 624, 625, 650, 652, 680, etc.) Recapitulating we may say then that the distinctly brown variety of hornblende appears in the basic and intermediate members, the greenish brown one in the basic, intermediate, and more acid members and the green variety in the intermediate and more acid, but also in the most acid ones of the series (the granites excepted).

All these hornblende types may show complications. In quite a number of thin sections local discoloration of the crystals appears. Instead of the different tints we observe pretty well colourless portions, which, if not very sharply, are yet clearly separated from the coloured part of the crystal. Besides this, the discoloured parts may show twinning. It is remarkable that usually instead of two or three, a larger number of lamellae (4—10!) appear in the same colourless field. The lamellae vary in breadth, and differ from each other in length, sometimes wholly intersecting the field, while others begin at the edges and end abruptly in the colourless field; again others appear but locally in it (Pl. 36 fig. 5). The twinning-plane is (100). Partial discolouring goes on to such an extent that quite colourless crystals appear. As the partly discoloured crystals occur here too, and, as none differ in refraction or other properties, we must assume contemporaneous origin; at any rate, the colourless type has nothing in common with the secondary hornblende. The colourless hornblende appears by the side of and combined with the three different colour-types in all the members of the rock-series. In the pronouncedly basic ones, the norites and the gabbros, it is less common (V. 516, 520, 529); it appears more, however, in the quartz-bearing rocks beginning with the quartz gabbros, through all the quartz-bearing diorites, and also in the pyroxene-free quartz mica hornblende diorites, even if it is less frequent there. The annexed list of numbers gives examples of practically all the members of the series (save the granites) (V. 309, 315, 341, 354, 504, 516, 520, 529, 544, 563, 564, 606, 607, 610, 613, 614, 615, 620, 630, 632, 633, 637, 645, 648, 652, 716).

In all the basic and medium acid and, partly, too, in the acid rocks, the hornblende may be irregular in shape without, however, conforming xenomorphically to other minerals. In other cases the plagioclase may cut the hornblende with broken lines; in that case idiomorphic plagioclase may be enclosed (Pl. 36 fig. 6). We very often see the phenomenon that hornblende grows at the edges of the pyroxene and consequently crystallized later, whilst the pyroxene need not show well-developed idiomorphism. This phenomenon is conspicuous, when the hornblende surrounds the pyroxene as a narrow zone reminding us of a reaction-rim. This rim, however, is not synantetic (see e.g. the norites V. 399, 701). In many cases we get the impression that pieces of hornblende and rims appear as a continued growth of pyroxene crystals, so vague is the boundary; in others, the pyroxene is sharply separated from the hornblende. Often too, pyroxene and hornblende penetrate each other. The hornblende of the quartz mica hornblende diorites usually shows the ill-defined forms seen in the corresponding rocks of the Gran-rio massif.

Biotite.

Biotite, invariably with the same optical properties, viz.: strong pleochroism ranging from dark, reddish-brown to pale yellow is very characteristic of the rock-series. We sometimes find it sporadically in the norites and in the gabbros, but in the more acid rocks it appears either as an accessory, or abundantly. The form of the biotite varies. In the basic and moderately acid rocks the forms are irregular; here the biotite shows a tendency to grow around the ore. In the pyroxene-free quartz mica diorites and granites the basal face is sometimes developed. Pleochroitic single haloes both around zircon and apatite are common; they may also appear as pleochroitic rims if biotite borders on orthite (V. 564).

Plagioclase.

In connection with the very divergent basicity of the members of the rock series, the anorthite-percentage also varies within very wide limits. The form, degree of idiomorphism and twinning vary considerably and are best treated with the rock-types in question.

Potash feldspar.

Except in the granites, where microcline of a special type is present (see p. 258) potash feldspar occurs very rarely. Only in a quartz hypersthene hornblende diorite (V. 1064) a single irregular piece showing no lamination, probably orthoclase, is found. Myrmekite appears on the border together with plagioclase.

Quartz.

The quartz exhibits no special features. Enclosed dust, often arranged in strings, is present in a number of rocks.

Ore.

Ore is very widely distributed in this rock series. The percentage of ore need not in any sense be large; in general it is present in slight quantities.

In the gabbros, for instance, the ore is invariably of trifling importance, likewise in the relatively basic diorites. Neither in the gabbros, nor in the diorites, does ore occur in octahedral form, but as grains and as large patchy ilmenite. Pure magnetite seems to be wanting.

Pyrite.

Some pyrite without idiomorphism may occur both in the basic and in the acid members of the rock series.

Apatite.

We seldom find apatite in the true gabbros. It appears, however, in considerable quantities in the quartz gabbros, and in all the more acid rocks. Abundance of apatite occurs in a number of quartz-bearing hypersthene hornblende diorites and also in a number of pyroxene-bearing quartz diorites, but it need not be constantly present even here. In the diorites mentioned, we often observe idiomorphic crystals showing either long or short prismatic shape; the shorter ones having endfaces (base and pyramid may be developed) which are otherwise but rarely developed in apatite.

Zircon.

Zircon is seldom recognizable in the true gabbros and is seen only here and there in the basic diorites. In the more acid rocks, however, it is common but always in small crystals. Zonal structure is absent.

Orthite.

Orthite is confined to the acid and most acid members of the series. It has passed more or less into isotropic modification. The crystals are developed according to the c-axis, the faces (001) and (101) may be present. Other crystals appear as irregular pieces. The isotropic modification has a feebler refraction than the original mineral must have had, but many crystals consist of a yellowish-green mass of strong refraction, which locally makes room for a turbid mass and sometimes, too, for a brown or reddish-brown discoloured mass. Indications of radial cracks around these pseudomorphs sometimes point to an increase in volume. The mineral occurs in a single quartz hypersthene hornblende diorite (V. 617), often in the hypersthene-free quartz mica hornblende diorites, and also in the granites.

Garnet.

Garnet occurs very rarely in colourless grains of irregular shape; some quartz may be enclosed. It may attain to a size of 2 mm., usually, however, the grains are considerably smaller. It bears the character of a local accessory component, and is only found in a couple of quartz mica hornblende diorites (V. 652, 686) and in a quartz mica diorite (V. 554).

Tourmaline.

A very trifling quantity of bluish tourmaline occurs in a single quartz mica diorite (V. 554).

PETROGRAPHIC DESCRIPTION AND CLASSIFICATION.

Gabbros.

The mineral-combination of the gabbros varies, and a number of types may be distinguished, which, however, are so much linked up by transitions that classification is hardly possible. They may be quartz-free or quartz-bearing. The *quartz-free* gabbros yield the following types:

Troktolites: gabbros containing olivine almost exclusively as coloured mineral. Such-like rocks by the lack of pyroxene may be traced back either to the norites or to the gabbros.

Gabbros rich in olivine, containing more olivine than pyroxene.

Norites, bearing practically only orthorhombic pyroxene (hypersthene or bronzite) as coloured mineral. If, in this case, olivine is present in considerable quantities the name *olivine norite* has been chosen.

Gabbros bearing orthorhombic and monoclinic pyroxene as coloured main components; either the pyroxenes are present in approximately equal percentages, or there is more monoclinic than orthorhombic pyroxene. Those, moreover, which contain a considerable percentage of olivine are called *olivine gabbros.*

Gabbros rich in hornblende we call those which, besides pyroxene, contain a large percentage of hornblende; if there is also a considerable quantity of olivine present, we may speak of *olivine gabbros very rich in hornblende.*

The *quartz-bearing gabbros* contain interstitial quartz of secondary importance. Their mineral combination is likewise variable; as essential components there may appear: orthorhombic or monoclinic pyroxene, or hornblende. For the former the term of *quartz-gabbros* has been chosen, for the latter *quartz hornblende gabbros.*

Troktolites.

We know of but one rock answering to the above-mentioned mineral-combination (V. 693). It is massive, consisting of about equal quantities of black olivine and gray feldspar. Microscopically we observe clearly polysynthetic plagioclase (70 % of An.) which, together with olivine and some hypersthene, shows gabbroid texture. The oblong-shaped plagioclases impede each other mutually. Here and there they contain strings of dust; in places, too, the otherwise irregularly shaped pieces of olivine conform to the plagioclases and may enclose them in part. The olivine, without exception, shows the double kelyphytic zone. Wide cracks cross the olivine; some granules of ore and some limonite have been formed in them. Weakly pleochroitic hypersthene shows the well-known titanomagnetite (?) leaflets; it conforms in shape to the plagioclase. Some brown hornblende has grown around the patchy ore, or around the olivine. Some pyrite grains occur, too. The sequence of crystallization is poorly-developed, none of the components having been formed pronouncedly earlier than the others, ore forming a possible exception, although it shows no idiomorphism. The rock shows no trace of cataclasm.

Gabbros very rich in olivine.

Macroscopically and microscopically two rocks agree with the preceding ones both as regards their mineral-combination and their structure. (V. 69, 650). Hypersthene only is present in somewhat larger quantities, yet it is in the minority with regard to olivine. Some monoclinic pyroxene may also be present. In one rock (V. 69) kelyphitic zones have almost completely taken the place of the olivine.

Norites and olivine norites.

We know a large number of norites. As coloured maincomponents they have orthorhombic pyroxene, by the side of which a very trifling quantity of monoclinic pyroxene may be found (V. 334, 399, 621, 694, 701, 709). Others again bear hornblende (V.400, 401, 402, 516, 695). One of these rocks contains olivine as an accessory mineral (V. 709), while a few rocks have a considerable quantity of olivine and are consequently termed olivine norites (V. 511, 521). In the sample they are usually massive and normal-grained, sometimes also fine- or almost coarse-grained rocks (V. 709); they show about as much black pyroxene as gray feldspar. Microscopically, the orthorhombic pyroxene is mostly colourless. It may contain titanomagnetite (?) leaflets in great masses which are extremely fine and produce pseudo-pleochroism (see V. 399, 400, 695, 701). The colourless pyroxene may be optically negative (hypersthene, e.g. V. 621), or positive (bronzite, V. 701), or the axial angle may amount to about 90° (V. 709). The hypersthene may show feeble pleochroism in the olivine norite (V. 521). The hornblende has a distinct tendency to grow as rims around the pyroxene (V. 400, 695); the rim may attain to a considerable breadth (V. 401). The hornblende may also be intergrown with orthorhombic pyroxene (V. 516). It is a greenish brown or pale greenish hornblende which sometimes passes into the colourless polysynthetic variety. Some brown biotite, ore and pyrite belong to the accessories. Grains of ore may be present in considerable quantities (V. 401). We find olivine with the double kelyphitic zone in the olivine norites; while in one single rock, olivine appears as an accessory, enclosed in orthorhombic pyroxene (V. 709). The clear plagioclases (60 % of An, in V. 399) are usually more or less oblong-shaped, impeding each other mutually. The orthorhombic pyroxene shows a tendency to conform to the shape of the plagioclase. This is the case especially where the pyroxene crystals are considerably larger than the plagioclase, the latter may be entirely enclosed in that case (see V. 399, 400, 516, 521 and Pl. 37 fig. 1).

In another type both the pyroxene and the plagioclase have a tendency towards oblong shape. Neither of them reach absolute idiomorphism, they impede each other mutually (Pl. 37 fig. 2; do V. 695, 701, 709). Or the plagioclase has a well-developed oblong shape, while the pyroxene appears in small irregular pieces, without either of them manifesting idiomorphism. In others again, both form pieces varying in shape (V. 401). Or the plagioclase forms a mosaic of small, polyhedral, partly twinned grains, between which pieces of pyroxene are found, some of which are of considerable size and often perforated (V. 334). All these types are varieties of the gabbro-structure. Except perhaps in tne ore and in the rocks in which a tendency to ophitic structure appears, sequence of crystallization is practically negligible. Signs of pressure are wanting.

The gabbros and olivine gabbros.

There are other gabbros with approximately equal quantities of orthorhombic- and monoclinic pyroxene (V. 396, 502, 512, 522, 646, 689, 705, 707, 716), and others again with a larger quantity of monoclinic- than of orthorhombic pyroxene (V. 398, 517, 519, 520, 567, 682, 700, 706). Among them there are a few with a considerable percentage of olivine, named olivine gabbros (V. 502, 512, 567, 691, 705). Some gabbros only have accessory olivine (V. 682, 700, 707). In the sample all are massive, normal-, sometimes fine-grained rocks showing dark or brownish pyroxene, and grey feldspar, in approximately equal quantities.

Those which possess relatively large quantities of orthorhombic pyroxene are closely linked up with the norites. The orthorhombic pyroxene is a very feebly pleochroitic, or colourless hypersthene (e.g. V. 396, 691, 707) or a colourless bronzite (e.g. V. 705). The monoclinic pyroxene is augite, sometimes with base-cleavage.

Olivine shows double kelyphitic zones, and is irregular in shape. In one of the olivine gabbros (V. 502) the olivine has undergone considerable change and is only recognizable by the typical zone. The plagioclase is basic (70% of An. in V. 396 and in V. 398; 85% of An. in V. 502). Hornblende, mostly brown or greenish-brown, sometimes also as good as colourless, is unimportant, exceptly in the gabbro V. 682, in which it is of significance, whether independent or as rims around pyroxene, or intergrown with monoclinic pyroxene. Some brown biotite may occur. Just as in the preceding rocks the accessories vary little. Ore-grains are of little importance; occasionally they occur together with some pyrite (V. 596, 682). Apatite-grains appear in one single rock and haloes are formed in the adjacent biotite (V. 682).

Structurally there are various types. The plagioclase and pyroxene often show a tendency to ophitic structure; but here, too, it appears on closer inspection, that the crystallization-interval between the two is not large, for the plagioclase shows no sharply defined idiomorphic shape (V. 502, 519, 520, 522, 682, 700, 705). Or the plagioclase and pyroxene have a tendency towards oblong shape; this is especially true of the rocks relatively rich in orthorhombic pyroxene (V. 396, 689, 707). The plagioclase and pyroxene in that case are only idiomorphic in the general shape; they impede each other mutually. In another type again, the plagioclase is sometimes more or less distinctly oblong, while the pyroxene forms irregular pieces (V. 646, 706, 716) or both are irregular in shape (V. 398, 512, 691, 700) (Pl. 37 fig. 3). The structure in a single rock rich in olivine is quite different (V. 567). Lath-shaped plagioclase cuts the augite so that the structure is typically ophitic, and the rock may be termed an olivine diabase. It differs from the intrusive olivine diabases already discussed by the kelyphitic zone around the olivine. Olivine, in so far as it is present, invariably has poorly-developed crystal-shape.

Concerning the crystallization-sequence we may say: apatite is the oldest component, possibly older than ore and pyrite. Pyroxene, plagioclase, and olivine show a indistinct sequence, although sometimes smaller pieces of olivine may be enclosed in pyroxene (V. 691). The plagioclase, as we have seen, sometimes shows a tendency towards ophitic structure. Hornblende, just as biotite, is usually later than pyroxene; the former is occasionally intergrown with the latter, and consequently is, in this case, contemporaneous with it. In general the sequence of crystallization is poorly developed. Signs of pressure are wanting.

The gabbros rich in hornblende and the corresponding olivine gabbros.

The few quartz-free gabbros containing a considerable quantity of hornblende, differ greatly both as to their mineral combination and their structure. Those richest in hornblende are normal-grained rocks containing only accessory monoclinic pyroxene, and consequently may be called hornblende gabbros. (V. 529, 530).

The hornblende is partly the brown variety, often with a discoloured rim; the colourless hornblende also appears independently. It is certain that not all the hornblende is primary. Fibrous hornblende partly surrounds pyroxene, the edges of which are frayed and may also penetrate into the plagioclase: incipient epidioritization is present. The augite is partly intergrown with hornblende. Orthorhombic pyroxene appears as oblong-shaped pieces showing very weak birefringence. The plagioclase is basic (65 % of An. in V. 529). Brown biotite and some ore form the accessories. The plagioclase, oblong in shape and enclosed in the coarser pieces or hornblende here and there, forms together with the latter typical gabbro-structure. Signs of pressure are wanting.

Three other normal- to fine-grained gabbros (336, 361, 712) have only a small percentage of brown or greenish-brown hornblende. Besides this, colourless hypersthene sometimes occurs, mostly in the form of oblong-shaped crystals (V. 561), or the pyroxene is almost exclusively augite appearing in irregular pieces (V. 336, 712). The hornblende is partly independent, or grows around the pyroxene, or some mutual intergrowth may be seen. In the rock V. 336 we observe patchy olivine, not surrounded by the typical kelyphitic zone, but by a rim of hornblende, which seems constantly to accompany it. The percentage of olivine is so important that we are concerned with an *olivine gabbro rich in hornblende* (V. 561). As accessories we may find brown biotite, apatite, ore and pyrite, sometimes also some zircon (V. 561). Besides this we observe numerous strongly refracting and doubly-refracting microlites in the plagioclase. The apatite (V. 561) is present in fine but sharply crystalline-shaped needles. All these fine-grained rocks show massive texture. Except in some oblong-shaped hypersthene crystals, idiomorphism of the essential components is lacking. By their mutual enclosure we can make up the sequence of crystallization: first come apatite, zircon, ore and pyrite, next pyroxene and olivine, and already contemporaneously with these, hornblende, biotite and plagioclase. Signs of pressure are wanting.

Another structure is met with in the following gabbro (V. 548). The sample is fine-grained, and only glittering spots of pyroxene may be recognized here and there. Microscopically some likeness to ophitic diabase-structure strikes one immediately, which is strengthened by the slight dimensions of the components. We observe plagioclase, monoclinic pyroxene, pale-brown hornblende, some brown biotite and a little ore. The plagioclase is approximately labradorite or basic labradorite. The laths are all jumbled up together and the relation to the coloured minerals is vaguely ophitic because of the latter not wholly occupying the space left by the laths but obstructing the shape of the laths at the edges. The coloured minerals together are, locally, equal to the quantity of the plagioclase. The pyroxene appears in grains and pieces; all of them are smaller than ¼ mm., while many are still smaller and appear in little clusters as inclusions of the feldspar. Cinnamon-brown hornblende appears in approximately equal quantities as pyroxene, but has no shape peculiar to itself; the pyroxene may be surrounded by hornblende. The minerals are not systematically grown together but their period of crystallization partly coincides, judging from their intergrowth, while that of the hornblende extends over a longer time. Here and there we notice a piece of orthorhombic pyroxene with very feeble double-refraction. The biotite shows some well-developed base-faces and pleochroism ranging from bright-yellow to deep chestnut-brown. Quantitatively the biotite is of trifling importance. Scarce ore may be enclosed in the coloured minerals. Other minerals have not been noticed. The sequence of crystallization except with regard to the plagioclase is, as has been stated, poorly developed. Signs of pressure are wanting. The mineral-combination in this sample and its fine grain, reminds one of rocks, which, in imitation of Gümbel, are called proterobases.

The quartz gabbros.

In the sample the quartz gabbros are normal-grained-, sometimes also fine-grained rocks, showing coloured pyroxene and gray feldspar. Sometimes the pyroxenes are brownish, so that the rock has a gray speckled appearance (V. 544). These gabbros agree to a certain extent with the preceding ones, but differ from them by interstitial quartz of secondary importance, and by a somewhat smaller percentage of pyroxene and sometimes by somewhat more acid plagioclase, hence they form a direct link with the diorites. They contain some orthorhombic- and less monoclinic pyroxene, hornblende and biotite (V. 544, 611, 613, 614, 633, 636, 637, 663). One single sample contains predominating monoclinic pyroxene (V. 713). One rock, showing much hornblende, stands alone, i.e. a quartz gabbro rich in hornblende (V. 173). The orthorhombic pyroxene is practically colourless in the thin section. A considerable number of crystals have a well-developed prism-zone with typical cross-fractures. The double-refraction is generally not very feeble. Irregular pieces of monoclinic pyroxene are of trifling importance. The plagioclase has a basic composition (in V. 613 and 614, it was ascertained to contain 60% of An.; in V. 637, 55% of An.) The crystals, when bordering on interstitial quartz, show beautiful idiomorphism. Brown, usually greenish-brown, and also colourless polysynthetic hornblende is invariably present, but occupies a minor position. The hornblende appears independently, or has grown around the pyroxene. The coloured biotite appears as an accessory. Of the accessories, too, a considerable quantity of ore invariably occurs in the form of grains and patches. Apatite in these rocks has a fairly wide distribution (V. 544, 611, 614, 633). It forms prisms of varying lengths with respect to the breadths. The interstitial quartz sometimes shows strings of dust.

The rocks show typical gabbro-structure. The coloured components, the hypersthene partly excluded (namely the prismatic crystals), have no idiomorphism; the larger pieces sometimes conform in shape to the plagioclases, and enclose a few of the latter; this phenomenon may also be seen with hornblende and biotite (V. 614). The sequence of crystallization is: apatite, ore, and pyrite, orthorhombic and monoclinic pyroxene, hornblende and biotite, plagioclase whose period coincides with that of all the coloured minerals and interstitial quartz.

The quartz gabbro, rich in hornblende, has another composition (V. 173). This rock, however, agrees entirely with the hornblende gabbros described above, to which we refer the reader; it differs only by some interstitial quartz, and the appearance of accessory olivine showing a double kelyphitic zone. It is possible here too, that not all the hornblende is of primary nature. None of these rocks show signs of pressure.

The diorites.

The separation of the relatively basic diorites from the quartz gabbros is entirely artificial. All the diorites together form a transitional series from the quartz gabbros to a number of biotite granites. For the division into groups, the dark components, the composition of the plagioclase and the quantity of quartz have been taken into account. The most basic types have much pyroxene among the coloured minerals, the plagioclase is andesine or labradorite; quartz is present in varying quantities. We call them *quartz-bearing hypersthene hornblende diorites.* The intermediate diorites contain pyroxene, hornblende and biotite in varying percentages, together with plagioclase which, on an average, has the composition of andesine. Quartz is present in considerable quantities. They all contain a significant quantity of pyroxene, mostly orthorhombic (hypersthene). Those which, besides, contain a considerable quantity of hornblende (and frequently biotite too), are classified here as *quartz hypersthene hornblende diorites.* If, however, monoclinic pyroxene takes the place of hypersthene, the name is *quartz augite hornblende diorites;* while those containing hypersthene and biotitie only are named *quartz hypersthene biotite diorites.*

While the quartz diorites just mentioned have an acid composition, this applies in an even greater measure to the following rocks. They have quartz, plagioclase, hornblende and biotite as essential components, the last two in varying percentages, and may be classified as *quartz mica hornblende diorites.* In these diorites pyroxene appears only as an accessory and is more often entirely wanting. Hornblende and biotite again constitute the coloured components in greatly varying percentages; plagioclase usually has the composition of oligoclase-andesine or is somewhat more acid; quartz is invariably present in abundance. A few of these acid and most acid diorites have gneiss-structure.

Although what has been said concerning the percentage of quartz in connection with the basicity of the diorites, applies in general, this percentage need not, however, decrease or increase in strict relation to the quantity and nature of the coloured components, and variation in this respect is possible.

The quartz-bearing hypersthene hornblende diorites.

In the sample these diorites are normal-grained, massive rocks, while mostly the coloured components, whether pyroxene, hornblende or biotite, are recognizable, by the side of feldspar. Microscopically they appear to contain hypersthene and hornblende chiefly as coloured components (V. 315, 608, 615, 616, 617, 620, 632, 635) (Pl. 37 fig. 4) or a considerable percentage of biotite appears by the side of these (V. 309, 645, 648). In the first series biotite is present in small quantities, and in both series monoclinic pyroxene is met with in very small quantities. Interstitial quartz is quantitively of little importance, as in the quartz gabbros. Plagioclase has the composition of andesine or labradorite (the latter was found in V. 315 and 608: with 55% of An.). The general habitus of these rocks is the same as that of the quartz gabbros, and the same is equally true of the minerals separately. The practically colourless hypersthene is mostly well-developed according to the prism-zone. There are typical cross-fractures present. The double-refraction is now feeble, now less so. Hornblende appears as irregular pieces, both of the greenish-brown and the colourless variety; the latter may be abundant, often with polysynthetic twinning. Biotite is again reddish-brown, sometimes it has grown around the ore. As accessories apatite is common, in one single rock even strikingly much (V. 615). The crystals are well-developed. Pieces of ore are invariably present. Zircon, of short prismatic shape, is found here and there (V. 309, 315, 615). The interstitial quartz may show strings of dust. These rocks exhibit a diorite-structure on the one hand, and on the other hand, some indication of gabbro-structure. In places where hypersthene with a tendency towards idiomorphism is abundantly present, and also where the interstitial quartz conforms to the idiomorphic plagioclase, the structure is dioritic; where plagioclase is accumulated, however, and where many irregular pieces of hornblende and biotite occur, we had better call it gabbroid.

Here and there we may see how idiomorphic plagioclase intersects larger pieces of hornblende and biotite, but this is of trifling significance. The sequence of crystallization is: apatite and zircon, ore, hypersthene and monoclinic pyroxene, hornblende and biotite, plagioclase, whose period approximately coincides with that of all the coloured components and interstitial quartz. Signs of pressure are wanting.

The quartz hypersthene hornblende diorites.

The rock of this group, besides hypersthene, contain a considerable percentage of hornblende and biotite (V. 52, 354, 504). In the sample they all look alike, normal-grained, massive and dioritic. Both macroscopically and microscopically they are closely related to the preceding diorites; however, they have a larger quantity of quartz, and the plagioclase is invariably approximately andesine (50% of An. in V. 354). The colourless hypersthene again has a tendency to be developed according to the c-axis. The hornblende shows the greenish-brown and colourless varieties, the latter often with distinct polysynthetic twinning structure. Patchy pieces of biotite again of a dark reddish-brown, reach the size of 3 mm. and more. The plagioclase in connection with the fairly large percentage of quartz, exhibits rather often idiomorphic crystals. Pieces of ore are always present, often as patchy ilmenite. Apatite is invariably present; zircon is seen in two of the rocks (V. 52, 354). The structure is dioritic with perfectly massive texture. The sequence of crystallization is: apatite and zircon, ore, hypersthene, hornblende and biotite, plagioclase whose period again seems to coincide with that of all the coloured minerals, and interstitial quartz. Here we see for the first time some signs of pressure. In the rocks (V. 52 and 354) quartz is undulose and crushed to fields. Besides plagioclase may be slightly bent.

V. 1060 differs from the preceding rocks. In the sample we observe distinct parallel texture. It is normal-grained, irregularly spotted with relatively coarse feldspar crystals forming a contrast with a groundmass very rich in coloured minerals. Microscopically, we observe only hypersthene and hornblende as coloured essential components; biotite is entirely wanting. Quartz is present in abundance, though somewhat less than plagioclase (andesine). The texture shows quite a new feature: the oblong-shaped plagioclases run parallel in general; so do a few flattened pieces of quartz, and the coloured minerals are also arranged in strings. The texture is gneissose; the plagioclases however, still show signs of sequence of crystallization in respect to quartz; typical gneiss-structure therefore is wanting. The hypersthene is of an unusual type, namely yellow in colour in the thin section, yet it yields the normal negative interference-figure. It forms extremely irregular crystals, seldom clearly developed according to the c-axis. Apatite and ore are sometimes enclosed. The hornblende does not show crystal-shape either; here for the first time, we are concerned with the usual green type. Yet, here and there, typical discolouring appears; besides this, polysynthetic twinning may appear. Of the accessories patchy ore is abundant. Apatite appears in strikingly large quantities. It has a rounded-oblong shape. A single piece of an unknown, optically positive uni-axial and very intensely refracting and birefracting mineral is present. Signs of pressure are clearly present, the quartz is undulose, the plagioclase shows bent lamellae which may wedge out into lamellae-free fields. On the whole it is a gneissose diorite.

The quartz augite hornblende diorites.

Of this group we have but a few representatives (V. 619, 657, 673). They are normal- or fine-grained and very dark in the sample. They consist of plagioclase (andesine), a fair quantity of quartz, hornblende and biotite; hypersthene is wanting. The plagioclase shows well-defined idiomorphism to which quartz conforms; the crystals are pronouncedly oblong-shaped. The hornblende is greenish-brown, partly discoloured. The biotite shows the usual dark colour. The coloured components show no idiomorphism. Biotite, which is abundant in V. 657, may form an exception to this by development of the basal plane. Ore and needle-shaped apatite occur as accessories; ore, however, is wholly lacking in one number (V. 657) which is rich in biotite. Except in the accessories and in plagioclase towards quartz there is no important sequence of crystallization to be seen. The texture is perfectly massive. Cataclasm is wanting. V. 619 differs from this description by ill-developed sequence of crystallization and a smaller percentage of quartz.

The quartz hypersthene biotite diorites.

Three diorites rich in quartz contain hypersthene and biotite as coloured minerals, and an insignificant quantity of primary hornblende (V. 647, 1063, 1064). One of these (V. 647) has a considerable quantity of hornblende, but this has been for the greater part formed secondarily from hypersthene: fibrous hornblende surrounding hypersthene-remnants. The sample is very fine-grained, massive, and rich in coloured minerals, with a diabase-like appearance. Two of the rocks from the same locality (the Poeloekoemaroe fall in the Lawa V. 1063, 1064) may be discussed at the same time. The samples, it seems, are missing, at any rate those present fail to correspond to the thin sections. Microscopically these exhibit irregular texture. In parts they show well-developed sequence of crystallization of twinned plagioclase (andesine) before quartz; the rocks are poor in biotite of the dark reddish-brown type and in irregular pyroxene. The latter is a practically colourless, somewhat yellowish hypersthene. In the same thin section we observe portions of much finer grain and with a considerable percentage of the same hypersthene and biotite. The crystallization-sequence between quartz and plagioclase is slight here, and locally it is wholly wanting; the boundary-lines have an irregular, and in parts, undulating course; the hypersthene is also very irregular in shape; the rock has typical ortho-gneiss-structure. The coloured minerals are, in addition to this, arranged in strings. The coarser portions with-, and the finer ones without sequence of crystallization are linked up by transitions. Some green hornblende appears locally with the typical discolouring. Apatite, zircon and some ore appear as accessories.

The third rock (V. 647) is a massive, fine-grained diorite, rich in quartz, with very well-defined sequence of crystallization of the plagioclase (andesine) before quartz. With the exception of the secondary formation of hornblende from hypersthene, it belongs entirely to the type of the last-mentioned rock group.

The quartz mica hornblende diorites.

Although they are all true acid diorites, the mineral combination admits of a number of types being distinguished. In the first place there are rocks which are directly linked up with the preceding diorites but which differ from them by the orthorhombic pyroxene no longer constituting an essential component. Some contain hornblende only; so they are *quartz hornblende diorites* (V. 341 and 610), others bearing a considerable percentage of biotite in addition are called *quartz mica hornblende diorites* (V. 607, 618, 630, 638). While in the preceding rocks there occurs some hypersthene, a couple of rocks closely agreeing with the latter type show no pyroxene at all (V. 312, 664). In the sample all are massive, normalgrained rocks, the coloured components being macroscopically recognizable. Microscopically, all these rocks provide a uniform type, characterized once more by the same bright-coloured hornblende, the dark biotite and the strikingly well-defined idiomorphism of the plagioclase, to which the quartz conforms. The plagioclase varies very considerably in length in the different rocks and sometimes in one and the same rock. The plagioclase is strikingly oblong in parts, even lath-shaped in the rock V. 341. In the others the plagioclase varies from oblong to isodiametric, but invariably shows conspicuous idiomorphism; Pl. 38 fig. 1 gives a group of these plagioclases with interstitial quartz between them. In the rock from which this photo was taken, we can locally observe a complication in the border-lines between the plagioclase and the quartz: instead of being straight, the border-line is serrated, "sutured". The dimensions of the "teeth" at the edges of the plagioclase are, however, always small. Plate 38 fig. 2 shows the deviating border-lines; the figure is taken from the same group of plagioclases as the first photo, so the phenomenon is probably of little importance genetically. The twinning of the plagioclase is frequently vaguely developed. The hornblende is greenish-brown, partly discoloured, often quite colourless and in that case shows the conspicuous polysynthetic twinning. The ordinary green hornblende is less frequent (V. 664) and in this rock we observe a typical relation between hornblende and plagioclase (Pl. 36 fig. 6). The plagioclase is almost idiomorphic, distinctly oblong and the much larger hornblende crystals surround numbers of plagioclases, which also cut the hornblende at the edges. According to orientation and cleavage, the hornblende belongs again and again to one large crystal. Hence here we have an instance of well-defined sequence of crystallization between the two, which, otherwise, is not the case. Biotite forms very irregular patchy crystals attaining to a size of several mm. Hypersthene, in so far as it is present, is confined to insignificant, colourless, oblong-shaped pieces with feeble, double-refraction, often with some hornblende at the edges. Apatite, ore and zircon are accessories with a wide distribution, sometimes also pyrite (V. 341, 607). In one single rock (V. 638) an isotropic relic of an insignificant orthite-granule seems to be present. The structure is typically dioritic. Some traces of cataclasm viz. undulose extinction of quartz are of trifling importance.

Other *quartz mica hornblende diorites* are very closely related to the preceding ones. They are normal- or fine-grained rocks, of granitic habitus, and massive texture, occasionally showing some parallel texture by the orientation of the mica-leaflets. Microscopically they differ from the preceding ones only in details, namely by the lack of pyroxene, and by the plagioclase being somewhat more acid (oligoclase-andesine). Quartz is mostly present in abundance. The hornblende may show the typical variation in colours again. The biotite is again the same. The plagioclase very frequently shows idiomorphism towards quartz, the shape invariably being slightly oblong. As accessories ore, apatite, and zircon are common, occasionally pyrite also appears. The orthite deserves special attention having almost wholly passed into an isotropic modification. It still shows well-developed crystal-shape. Several crystals may be met with in the same thin section; they attain to a size of 1 mm. or more.

One single rock (V. 1062) deviates by the parallel texture in the sample, in consequence of the equal orientation of the biotite and hornblende and the more oblong-shaped plagioclase crystals. The latter show fewer signs of idiomorphism; the rock resembles a gneissose diorite. On the whole, however, all are typical rocks, variegated by the coloured minerals, mostly green hornblende and reddish-brown biotite, usually with well-defined sequence of crystallization of plagioclase in respect to quartz. Biotite and hornblende vary in quantity (V. 133, 537, 547, 563, 564, 602, 624, 625, 651, 652, 680, 681, 711). In one single rock hornblende occurs almost exclusively as coloured mineral; so this is a quartz hornblende diorite (V. 681). Signs of pressure: i.e.: undulose quartz and sometimes also crushed quartz repeatedly appear.

Owing to decrease or total lack of hornblende these rocks pass into *quartz mica diorites* (V. 554, 623, 653, 686). In the sample the latter are normal to fine-grained, of granitic habit, occasionally with some parallel texture once more caused by parallel trend of the brown biotite. The plagioclase (oligoclase) it but slightly oblong-shaped and usually manifests well-defined idiomorphism towards quartz. The twinning is only moderately distinct. In one fine-grained rock (V. 623) rich in biotite, parallel orientation of the biotite is clearly developed, but the sequence of crystallization is less distinct. The biotite, here, is rich in pleochroitic halos. Ore, apatite, and zircon belong to the accessories; in number V. 554 there is also some garnet and a trace of tourmaline.

The biotite granites.

The granites discussed here might be treated as well with the Gran-rio granites. On the one hand they are Gran-rio granites, but of a special type, on the other hand they are closely related to the acid members of the above series (V. 538, 548, 658, 659, 660). They are normal- to fine-grained massive rocks. Microscopically we observe quartz, plagioclase (oligoclase), biotite, and microcline as the essential components. The indistinctly twinned plagioclase now shows a tendency towards idiomorphism, now none. The potash feldspar now has crystal faces towards quartz, now none.It is invariably microcline. Besides this, apart from the grating-structure, twinning according to the Baveno-law is often developed; there may be simple twins among them, but very often also multiplets (Pl. 28 fig. 6; Pl. 29 fig. 1 and 2). Similar twins rarely appear in the typical Gran-rio granites. The reddish-brown biotite which is patchy or developed according to the base and which is typical of the preceding rocks, is also present here; because of the typical biotite and the microcline Baveno-twins, this granite constitutes a separate type of Gran-rio granite. Hornblende appears here and there, and shows the grass-green and bluish-green tint of the diorites discussed last. Ore, apatite, and zircon belong to the accessories and typical orthite-remnants also occur (for the latter see V. 548, 659, 660). Signs of pressure are present, the quartz manifesting undulose extinction and being crushed.

A fine-grained sample (V. 545) shows a deviating texture; very dark spots appear. The latter have the same mineral combination as the quartz mica hornblende diorites, but microscopically well-defined gneiss-structure is present through the lack of sequence of crystallization; so we are concerned here with local groups of ortho-gneiss.

Metamorphic gabbros and allied rocks: hornblende gabbros.

In connection with the unmodified rocks of the series, we may mention here a number, which have been materially affected by metamorphism. They are in particular gabbros rich in hornblende, which latter is, for the greater part, of secondary nature and has arisen from pyroxene, either monoclinic or orthorhombic, and occasionally also from olivine. The nature of the metamorphism does not seem to be the same as in the epidiorites, which are derived from the later intrusive diabases and gabbros. There seems to be a close affinity between the hornblende which we may take for primary and the other kind which we may quite certainly take for secondary. It is not improbable that we are dealing with changes which are closely associated with the process of crystallization and which therefore belong to auto-metamorphism. The name of hornblende gabbro has been chosen here. For the formation of hornblende we refer the reader to p. 323. Most rocks have evidently been formed from gabbros and allied rocks (V. 509, 513, 514, 518, 558, 644, 688, 690, 698 A. 1061). In one single rock the relics show that we are concerned with a greatly modified olivine norite (V. 503). Others again, are possibly the equivalents of quartz and pyroxene-bearing diorites (V. 604, 654, 675). None of those rocks are cataclastic and they do not show any tendency towards parallel texture; so pressure-action cannot have been the cause of their metamorphism.

Pressure-phenomena.

Signs of pressure are irregularly distributed among the rocks of the De Goeje mountains. The basic members have not been affected at all, the moderately acid diorites, strikingly little; the acid diorites and the granites, on the other hand, as has already been stated in their petrographic description, very often show undulose or cataclastic feldspars; signs of pressure in them may be compared with those of the granitodiorites of the Gran-rio massif elsewhere.

Yet pressure-action is not wholly lacking in the typical hypersthene-bearing representatives. In a quartz hypersthene hornblende biotite diorite the plagioclases are slightly bent (V. 52); ditto in a quartz-bearing hypersthene diorite (V. 637), while interstitial quartz is often undulose.

Some chemical data on the rocks of the De Goeje mountains.

Table 25 gives the chemical composition of some basic and moderately

TABLE 25.

	Gabbro rich in olivine V. 650 [1])	Norite V. 399 [2])	Gabbro V. 520 [3])	Quartz gabbro V. 544 [4])	Quartz-bearing hypersth. hornblende diorite V. 635 [5])	Quartz hypersthene hornblende diorite V. 52
SiO_2	47.59	49.88	51.28	49.56	48.34	54.10
Al_2O_3	9.76	18.96	17.33	15.39	15.10	17.87
Fe_2O_3	2.07	1.85	2.89	4.26	2.23	1.82
FeO	11.97	9.39	5.77	8.91	9.62	9.94
MnO	0.30	traces	0.21	0.28	traces	0.20
MgO	11.26	6.95	8.98	8.17	8.01	3.80
CaO	13.31	10.24	11.76	10.32	9.70	7.06
Na_2O	0.60	1.62	1.71	1.36	1.92	1.53
K_2O	0.51	0.55	0.43	0.49	0.77	1.50
H_2O+ / H_2O-	0.33	0.06	0.26	0.38	0.16	0.45
TiO_2	1.74	0.43	0.47	1.10	3.35	1.78
P_2O_5	0.09	0.08	0.08	0.33	1.10	0.50
	99.53 [1]) 0.11 SO_3	100.01 [2]) 0.18 SO_3	101.17 [3]) 0.07 SO_3	100.55 [4]) 0.14 SO_3	100.30 [5]) 0.08 SO_3	100.55

Anal. Koning & Bienfait, Amsterdam.

	si	al	fm	c	alk	k	mg	section
Gabbro rich in olivine V. 650	95	11.5	58	28.5	2	0.36	0.59	4
Norite V. 399	114	25.5	45	25	4.5	0.18	0.53	4
Gabbro V. 520	111	22.5	45.5	28	4	0.14	0.65	4
Quartz gabbro V. 544	109	20	51.5	25	3.5	0.19	0.53	4
Quartz-bearing hypersthene hornblende diorite V. 635	116	20.5	50	24	5.5	0.21	0.55	4
Quartz hypersthene hornblende diorite V. 52	149	29	43	21	7	0.39	0.37	4

Mineral combination:

V. 650: basic plagioclase, olivine with double kelyphitic zone, some orthorhombic and monoclinic pyroxene, some ilmenite.

V. 399: plagioclase (60 % of An.), orthorhombic pyroxene with leaves of titanomagnetite (?), little augite, pyroxene partly with rims of hornblende, ilmenite, some pyrite.

V. 520: basic plagioclase, more monoclinic than orthorhombic pyroxene, traces of brown hornblende, some ilmenite.

V. 544: Plagioclase (abt. 60 % of An.), orthorhombic pyroxene, some colourless hornblende and brown biotite, interstitial quartz.

V. 635: Plagioclase (abt. 55 % of An.), orthorhombic pyroxene, greenish-brown and colourless hornblende in about equal proportion, some biotite, ilmenite and apatite, interstitial quartz.

V. 52: Plagioclase (approximately andesine), orthorhombic pyroxene, greenish-brown hornblende and biotite in about equal proportion, ilmenite and apatite, important percentage of interstitial quartz.

siliceous representatives of the rock-group. The Niggli-values have been added.

There is some difference between the chemical analysis and the mode of the gabbro rich in olivine (V. 650). While the norm calculated from the analysis gives but 4 % of olivine, the slide shows much more. In connection with this the low percentage of aluminium shown by the analysis is somewhat doubtful, the latter causing us to find but little anorthite in the calculation of the norm, so that much silicium is left which may combine in forming hypersthene and consequently too little olivine is calculated.

The analysis of the norite (V. 399) agrees with the mode fairly well. The calculation of the norm gives but 6 % of monoclinic pyroxene and about 31 % of hypersthene.

The quartz-bearing hypersthene hornblende diorite (V. 635) contains several percentages of free quartz in the mode; the calculation of the norm, however, gives no free quartz.

The percentages of Al_2O_3, MgO and CaO are normal when compared with those of the corresponding rocks from elsewhere. The percentage of alkalis, however, is rather low, but it is higher in the more acid members of the series.

They are typical calcalkali rocks.

The mutual magmatic relation between the members of the series. Their geological behaviour.

The arguments for the co-magmatic relation between these rocks are following: The mineral combination changes with the percentage of SiO_2, but some components are constant in part of the series. As we have seen orthorhombic pyroxene is present in these rocks beginning with the most basic gabbros (troktolite and gabbro rich in olivine) up to and including some quartz mica hornblende diorites. Pyroxene is developed as bronzite (or enstatite) in the basic rocks, and invariably as hypersthene in the quartz gabbros and acid rocks. Of the hornblende, which is only wanting in the most acid members, the greenish-brown variety can be traced from the basic rocks up to the quartz mica diorites, in which grass-green hornblende prevails; the colourless, polysynthetic type, occurs in all rocks, with the exception of the very basic ones. The conspicuous dark reddish-brown biotite is invariably present, beginning with the gabbros and norites. Plagioclase shows a gradual diminution of calcium throughout the whole series. Other minerals exclude each other mutually. Olivine, for instance, practically disappears when an insignificant quantity of quartz occurs. Hence the mineral-components possess, to some extent, constant properties, and besides partly vary in connection with the percentage of SiO_2.

The division as adopted in the petrographical description is artificial. The gabbros pass, through quartz gabbros, into diorites with a varying combination of hypersthene, hornblende, biotite, monoclinic pyroxene and a changing percentage of SiO_2 and these again, owing to the reduction of the quantity of pyroxene pass into quartz mica hornblende diorites with or without hypersthene. We might be inclined to think that the very last hypersthene-free forms are not related to the preceding ones but that they are an acid diorite facies of the Gran-rio granites of the district, so that the pyroxene-free diorites do not belong to the series. When, however, we look through the samples of diorites with or without pyroxene and also pay attention to what has been stated concerning the characteristic features of part of the minerals, it will appear that the presence or absence of pyroxene is but an insignificant variation in the same rocks. Owing to the diminution of hornblende and the appearance of potash feldspar, these acid diorites, in their turn, pass into quartz mica diorites and granites.

There are also indications, however, that all these pyroxene-free acid diorites are but a diorite-facies of the Gran-rio granites and that the granites are but a local type of the Gran-rio granites. The mineral orthite, characteristic of the granites and the diorite-facies of the Gran-rio massif, is common in the quartz mica hornblende diorites and granites, and has been seen once of twice in a quartz hypersthene hornblende diorite. It has the same habitus as in the Gran-rio granite, although it is never surrounded by primary epidote. In the description of the granites of the De Goeje mountains, we emphasized the occurrence of dark reddish-brown biotite, and the frequency of Baveno-twins of the microcline. These are, indeed, characteristic properties. We also know, however, a number of granites from the immediate neighbourhood which fail to show the typical biotite, but which contain the Baveno-twins; and these again pass into other granites, in which even the Baveno-twins are lacking and which are typical Gran-rio granites. It seems that the few most typical granites belonging to the series, are only a local type of Gran-rio granites, and the same is true of the most acid diorites.

Let us now look at the distribution of the rocks in the field. The main-ridge proper of the De Goeje mountains, the highest summit of which is 700 m. in height runs ESE.—WNW. Besides the main summit, there are two other conspicuous peaks in the SSE. (see sketch-map III). The continuation of the ridge is indicated by a series of falls at the junction of the Lawa and the Tapanahony. In the report of the Government Mining-Exploration [1]) the ridge is said to be composed principally of basic rocks, e.g. diabases. The distribution of these basic rocks could not be traced in detail in the field on account of the intense weathering, but some indications were obtained by studying the surface relief [1]). The contrast between the basic rocks and the granite-region to the South and West is very strong, the basic rocks forming a ridge which has very steep slopes cut by deep ravines. In the country of granite, however, we find but shallow creek-beds. Further, to the South and West of the main ridge proper, there are a few extremely steep and long drawn-out ridges of basic composition. They run parallel to the main ridge; they even extend into the granite region and have been regarded as intrusions contemporaneous with that of the main ridge (Middelberg l.c.). Whereas the transition of the main ridge to the granite-area in the South, S.-West, and West is rather sudden, we find in the North and especially in the North-East, a more composite surface relief.

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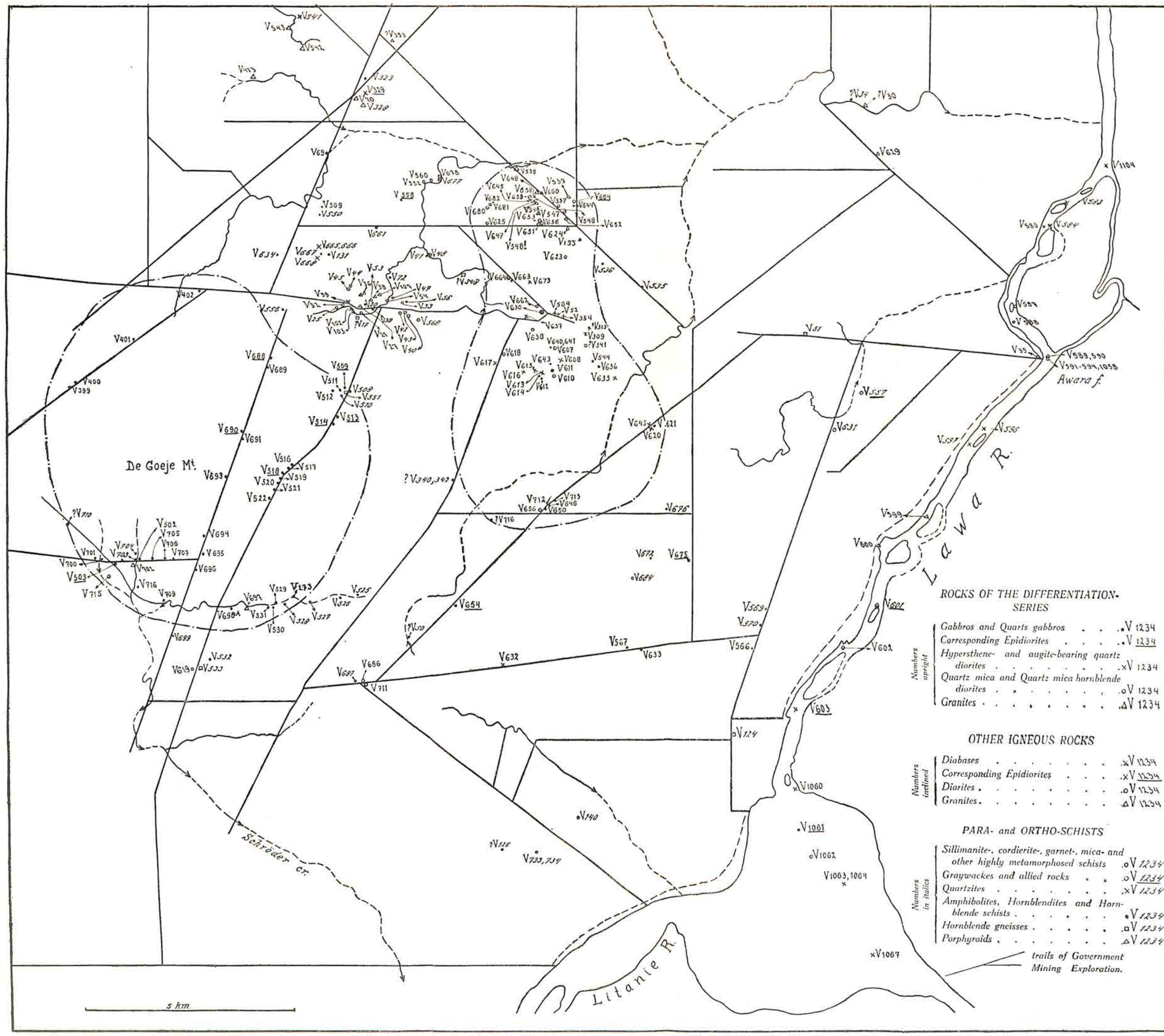
[1]) E. Middelberg. **64.**

MAP III.



Sketch-map of the De Goeje mountains showing findspots of rocks.
Two areas outlined by dotted lines are supposed to be occupied by "massifs".

Here are several low crests running parallel to the main ridge, but continually broken bij creeks flowing to the North. These creeks unite into three main creeks and these again into the Njam creek which flows in an Easterly direction. The whole transitional region seems to have a more composite structure than that in the South. The distance from the main-ridge to the basin of the Njam creek is 12—14 km. and is made up especially of metamorphic basic rocks (Middelberg calls them epi-diorites, amphibolites or hornblende schists). He regards them as metamorphic diabases and attributes their metamorphism to the intrusion of later diabases, of which he presumes that they also partially cover the metamorphic rocks. No details concerning this last and important question are given.

Further, diorites are reported to contribute to this composite region; it is briefly stated that they bear accessory quartz. They occupy an area of about 8 km. in length and a maximal breadth of 1 km., being surrounded by the metamorphic basic rocks, and in the South touching the diabases of the main ridge. Mentioning the fact that pressure-phenomena are wanting, Middelberg accepts a geological relation between these diorites and the intrusive diabases. The distribution of the rocks in the field has been indicated by Middelberg on a coloured map, scale I : 50.000 (appendage IV of the report).

Our gabbros, diorites and allied rocks practically all fall within the area under discussion, and we shall now try to reconstruct their geological behaviour from the data given by the Mining-Exploration and from the results of the petrographical research. In the first place it should be borne in mind that the rocks recorded in the report of the Mining-Exploration as diabases on microscopical investigation appear to be of different nature, e.g. gabbros and diorites, and a few amphibolites [1]). From the distribution of all these rocks it follows that the NW. portion of the main ridge consists for the greater part of gabbros.

In the extreme NW. part we have four norites (V. 399—402). Then on a trail East of the summit of the De Goeje mountain follow gabbros (V. 689, 694), norites (V. 695, 696), olivine gabbros (V. 691), metamorphic gabbros (V. 688), together with a troktolite (V. 693), and some diorites or epi-diorites (V. 688, 690). To the South of the same summit there are gabbros (V. 706, 707, 716), an olivine gabbro (V. 705), a norite (V. 709), and an allied diorite (V. 715). Next on the extreme upper course of the Schröder creek there are gabbros, partly rich in hornblende (V. 529, 530) metamorphic gabbros (V. 698 A), an olivine gabbro rich in hornblende (V. 531) and a quartz gabbro (V. 173); on a trail to the North of this: gabbros (V. 519, 520, 522), an olivine gabbro (V. 512), a norite (V. 516), an olivine norite (V. 511, 520, 522), and metamorphic gabbros (V. 509, 513, 514, 518).

Here then, we are concerned with a series of gabbroid rocks, forming a massif with a diameter of about 7 km. with the De Goeje mountain in the centre. This massif forms part of the main ridge. It is possible that the same rocks run on farther into the hilly country joining the main ridge on the North; the geological map of the Mining-Exploration suggests this, but we have no material from there. This map also suggests that the main ridge in the East has the same composition. From here we have a few acid and a few basic members of the rock group, found far from each other in a zone running to the Lawa.

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[1]) We should remember the fact that the rocks were identified by the Mining-Exploration chiefly from their external habitus, which accounts for their being entitled diabases only.

They are a quartz gabbro (V. 633), quartz diorites containing hypersthene and hornblende as coloured minerals (V. 632, 1060), or hypersthene and biotite (V. 1063, 1064), or hornblende and biotite (V. 602, 711), or biotite only (V. 686), and an olivine diabase or a gabbro, having ophitic structure (V. 567). Besides these, we have several amphibolites here.

There are too few data to give an idea of the whole zone; at any rate, it is not a diabase-region as the map of the Mining-Exploration presumes.

A second massif seems to comprise practically all the remainder of the rocks of the series. It lies to the E. and to the NE. of the preceding ones. It is oblong in shape, having a length of about 9 km. and being at most half as broad. In the South we meet especially with basic representatives and moderately acid ones, in the centre we find the latter together with acid ones; in the North many acid and also the most acid members, together with but a few basic representatives occur.

In the South there are mostly gabbros: an olivine gabbro (V. 650), gabbros (V. 646, 712), a norite (V. 621), and the moderately acid rocks: a quartz gabbro (V. 713) and quartz-bearing hypersthene hornblende diorites (V. 620, 645), with only a single pronouncedly acid rock viz. a quartz mica hornblende diorite (V. 656).

In the centre of the massif we find many moderately acid rocks, quartz gabbros (V. 544, 611, 614, 636), a quartz-bearing hypersthene diorite (V. 613), quartz-bearing hypersthene hornblende diorites (V. 315, 608, 615, 616, 617, 635); together with acid rocks: quartz hypersthene hornblende diorites (V. 52, 354, 504), quartz hornblende diorites (V. 341, 610) and quartz mica hornblende diorites (V. 607, 618, 630, 638).

In the North the acid members prevail by far, here we find the most acid members: granites (V. 538, 545, 548, 659, 660), quartz mica diorites (V. 623, 653), numerous quartz mica hornblende diorites (V. 133, 537, 547, 624, 625, 651, 653, 654, 664, 680), a quartz hornblende diorite (V. 681), a quartz hypersthene biotite diorite (V. 647), a quartz augite hornblende diorite (V. 648) and only two pronouncedly basic rocks, a gabbro (V. 682) and a hornblende-bearing gabbro (V. 548).

The boundaries of this second massif are not known; on the West-side it seems to be separated from the preceding massif chiefly by amphibolites and other rocks of very different composition. In the South it is possibly directly connected with the rocks of the main ridge. After the above specifications we need hardly point out that the distribution in the field is a very strong argument for the magmatic relationship that was accepted on the ground of microscopical research. In general, basic members appear together with other basic ones, moderately acid ones with others of the same composition, acid members together with large numbers of more acid ones, and the most acid rocks together with the latter. But quite a number of examples of far-going local differentiation also occur, as on the one side basic, and on the other side acid rocks, with transitional forms have been collected next to each other. Striking examples we find in the olivine gabbro (V. 650) the gabbro (V. 646), the hornblende-bearing gabbro (V. 712), the quartz gabbro (V. 712), and the quartz mica hornblende diorite (V. 656), all in the extreme South of the second massif; or in the hornblende-bearing gabbro (V. 548), together with the slightly more acid quartz hypersthene biotite diorite (V. 647) and several granites of the same series; all in the extreme North of the massif etc.

In our opinion then, a local differentiation of the magma of the Gran-rio granites has taken place in the De Goeje mountains. It has gone much farther than elsewhere in the Colony. The most basic members constitute mountains; the more acid members, contribute to the formation of the hilly country. It is also possible that, by the side of these massifs, members in the form of dykes, occur. Concerning the manner in which these hypothetical massifs and dykes are connected with the Gran-rio massif, and under what conditions the whole has originated, inter alia concerning the "mise en place", we have no clear conception. Middelberg looks upon these rocks as being related to the later diabases; this, however, we cannot accept. Petrographically they are not related to them, and must be regarded as differentiations of the Gran-rio granites, as is shown by the gradual transition to the latter. They have also partly undergone the pressure-action which characterizes a number of the granites; the acid representatives are clearly cataclastic, the moderately acid ones, very slightly so, and the basic ones, not at all.

On the N. and NW. they are partly surrounded by different metamorphic rocks. It is likely that the igneous rocks are intrusive into them. On the S., SW. and W. side, on the other hand, they seem to border directly on the extensive granite region. And what about the geological connection here? Are they intrusive into the granites? If so, we might regard the whole series as a differentiation that has come into action after the more acid main mass of the igneous complex had already crystallized. Or is the transition between the granites and the series in the field a direct one, so that we are only concerned here with basic portions of one massif? We know such-like differentiations, even though they be of less basic composition, to occur in abundance in other parts of the Gran-rio massif.

V. THE GABBROS, GRANITODIORITES AND ORTHO-GNEISSES OF THE NICKERIE REGION.

INTRODUCTION.

A second differentiation-series has already been described by Dr. H. van Cappelle. In 1900 he explored the outcrops along the Nickerie river and along a trail, which, starting from the Fallawatra (a tributary of the Nickerie) was cut, first in a Southerly, later on in a South-Easterly direction through the forest between the rivers Nickerie and Coppename. [1]) Numerous rock-samples were gathered. This collection has been studied by Dr. E. H. M. Beekman Eng. [2])

Bergt has also described a few rocks of the same region, besides some of the Coppename, which are closely related to them. [3])

It is not my intention to repeat in this publication what has already been recorded by others. The relation of these rocks to others in the Colony requires, however, a new discussion. Moreover a number of my identifications differ from earlier ones.

The igneous rocks of the Nickerie region are highly variable. Mineralogically they constitute a transition-series embracing gabbros as basic and quartz-bearing diorites as the most acid members. The mineral hypersthene occurs in all members of this series, hence it may be considered as the guide mineral of the group. The mineralogical association on the one hand, and the distribution in the field on the other hand, point to geological affinity. In this respect they show the same features as the rock-series of the De Goeje mountains. Structurally, however, they are more variable than the latter, as a number of rocks possess the characteristics of ortho-gneisses, or are gneissic intermediate forms. The gneisses are of two kinds: partly they show lack of crystallization-sequence of the main constituents, partly they are cataclastic gneisses, whose gneiss characteristics are imposed on rocks with normal structure (cf. p. 334 for a more detailed description of the differences of these groups).

The rocks of the Nickerie region were subjected to intense pressure. It is true, the pressure-phenomena may reach the same intensity elsewhere in the Colony, but nowhere they are so frequent as here.

The mineral components.

The following minerals are to be met with: hypersthene, monoclinic pyroxene, green hornblende, biotite, plagioclase, potash feldspar, quartz, ore, apatite, zircon, garnet and pyrite.

Hypersthene.

Hypersthene rather often shows a tendency towards oblong shape with

[1]) H. van Cappelle. **62**.
[2]) E. H. M. Beekman. **63**.
[3]) W. Bergt. **45**. p. 151—153.

indistinct faces of the prismatic zone. (110) Cleavage is present, but seldom to be traced uninterruptedly over the whole length of the prismatic zone; perpendicular sections of this zone show the pseudo-quadratic cleavage of monoclinic pyroxene, but less regularly developed, which may be a means to distinguish these sections. Coarse cracks across the prismatic zone occur generally, while here and there cracks or fissures are seen according to (010), and another cleavage according to (100). The pleochroism passes from light wine-red (n α) to brownish or to colourless (n β), and to distinctly greenish (n γ). The last colour resembles one of the tints of monoclinic pyroxene to a confusing degree, when both minerals occur in the same rock. The pleochroism of hypersthene varies considerably, however, in intensity, and in many thin sections it is hardly discernible. Sometimes also some indications of fibrous structure are seen in the direction of the c-axis. As inclusions the well-known brown or black lamellae (titanomagnetite?) are present, arranged according to different systems.

Monoclinic Pyroxene.

This never shows clear idiomorphism, but irregular granular shape. The coarse pseudo-quadratic cleavage is in most instances clearly developed, and, besides, very thin parallel fissures often appear according to (100): the diallage cleavage. The great angle of extinction on plane (010) (about 58°) points to a pyroxene of augitic composition. The axial angle was determined at 52° and the mineral is positive. The colour is a typical pale green with very weak pleochroism. As inclusion ore occurs, now as dust, now as lamellae of titanomagnetite (?) arranged according to definite systems, just as in hypersthene. Distinct uralitization is of little significance, although some hornblende may be seen at the edges. Remarkable are the notched rims which appear round hornblende in some rocks (V. 165).

Hornblende. The hornblende is always of the ordinary green kind. The shape is seldom idiomorphic according to the prismatic zone; irregular and especially short forms are general. The pleochroism passes from a bright yellow to green or yellowish green, sometimes to brownish green. Ore inclusions are frequent.

Biotite. Idiomorphic biotite is never present, only the face (001) may be developed. In the more basic members of the series biotite is strongly pleochroitic from bright yellow to chestnut brown, but in the quartz-bearing members it is more greenish brown. Frayed-edged biotite occurs in one of the gabbros (V. 1997). Pleochroitic haloes are of small importance.

Plagioclase.

Plagioclase is the principal colourless mineral. Its chemical nature will be considered with each of the rock-groups separately. Considerable variation in shape is possible, but it is a conspicuous phenomenon that in the rocks rich in quartz, well-defined idiomorphism never appears in respect to the last-mentioned mineral. On the whole the tendency to idiomorphism is strikingly small, while different types of irregular shape are present, sometimes entirely agreeing with the ortho-gneiss feldspars. The twinning-structure is variable. In the gabbros, especially, fine twinning according to the Albite-law, sometimes crossed by a second system, according to the Pericline-law may be developed. In many rocks the twinning is vague or wanting, possibly as a result of pressure. This causes plagioclase only with difficulty to be distinguished from quartzes, and still more so, when undulose extinction is present in both minerals. Antiperthitic structure characterizes the plagioclases of the whole group, although it is scarce in most of the basic members. The orthoclase inclusions are oblong-shaped and parallelly arranged, or short, rarely rectangular, more often irregular. They differ conspicuously from the anti-perthitic potash feldspar, which appears in the granitodiorites already described, by their frequently irregular shape, while the antiperthite is sometimes present in such quantities in the more acid rocks, but also in the relatively basic ones, that it cannot but contribute considerably to the percentage of potash feldspar in the rock; sometimes the fields even half replace the plagioclase crystal. Microcline-lamination has never been observed in this intergrowth. Other inclusions are of little importance. Occasionally the same hair-inclusions appear as in quartz.

Potash feldspar.

Free potash feldspar occurs in some of the hypersthene diorites and hypersthene gneisses, in spite of the relatively high percentage of pyroxene (V. 2092). The potash feldspar lacks idiomorphism. In the diorites it is often interstitial between slightly idiomorphic plagioclase and quartz. It is striking that microcline structure, which, in the granitodiorites already discussed, is always present, is only exceptionally developed here. Some microperthite may be present in the potash feldspar.

Quartz.

The quartz is clear, contains hair-inclusions, and often too, fine rounded-off granules of an unidentified coloured mineral, sometimes arranged in strings.

Ore.

Ilmenite (or titanomagnetite) is especially common in the basic members (gabbros). If we are dealing with large pieces, the ore is irregular in shape, and may even be patchy. Its relation towards pyroxene and hornblende shows that the crystallization of the ore must have begun earlier, judging from the inclusions of ore; on the other hand the ore may conform to pyroxene. Sometimes even masses of ore appear, which send out prolonged pieces between the plagioclases, so that the ore must have had a long period of crystallization. In the more acid rocks octahedral ore also appears.

Apatite.

Apatite has a general distribution in the form of rounded-off pieces; short needle-shaped ones with a distinctly prismatic shape are rare.

Zircon.

Zircon is sparse; it occurs in little characteristic crystals, as idiomorphism is less frequent than in other groups of the granitodiorites. Zonal structure is not seen.

Garnet.

The appearance of garnet is remarkable. It occurs especially in the gabbros. It is neither independent nor idiomorphic but invariably appears in reaction rims around ore, pyroxene or hornblende (Pl. 38, fig. 3) [1]; it also often fills the interstices left by these minerals, so that its crystallization-period is later. The garnet may conform to the adjacent feldspar. The relief is strong, and on its being strongly magnified distinctly porous structure is to be seen as if numerous channels and cavities were present. Numerous rough cracks are also to be seen. The colour is invariably pale wine-red.

Pyrite.

In some of the gabbros, besides ilmenite, some pyrite occurs. Neither of them show idiomorphism, not even where they touch.

PETROGRAPHIC DESCRIPTION AND CLASSIFICATION.

The Gabbros.

It appears that on the whole the gabbros bear a less basic plagioclase than is usually the case in this group of rocks. Table 26 gives the result of new determinations of the anorthite-percentage by comparison with liquids of known index of refraction. Beekman's numbers are subjoined. Beekman determined the composition of the plagioclases by measuring the maximal symmetric extinction; for one single rock he gives the very divergent composition: andesine, labradorite, bytownite and anorthite (l.c. p. 132); while for other rocks he gives maximal angles of extinction of 18, 25, 34 and 30° [2]), and also says: „la basicité est très grande car les extinctions varient jusqu'à 36°" (l.c. p. 137). These data correspond with compositions varying from approximately 35—70 % of anorthite.

The percentage given in table 26, referred to Tschermak's nomenclature, yield for the first nine gabbros plagioclase which falls within andesine (according to Tschermak 33—50 % of anorthite). The last two numbers only bear strongly basic plagioclases, the first basic labradorite, the second a transitional form of bytownite to anorthite. Hence only the last two rocks contain typical gabbro plagioclases. On the other hand the quantity and combination of the coloured

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1) Reaction-rims of garnet around ore and pyroxene have been described by Adams with regard to anorthosite. Neues Jahrb. Miner. 1893. Beil. Bd. VII. p. 447.

2) l.c. respectively on p. 135, 135, 138 and 140.

V.	Numbers of Beekman l.c.	Percentage of Anorthite
2058	115	37
2076	131*?	38
2057	114	42
2079	133*	42
2082	134	42
1997	71	44
2048	104	44
2055	112	44
1981	62	46
1966	49	60
1989	66	85

TABLE 26.

components are typical of the gabbro-group. The rocks named by Beekman "gabbro à hypersthene", "hyperite" etc., fall under these gabbros. The last name was used for gabbros which, besides pyroxene also have copious hornblende. The name had better not be employed, because the hyperites of Törnebohm, in addition to hypersthene, also contain olivine, and in such a manner that their total amount is pretty well constant; while, in the rocks treated, olivine is entirely wanting.

Bergt's two gabbros I have described as pyroxene hornblende gneisses; the affinity with gneisses has indeed been brought forward by Bergt himself.

Macroscopically the gabbros are mostly fine-grained rocks, perfectly massive. The colour changes with the quantity of coloured minerals; those rich in coloured minerals are almost black, those relatively poor in them, finely speckled. Microscopically they show next to monoclinic pyroxene less hypersthene or both are present in approximately equal quantities (V. 1981, 1996, 1997, 1999, 2048, 2058, 2076, 2079, 2080, 2093); in other rocks on the other hand, hypersthene is in the majority with regard to monoclinic pyroxene (V. 1953, 1966, 1971, 2055; B 1). Besides pyroxene a third group contains a considerable percentage of green hornblende (V. 1951, 1965, 1967, 1969, 1971, 1979, 2011, 2015, 2082, 2129). The variability of the quantitative relation between the coloured and colourless components is great, which often finds expression in one sample. Among the normal gabbros there are some with 1 or 2 % of garnet (V. 1999, 2076, 2082). Brown biotite in all these gabbros is negligible (V. 1951, 1996, 1997; B 1). Patchy ilmenite often is the only ore-mineral (V. 1999, 2048, 2076, 2082, 2129). Some pyrite and apatite may occur.

Structurally various forms are represented. We may observe that sequence of crystallization between plagioclase and pyroxene is poorly developed.

A number of rocks call for some remarks in connection with their mineral-combinations. A rock from Blanche Marie fall has a large quantity of hypersthene and little plagioclase; from the quantity of hypersthene we might call it a norite; a not insignificant quantity of hornblende, however, also occurs (V. 1953). A fine-grained rock from the Blanche Marie

[1]) l.c. p. 147.

fall containing a small quantity of pyroxene is very rich in hornblende; structurally, moreover, it inclines towards amphibolite; Beekman has therefore called this rock amphibolite but doubts its nature. A gabbro from the Wilhelmina fall contains green hornblende and red garnet as coloured minerals, the latter in abnormally large quantities. Besides this there is a slight quantity of monoclinic pyroxene (V. 2015). In the norite-like type (V. 1953) the hypersthene has a better crystal-shape than generally: it has developed as short prisms. We meet with coarse crystals of perforated pyroxene and hornblende in a rock from the Granieteiland fall (V. 1951); here we are no longer able to detect the slightest trace of crystallization sequence.

In general, however, the structure is typically gabbroid, although it be a type having little sequence of crystallization.

The quartz gabbros.

The quartz gabbros are closely related to the preceding rocks. The coloured mineral-components are the same greenish monoclinic pyroxene and pleochroitic hypersthene, while also a little brown biotite and green hornblende occur. The plagioclase is andesine. Patchy ilmenite, some apatite and zircon are present as accessories. Besides these, there is a considerable quantity of quartz. It is by the latter that these rocks differ from the preceding gabbros. Otherwise they agree with the forms poor in hornblende, also in the sample. Structurally the pyroxenes again show irregular forms. It is striking that the sequence of crystallization between plagioclase and quartz is poorly defined. The border lines locally may even have a sinuous course; structurally then, these gabbros are related to the quartz-bearing pyroxene gneisses to be discussed later on. Some anti-perthite occurs in the plagioclase. The intense pressure-action which these rocks have undergone, has warped the plagioclase-twinning or has caused it to disappear. On the whole we might just as well call these rocks pyroxene diorites. To the quartz gabbros belong the numbers: V. 1956, 1997, 2053, 2057, 2107.

The quartz pyroxene diorites.

In the sample they are massive or practically massive, normal to fine-grained rocks showing a fine sprinkling of coloured minerals against a lighter background of a different tint. Microscopically the few rocks falling under this group appear to vary considerably both in the combination of the coloured minerals, and in the quantity of quartz.

One of the rocks contains monoclinic pyroxene, some hypersthene, a brown biotite and some quartz (V. 1957). In another type we observe hypersthene, green hornblende, biotite and copious quartz (V. 1922). In another number again hypersthene only seems to have been present, now it is entirely weathered (V. 2031). Yet another shows scarce coloured components, the two pyroxenes with biotite and copious quartz (V. 1906). Or biotite and hornblende have only accessory pyroxene next to them (V. 2036), while again another sample, on account of the small quantity of coloured minerals, has almost aplitic composition (V. 2050). We may call these various types quartz-hypersthene-hornblende-diorite etc., according to their combination of dark minerals in the same way as Beekman has done. The pyroxenes, the green hornblende and brown biotite have again the same features as in the preceding rocks. The pyroxene exhibits no idiomorphism, but shows irregular pieces.

The plagioclase has the composition of oligoclase, oligoclase-andesine or andesine. The lamination is often vague or bent by pressure. Antiperthite may be present in abundance. In one of the rocks (V. 2036) there is also some free orthoclase present accompanied by myrmekite-like intergrowth: this rock has a granodioritic composition. The percentages of patchy ore, apatite and zircon vary considerably. These rocks also exhibit but an indistinct sequence of crystallization of the colourless components mutually; the plagioclases, for instance, show no well-defined idiomorphism towards quartz, but only a few faces peculiar to themselves, and for the rest irregular forms. In this respect then these rocks may be called gneissic diorites.

The pyroxene gneisses.

According to their basic or more or less acid composition the pyroxene gneisses may be classified into two groups, very closely related mutually and also to the preceding rocks. Equivalents of the gabbros are few; of the diorites many.

a. Basic pyroxene gneisses.

Two rocks fall under this term, one from Antonius creek in the Nickerie region (B. 6), the other from the Kwari creek, Coppename river (B. 28). Both have already been excellently described by Bergt. He uses the term hypersthene gabbro, however, while the rocks correspond to ortho-gneisses, which is brought to the fore in Bergt's description.

The rocks from both places are practically alike. They are fine-grained rocks, of almost black colour, with indistinct parallel texture in the sample (the latter is never completely wanting neither macroscopically nor microscopically; Bergt states the reverse). In places where the rocks are massive, pyroxene or hornblende are seen by the side of colourless to white feldspar. Microscopically we observe plagioclase, monoclinic pyroxene, hornblende, very little biotite, quartz (in B. 6), ore and apatite. The coloured components may substitute each other but otherwise they are equally distributed with regard to the colourless minerals. The green hornblende is the same as in the gabbros. The hypersthene is intensely pleochroitic. It is sometimes difficult to distinguish it from the monoclinic pyroxene which is also green, unless some diallage cleavage is seen. The pyroxenes are of quite the same types as in the gabbros. Structurally none of the coloured components exhibit idiomorphism; on the contrary, they are irregular to patchy; they may enclose feldspar grains; in one of the rocks (B. 6) even skeleton-like pyroxene occurs. The plagioclase shows no twinning structure; it is not influenced by pressure. The composition was fixed at 40 % (in B. 6) and at 45 % (in B. 29) of anorthite. Bergt gives with regard to extinction directions: „Bytownit bis zur Grenze des Anorthits" (l.c. p. 153). We need hardly mention brown biotite. Patchy ore, probably ilmenite, appears locally in the rock from Antonius creek in abundance, but is wanting elsewhere. Quartz sometimes shows liquid inclusions. It is either rare, or wanting in other parts. Apatite is restricted to a few crystals in plagioclase. Structurally the colourless components show an irregular shape instead of idiomorphism; the border-lines of the feldspars in particular are curved and in parts wavy. Locally the crystals also blunt each other until they are isodiametrical polygons (B. 28). Drop-shaped pieces of pyroxene but even more often of quartz, occur in the plagioclase. The gneiss-structure is best developed where quartz borders on plagioclase; instead of the former conforming to the crystal-shape of the latter, as is the case with normal quartz-bearing gabbros, the border-lines between the two are wavy. Microscopically an unmistakable tendency towards parallel texture also appears to be present. The coloured components in particular show an inclination to run parallel with their maximum length.

Considering the quantity of hornblende we are concerned here with *pyroxene hornblende gneisses.*

As has already been recorded by Bergt, the fine-grained rock from the Kwari creek is connected in the sample with a coarse aplitic mass which is regarded as acid "Nachschub" or "Ausscheidung". In it the two pyroxenes are again present and exhibit well-developed perforated structure. As quartz is present in abundance, the wavy course of the border-lines with respect to feldspar (andesine) comes still more clearly to the fore than in the more basic parts of the sample.

b. Moderately acid pyroxene gneisses.

We meet the equivalent of the pyroxene-bearing diorites again in the more or less acid pyroxene gneisses. The ill-defined sequence of crystallization of the colourless minerals in the diorites, is lacking entirely in the gneisses; they show typical ortho-gneiss structure: the border-lines of the plagioclase and quartz being extremely irregular, usually curved, often so much so that adjacent crystals fit into each other by means of protrusions. In addition to this, some rounded-off quartz crystals or drops often appear in the plagioclase. The pyroxenes form patch-like pieces and grains, sometimes even skeleton-like ones. Microscopically both the colourless and the coloured mineral-components appear to contribute towards the parallel-texture, owing to the crystals generally running parallel with their maximum length.

Structurally, and also mineralogically these rocks agree in many respects with the pyroxene granulites of Saxony (Pl. 38, fig. 4).

Here follow a few details:

In the sample they are normal or fine-grained rocks, consisting of a paler mass of variously tinted feldspar and gray quartz against which a moderate, sometimes slight quantity of coloured minerals stands out. Indistinct parallel texture finds expression especially through the coloured minerals which are equally oriented, and in the more acid types may be accumulated into spots and strings. The habitus of these rocks is that of the gneissose, acid diorites. Microscopically all of them show quartz and moderately acid plagioclase (oligoclase-andesine to andesine), and, in varying combinations, hypersthene, monoclinic pyroxene, biotite, and hornblende, with ore, apatite and zircon as accessories. Just as in the diorites the quantitative relation and combination of the essential components vary considerably; again there seems to be no connection between the nature of the coloured minerals and the quantity of quartz. Some, rich in quartz partly contain practically only hypersthene as coloured mineral (e.g. V. 1949, 2074, 2106), others besides hypersthene, contain monoclinic pyroxene and hornblende (V. 2005), or the latter mineral is wanting (V. 2092), or next to hypersthene there is a considerable quantity of brownish biotite (V. 2100) present etc. The hypersthene is usually distinctly pleochroitic, the monoclinic pyroxene greenish. Potash feldspar is of general occurrence in the plagioclase as anti-perthite fields. In a few rocks also, some free potash feldspar appears as orthoclase (V. 2100, 2113); the orthoclase may show some micro-perthite and be accompanied by myrmekite-like intergrowth (V. 2100). The latter rock is of granodioritic mineral-combination because some potash feldspar occurs; the coloured minerals are hypersthene and biotite. The accessory ore as far as present appears in patch-like pieces; the apatite in rounded-off grains; the zircon is also indistinctly idiomorphic. Cataclasm is common, and often developed to an advanced state, judging from the undulose extinction and the bent plagioclase, while quartz may be partly crushed. To these gneisses belong the numbers: V. 1948, 1949, 2005, 2035, 2042, 2043, 2074, 2092, 2094, 2100, 2106, 2113.

For a few pyroxene gneisses with cataclastic gneiss-features superimposed on a quartz dioritic mineral combination, we refer to p. 336.

SOME CHEMICAL DATA ON THE ROCKS OF THE NICKERIE REGION.

The table annexed gives the chemical composition of some typical rocks of the Nickerie region. The Niggli values have been added.

The percentage of Al_2O_3 both in the first two rocks and in the fourth seems to be rather low, but it is more than enough to saturate the combined alkalis and lime. In all rocks, except in the last one, the quantity of lime is amply sufficient to saturate the excess of aluminium over alkalis and to form anorthite, which

TABLE 27.

	Gabbro V. 2079	Gabbro V. 2129 [1])	Quartz Gabbro V. 2053 [1])	Quartz pyroxene diorite V. 1957	Acid pyroxene gneiss V. 2092
SiO_2	49.96	48.02	52.55	61.22	68.89
Al_2O_3	14.38	12.94	19.25	10.77	14.54
Fe_2O_3	3.40	6.31	7.52	11.24	0.77
FeO	8.55	12.40	3.58	0.98	2.96
MnO	0.33	0.24	0.22	0.00	0.04
MgO	7.02	4.70	3.16	2.78	1.70
CaO	10.40	8.86	6.31	7.02	4.36
Na_2O	2.96	2.66	4.35	3.00	3.60
K_2O	0.68	1.11	1.27	2.01	2.04
H_2O+	0.45	} 0.46	0.13	0.09	0.36
H_2O-	0.02			0.00	0.02
TiO_2	1.93	2.47	1.25	0.87	0.76
P_2O_5	0.17	0.31	0.77	0.02	0.25
	100.25	100.48 [1]) 0.26 SO_3	100.36 [1]) 0.10 SO_3	100.00	100.29
anal.	Dr. S. Parker Zürich	Koning & Bienfait Amsterdam	Koning & Bienfait Amsterdam	Dr. K. Brauer Cassel	Dr. S. Parker Zürich

	si	al	fm	c	alk	k	mg	Section
Gabbro V. 2079	115	19.5	47	26	7.5	0.13	0.51	4
Gabbro V. 2129	113	18	52	22	8	0.22	0.32	3
Quartz gabbro V. 2053	144	31	37	18.5	13.5	0.16	0.35	4
Quartz pyroxene diorite V. 1957	193	20	42.5	24	13.5	0.31	0.31	4
Acid pyroxene gneiss V. 2092	294	36.5	23	20	20.5	0.27	0.48	5

Mineral combination:

V. 2079: basic plagioclase, hypersthene, augite, traces of green hornblende and biotite, ilmenite, pyrite and apatite.

V. 2129: basic plagioclase, augite, hypersthene and green hornblende in proportions locally varying, ilmenite, some pyrite.

V. 2053: andesine, hypersthene, some biotite, insignificant quartz-percentage, ilmenite, apatite and some pyrite.

V. 1957: andesine, quartz, augite, some hypersthene and biotite, ore and apatite.

V. 2092: oligoclase-andesine, quartz, hypersthene, some orthoclase, ore and apatite.

agrees with the modal hornblende or augite percentage. In the last rock, however, (V. 2092) this excess of aluminium is but trifling which finds expression in the mode by the occurrence of hypersthene as the only pyroxene. The same will certainly be the case with the chemical composition of many of the basic representatives of the series, which have not been analyzed, namely those containing almost exclusively hypersthene as pyroxene.

The percentage of Mg O in the gabbro rich in hornblende (V. 2129) is rather low, suggesting a hornblende rich in iron. The same may also be expected for the other basic representatives, if we consider that free olivine was nowhere found, and that the orthorhombic pyroxene generally suggests a relatively large percentage of iron, taking the optical properties into account.

As far as the few analyses permit us to decide, the rocks of this group fall all within the calcalkali series.

It may be mentioned here that there is some resemblance between the co-magmatic rocks of the Nickerie region and other series from elsewhere, which are also characterized by the occurrence of hypersthene throughout the series. Such rocks have been described by Holland [1]) and by Washington [2]) as occurring in Southern India, by Kolderup [3]) as in West and South-Western Norway, by Brugge [4]) as in Islands near Smith Sound (artic region), by Rogers [5]) as in New York (Cortlandt series) and by Watson [6]) as in Virginia. Washington (l.c.) has given a comparison of most of these types. At all these localities the rocks may range from gabbros, sometimes even pyroxenites or hornblende-hypersthenites to hypersthene-granites rich in quartz. All the series show local differences, and also the rock-association with which they occur varies; they are found e.g. with anorthosite and olivine gabbro in Norway, in New York with alkali rocks (trachytes and soda syenites) etc. Mineralogically the Surinam rocks generally show the same characteristics and also some points of resemblance of minor importance: the poorly developed twinning of plagioclase, the same types of hypersthene and hornblende, the occurrence of garnet in the gabbros (India, mentioned by Holland) etc. A difference however is the rather frequent occurrence of some biotite in the acid members of our series, while elsewhere biotite is rare or accessory or quite absent in most types.

Chemically the rocks from elsewhere are characterized by the predominance of iron oxides over magnesium and lime, the two latter being present in about equal amount; by rather large percentage of alkalis with predominating soda, by alumium in the majority of the types about equal to the combined alkalis and lime, and by wide variation in the silicity (Washington l.c. p. 337—338). It should be emphasized here that this characteristic falls entirely within the variability of the calcalkali rocks generally. The chemical characteristics given

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1) T. H. Holland. Mem. Geol. Survey. India. XXVIII. p. 104.
2) H. S. Washington, The Charnockite Series of Igneous Rocks. Amer. Journ. Science. XLI. 1916. p. 323.
3) C. F. Kolderup. Berg. Mus. Aarb. 1896. No. V; do 1903. No. 12; Ref. Washington l.c.
4) C. Brugge. Rep. 2nd Fram Exp. No. 22, 1910; Ref. Washington l.c.
5) G. S. Rogers, Original gneissoid structure in the Cortlandt Series. Amer. Journ. Science. (IV.). XXXI. 1911. p. 123.
6) T. L. Watson. Bull. Geol. Soc. of America. 1915.

by Washington, however, do not all hold good for the Nickerie rocks e.g. the relation between iron oxides, magnesium and lime.

Hypersthene granites (charnockites) have not yet been found in the Nickerie region; it is not improbable, however, that they are also present, some rocks, as has been stated above, being granodiorites, possessing free potash feldspar.

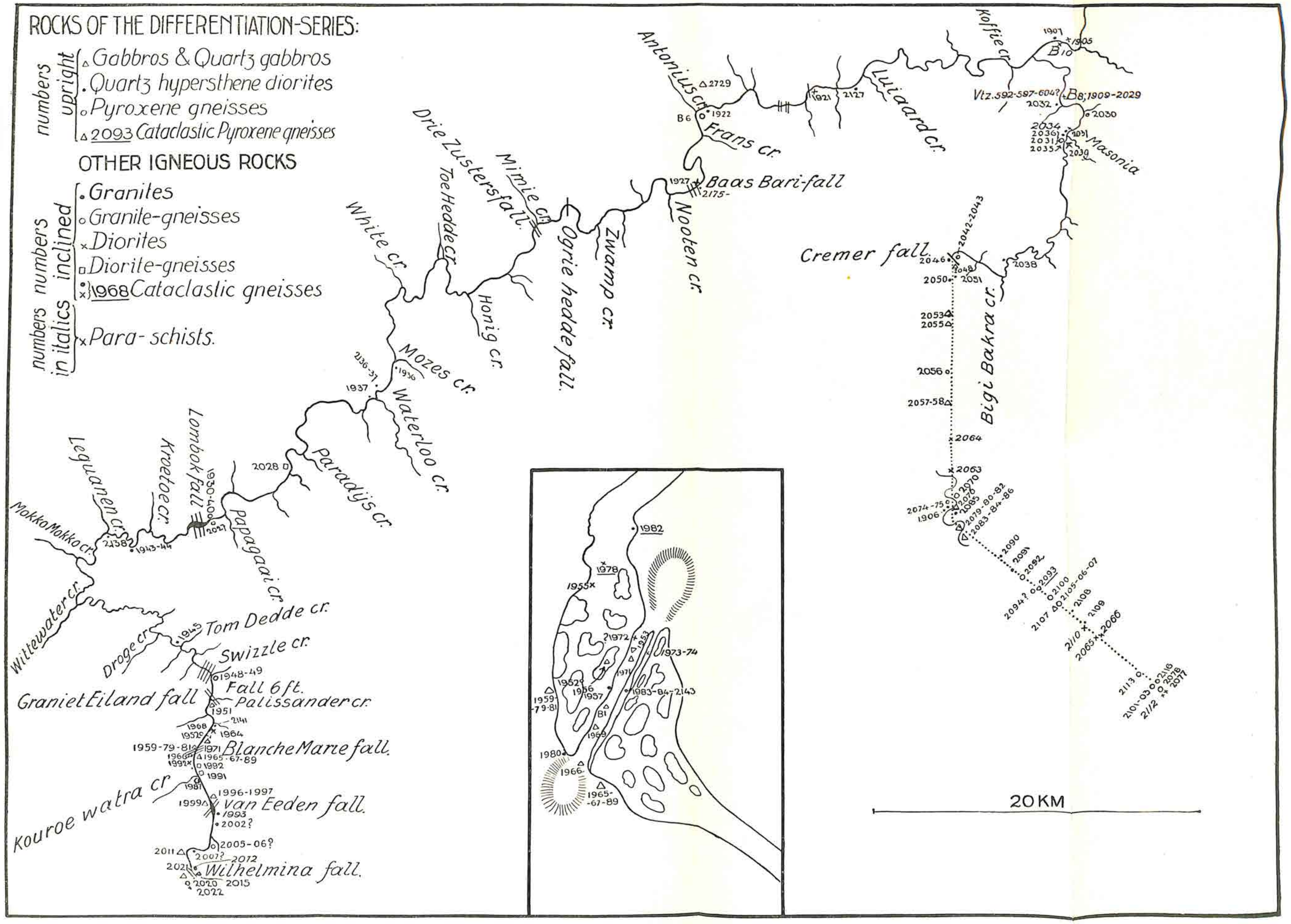
THE GEOLOGICAL BEHAVIOUR OF THE ROCKS OF THE NICKERIE REGION.

All the rocks discussed above can be traced back with certainty to the typical rock-series; all of them are characterized by the presence of hypersthene. It is a question in how far other rocks, appearing in the same region, may be regarded as being related to them magmatically, for the rocks discussed occur together with hypersthene-free granitodiorites and ortho-gneisses, which are described on p. 291. (See for the distribution of both groups sketch-map IV). The hypersthene-bearing rocks generally do not form extensive massifs but alternate locally with the granitodiorites mentioned. Rocks of a granitic composition predominate; locally, however, especially near the Blanche Marie falls and on the trail from the Fallawatra creek the basic rocks prevail. Even in a number of rocks still typical of the group, hypersthene is scarce; hence it is quite possible that the "remaining granitodiorites" of the region are the most acid hypersthene-free members of the group; in the same way as there appeared to be a relation between the rocks of the De Goeje mountains and the Gran-rio granites (p. 261 etc.). This, however, is difficult to decide. Typical minerals as orthite and primary epidote have not been met with in the hypersthene-bearing rocks; they are, however, also very rare in the rest of the granitodiorites of this region. Nor are there features of secondary importance, which might provide an indication of relationship. We might possibly regard the antiperthite as a local type, being the same in both groups of rocks; in both groups too, orthoclase appears, instead of the microcline invariably present elsewhere. Suchlike features cannot serve as a deciding basis for magma relationship. The common habit of the rocks, however, is the same, and this makes it not unlikely that some of the granitodiorites are nothing but the pyroxene-free members of the series.

That the pyroxene-bearing rocks of varying compositions are different facies of the same igneous masses, is very probable. If we trace the distribution of the rocks on the map, it will appear that gabbros and hornblende-bearing gabbros are associated with quartz hypersthene diorites. Van Cappelle cites quite a number of instances of this (l.c. p. 36—43). This also applies to the pyroxene gneisses, in so far as they occur in the Nickerie region proper. Pyroxene gneiss (V. 2035) together with quartz pyroxene diorites (V. 2031, 2036) has been collected on the Fallawatra creek. We see the same on the Cremer fall (V. 2042, 2043 together with V. 2046); on the bend of the trail from the South to the South-East (V. 2074, 2075, together with V. 1906) etc. There is no doubt then, that the pyroxene gneisses are nothing but a structural and textural facies of the diorites, agreeing entirely with them mineralogically.

In Van Cappelle's publication we find data concerning the important question

MAP IV.



Sketch-map of the Nickerie-river basin, showing the findspots of the rocks discussed in the preceding chapters. After data derived from Dr. H. van Cappelle's "Essai sur la constitution géologique de la Guyane hollandaise". In inset: Blanche Marie fall. Some of the findspots are dubious, especially near Blanche Marie fall.

as to whether the members of the pyroxene-bearing series are linked up by transitions with the "remaining granitodiorites", or whether they are of different age. The following quotations may be subjoined here:

„Ce qui mérite surtout l'attention dans cette région c'est l'impossibilité de tracer la limite entre les granites et les roches intrusives d'un caractère basique; les granites subissent de multiples modifications et se transforment peu à peu en diorites, en passant par la grano-diorite, dans le voisinage des roches ignées d'un caractère basique"; . . . (l.c. p. 36).

„Sur le terrain même, cette relation saute aux yeux, car de même que le granite et la grano-diorite sont généralement voisins, de même la diorite se trouve généralement dans le voisinage immédiat d'un gabbro."

„Cette hypothèse acquiert plus de raison d'être si l'on sait que nulle part dans cette région j'ai pû constater une superposition de ces roches au granite, et que, tout au contraire, le granite se présente quelquefois comme ségrégation filonienne dans la diorite et le gabbro. (Région de Blanche-Marie)" (l.c. p. 36).

„Du reste, pourrait-on douter d'une relation réciproque entre toutes les diorites, n'ayant pu trouver sur le terrain aucune limite bien définie et une connexion entre les gabbros et les granites n'étant pas invraisemblable?" (l.c. p. 39).

From this it is evident that, locally at any rate, both groups of rocks are connected by transitions, and that differences in age are wanting.

In other places, however, now superposition of the pyroxene-bearing rocks is mentioned, now of the pyroxene-free granitodiorites. The following quotations illustrate this. As to the influence the pyroxene-bearing rocks have on the formation of the landscape Van Cappelle says:

„Les roches basiques, représentées ici par des diorites et des gabbros forment des coupoles grandes et petites, et des dykes, qui traversent souvent la contrée dans une direction fixe." . . . (l.c. p. 34).

An example of this follows on p. 35, a row of diorite-domes being regarded as belonging to a dyke: „Ces sommets arrondis doivent donc être considérés comme formés des coupoles résultant de la décomposition d'une dyke de magma basique." The same is mentioned as being met with near the Blanche Marie falls: „où un dyke puissant de roches pyroxéno-amphiboliques traverse la rivière allant du S.S.O. au N.N.E. pour se prolonger à travers le bois en une série de sommets décomposés."

These cases are only mentioned by Van Cappelle to demonstrate the influence of the rocks on the geomorphology; but the use of the word "dyke" suggests at the same time the idea of "later" intruding rocks. The latter appears more clearly from: „ça et là seulement on remarque, dans les roches de teinte claire, des veines d'apparence plus basique; elles traversent tantôt la diorite, tantôt le granite, pour faire place à la cascade de Blanche-Marie au puissant développement dont nous avons parlé." (l.c. p. 37). And a little further: „Bornons-nous à constater ici que la Granieteilandval située un peu plus haut, n'est pas formée uniquement de granite, car elle est traversée en direction S.—E. par un filon de diorite à hornblende et à hypersthène (no. 38), large de 10 cm." (l.c. p. 38).

Essed, too, mentions the intrusive appearance of the pyroxene-bearing rocks, e.g. for the rocks from the Kwari creek on the Coppename, called by me pyroxene gneiss, by Bergt gabbro; according to Essed they cut granitite (read (granite-gneiss): "Here again a powerful mass of gabbro intruded the granitite. As far as could be made out, it is at least 100 metres broad; it continues into the country on the left side of the river, culminating in an extensive hill 50 metres high at a distance of 500 metres from the river." [1])

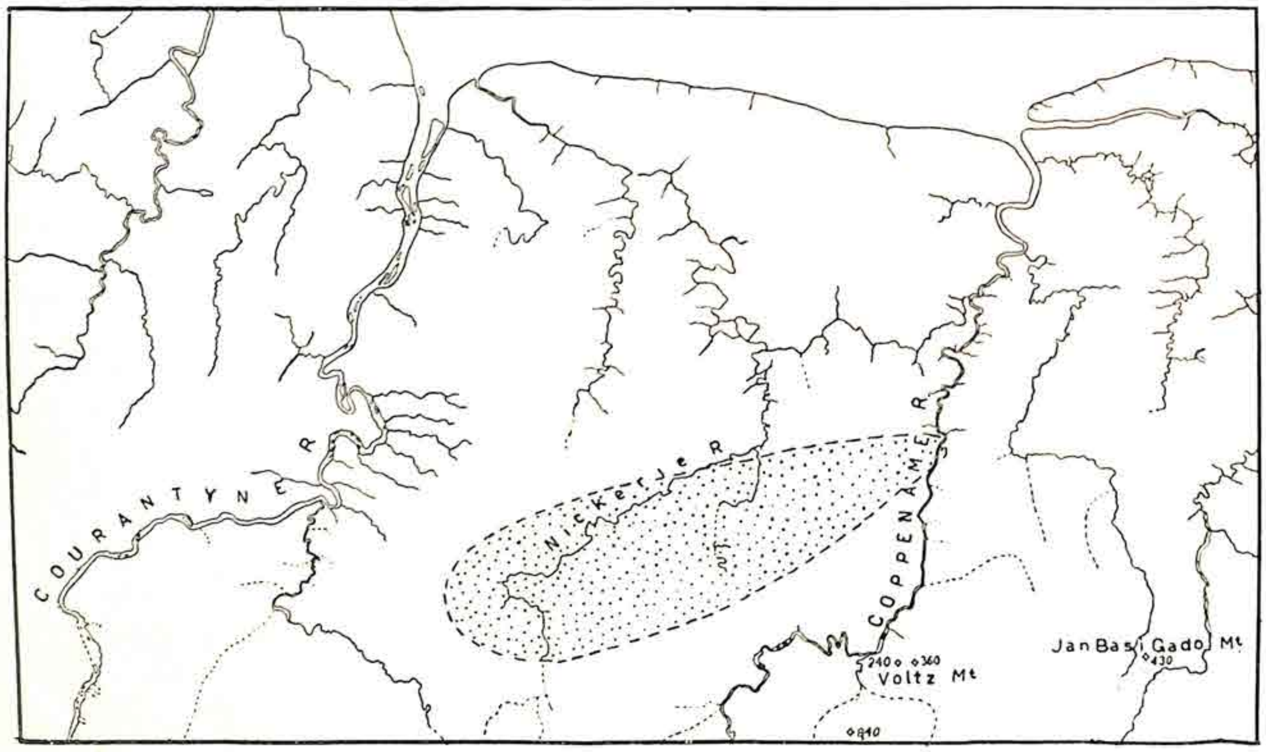


Fig. 45.

But also the reverse: intrusion of the pyroxene-free rocks into the pyroxene-bearing ones is mentioned; this important fact is evident from the quotations from Van Cappelle's paper:

„le granite se présente quelquefois comme ségrégation filonienne dans la diorite et le gabbro. (Région de Blanche-Marie)". (l.c. p. 36).

„il y a même une ségrégation de granite porphyrique (granite porphyrique à hornblende) (No. 137) dans le gabbro" (l.c. p. 41).

„Le granite pegmatitoïde (no. 143) qui traverse le gabbro (no. 144) près du km. Vme de la ligne S.E. nous rappelle encore une fois ce que nous avons observé à Blanche-Marie;" (l.c. p. 42).

The apparent contradiction, now mutual transition, now superposition in two different orders, is rightly regarded by Van Cappelle as an argument for magmatic differentiation. Probably the pyroxene-bearing rocks are partly a basic facies of the granitodiorites, and partly dykes, the latter having their origin in the deeper parts of the complex and being now of a basic, now of an acid

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[1]) E. Essed. **105.** p. 337.

composition and almost contemporaneous with the complex. It is rational to suppose that the basic rocks are differentiations of the granitodiorites, and not the reverse, since the latter have by far the greater distribution.

The region within which the pyroxene-bearing rocks of the series are met with, is marked on fig. 45. It comprises the Nickerie river above the Fallawatra creek and up to above the Blanche Marie falls; concerning any exposures along the river farther South, there are no data at all. Downstream, below the mouth of the Fallawatra the solid rocks disappear below the latest deposits. The typical rocks have a wide distribution along the trail to the watershed with the Coppename river. From the latter river we know a single rock (near the Kwari creek) petrographically agreeing in every respect with the group. So we may probably also include the region to the East of the Fallawatra, to where it touches the Coppename. [1])

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1) Beekman briefly mentions some gabbros and diorites of the Kabalebo and the Courantyne, petrographically of the same type, according to him, as those described above. Beekman's identification is based on their macroscopical habitus. Microscopically, however, the rocks of the Kabalebo and Courantyne regions appear to be gabbros belonging to the later intrusive gabbros and diabases.

VI. THE "REMAINING" GRANITODIORITES AND ORTHO-GNEISSES.

INTRODUCTION.

As we shall see, the remaining granitodiorites from a petrographical point of view are not distinctly different from the groups of rocks which we have already described. In some cases even they show the characteristic features of the above-mentioned rocks. Mineralogically they vary from very acid granites to diorites; besides, their structure is not constant; we have normal rocks, gneissose types, and ortho-gneisses. The reasons which impel us to discuss them separately have already been mentioned in the general introduction: the remaining granitodiorites are distributed over the Colony in such a way that their geological connection with the former groups is uncertain. Partly also the rocks are only known from field-observations and there is no material available for microscopic investigation. Sometimes the relation to the former groups is doubtful on petrographical grounds.

We shall give a detailed description only of those types which differ materially from the former two groups. Many details of local importance are to be found in the discussion of their geographical distribution. The ortho-gneisses, however, are treated more in detail. Among these gneisses we find the bulk of the rocks with doubtful petrographical and geological relations as compared with the typical granitodiorites from the Gran-rio massif.

Biotite granites.

A. *Types with abnormal structure.*

Some granites are characterized by abnormal structures e.g. by abundance of bi-pyramidal quartz; for the rest they are normal biotite granites, fine-grained and massive in the sample (Y. 241, 251, 341). They are composed of microcline, plagioclase (oligoclase), quartz, biotite, ore, apatite and zircon, and sometimes contain epidote which is possibly primary (Y. 251). Microscopically all these rocks show a tendency to porphyritic structure: plagioclase by its relatively large size suggesting phenocrysts. They have, however, no distinct crystal faces, the edges are interrupted by the adjoining grains of the groundmass, especially by the bi-pyramidal quartz, which may even be enclosed. The biotite may show partly idiomorphism too, in which case the structure of the whole shows a resemblance to that of granite porphyry (e.g. Y. 251). The size of the quartz-grains is small, the quartz belongs to the groundmass which is composed of the minerals mentioned already. The quartz is older than the other minerals of the groundmass.

B. *Acid granites.*

A special type of acid granites is frequent in the Wilhelmina mountains: generally medium-grained and always massive rocks. In the sample they are characterized by a light colour owing to the predominance of feldspar and quartz, and the sparseness of biotite. The rocks are often spotted with yellowish-green plagioclase, red potash feldspar, quartz, and greenish chloritized biotite. The greenish tint of the plagioclase is especially conspicuous when this mineral occurs in relatively coarse and idiomorphic crystals, so that the sample is indistinctly porphyritic. Other samples are less variegated, and pale-red or flesh-coloured. (See for this series Y. 193, 196 B, 197 F, 199, 200).

Microscopically the same main components are recognizable, besides a small percentage of accessoria. Plagioclase is always of importance, it often surpasses the potash feldspar in quantity. It is albite-oligoclase or approximately albite, with numerous lamellae. The plagioclase is often rich in microlites of epidote which may crowd the whole crystal in such way that the phenomenon is even betrayed macroscopically by the yellowish-green tint mentioned above. The epidote microlites seem to be of secondary origin, together with sericite-flakes which also may be present in abundance. The potash feldspar is not always easily recognizable as microcline. Now vague lamellae are to be seen, now these are wanting in the whole slide, but the latter case may be accounted for by the large quantity of microperthite which leaves but little space in which the microcline-structure may be recognized. Also copious dust may prevent us from deciding whether the potash feldspar is developed as microcline or not. Besides microperthite-fibres a coarser perthite sometimes occurs, not impossibly a primary intergrowth, which shows frequent albite-twinning and also has the composition of that plagioclase. The sparse biotite is not idiomorphic; the base may be developed or not. The mineral is generally chloritized, and sometimes accompanied by secondary masses of epidote. In some rocks also unimportant muscovite-flakes are present. As accessoria are to be found ore, pyrite, titanite, apatite and zircon. The ore is magnetite or ilmenite. The titanite is rare, either irregular in shape or showing the well-known "envelope" sections (Y. 199). Apatite is generally very sparse, and mostly appears in rounded-off grains. Small grains of zircon may cause haloes in the biotite. The sequence of crystallization of the colourless main-components is variable. Not unfrequently plagioclase is rather idiomorphic, and sometimes both potash feldspar and plagioclase show crystal shapes towards quartz, a phenomenon that is not common in the Surinam granites. Here and there some granophyric intergrowth of quartz and potash feldspar is present. Altogether these rocks are generally of a rather acid type: which is shown by scarceness of coloured minerals, composition of the plagioclase and scarceness of accessoria.

C. *Aplitic granites.*

Among the aplitic granites especially those of the Wilhelmina mountains should be mentioned. They are fine-grained rocks, pale flesh-coloured or pale-red and quite massive. With the pocket-lens only quartz, feldspar and very scarce biotite may be recognized; the latter mineral is often absent. In some samples here and there coarser quartzes are to be seen which have a tendency to bi-pyramidal shape (Y. 194, 194 B, 196, 198, 201).

Microscopically potash feldspar, plagioclase, quartz and an unimportant quantity of biotite-flakes are to be seen. Generally potash feldspar surpasses plagioclase in quantity. Of the accessories only ore is worth mentioning, the others, especially apatite may be absent, or are only found on close investigation. The potash feldspar mostly shows indistinct microcline-structure, and often contains dust. The plagioclase is very acid, approximately albite. Besides by their acid composition these rocks are characterized by their variable structure which may even vary in the same thin section. At first potash feldspar and quartz may show indistinct crystal shapes. The plagioclase seldom shows idiomorphic faces. A tendency to granophyric intergrowth between quartz and potash feldspar is often observed (Pl. 38 fig. 5). This structure passes into a real granophyre, in which only the scarce plagioclase is distinguishable. In these types there is much variation in the habitus of the granophyre, concerning the dimensions and shapes of the quartz-fields that are intergrown with the potash feldspar. When the granophyre is not too fine, microcline-structure may be seen. Also in some rocks here and there idiomorphic potash feldspar is to be seen, surrounded by a rim of radiating granophyre. As has been mentioned already coarser quartz-crystals having a tendency to idiomorphic shape may occur locally.

Granite-gneisses and diorite-gneisses.

I. Granite-gneisses.

A. *Biotite granite-gneisses.*

a. *Massive types.*

The granite-gneisses of the Lower Marowyne are normal- to fine-grained, sometimes coarse-grained rocks and are either massive, or show very indistinct parallel texture owing to regular arrangement of the biotite-leaves. The colour is generally light, owing to the presence of light-coloured feldspar and greyish quartz, against which the mica stands out clearly. Seen through the microscope the principal components appear to be quartz, microcline, plagioclase (oligoclase to oligoclase-andesine). As an accessory mineral muscovite may be met with. Ore, apatite and zircon are scarce. The quantitative relation of these minerals is the same we find in normal biotite granite, the microcline is now considerably in the majority with respect to the plagioclase, now about equal in quantity. The colourless minerals show no sequence of crystallization, but irregularly undulating or angular boundary-lines. The microcline shows beautiful grating-structure and occasionally microperthite-fibres; in the plagioclase twinning may be absent (e.g. Vtz. 395). Both feldspars are strikingly fresh and bear no typical inclusions, except here and there rounded-off quartz-drops, and small plagioclases in the coarse microclines, while in both feldspars, and also in the quartz, needle-shaped inclusions sometimes occur in abundance (in Vtz. 478). In a few samples some myrmekite appears. The quartz here and there shows strings of liquid inclusions. The biotite is greenish-brown or brownish, now with a trace of the basal face, now showing irregular patches. Pleochroitic haloes around zircon occur here and there. Of the accessories muscovite should be mentioned first. In Vtz. 465 and V. 415 we see primary muscovite, in Vtz. 478 so much of it that we are concerned with a bi-mica gneiss. Apatite and zircon may occur fairly often in rounded-off oblong grains. The typical accessories primary epidote and orthite, so often occurring in the preceding groups, are wanting here. Pressure is slight, undulose quartz only being of some significance. Quite unlike this, is the real mylonized granite-gneiss V. 2440 which shows parallel texture, and yet locally shows the original gneiss-structure (see p. 338). Apparently it is a local crush-zone. In accordance with the mineral-combination and structure, these granite-gneisses are in many respects like those of the Coppename near Copenkrissie, which are also to be reckoned among the "remaining" granitodiorites.

Closely related to the former are some ortho-gneisses from the Lower Suriname river near Carolina, Morea, Phedra and the Carolina creek (Upper Para river). The mineral-combination is the same (Pl. 38 fig. 6).

Other granite-gneisses, again closely related to the former, are known to occur at the Coppename river. They have been described by Bergt as "körnige Gneisse" [1]) (B. 29, 30, V. 1475, 1476, all from Copenkrissi; from Tjakka tjakka ston, V. 2334; from Pimbaholo V. 2335, 2336; from Longoston, V. 2345, 2346 and from near Kaaimanston, V. 2347). The sample now shows massive texture, now some parallel texture caused by equally oriented biotite-leaves. Seen through the microscope, however, it appears that the colourless minerals do not present the least indications of this phenomenon. For details I refer to Bergt (l.c.). (Pl. 39 fig. 1).

b. Types with parallel texture.

A granite-gneiss from the Upper Courantyne, King Frederick William IV falls, Northern group (Y. 298 B) shows slight parallel texture in the normal-grained sample; this is caused by the fact that the biotite shows a tendency to equal orientation. The biotite stands out against pink feldspar and grey quartz. Through the microscope microcline, plagioclase (oligoclase), quartz, biotite and some hornblende are seen, together with small quantities of titanite, ore, apatite and zircon, whilst a not insignificant percentage of primary epidote is also found. The presence of this last-mentioned mineral establishes a strong relationship with the Gran-rio gneiss. The plagioclase is vaguely twinned; so is the microcline which shows perthite-fibres here and there. The principal components are irregular in shape and differ considerably in size. In some places the irregular structure shows some resemblance to that of aplites. The quartz shows undulose extinction. The green-brown biotite is developed according to the base without other idiomorphic faces; it is partly heaped up in strings. The yellowish epidote shows oblong, strongly corroded crystals of the well-known type. Among the other minerals apatite and zircon strike the eye by their rounded-off and oblong shape. The apatite may be enclosed in titanite. The ore is irregular in shape, but seems to be magnetite. The light brown titanite shows no idiomorphism at all.

More distinct parallel texture is found in a granite-gneiss of the first large fall upstream in the Cutari (Y. 318). In the sample which passes from normal- to fine grained the biotite is parallelly orientated in a light groundmass of feldspar and quartz. The microscope shows that the parallel texture is not limited to mica; also the colourless minerals, microcline, plagioclase and quartz are oblong in shape and run parallel. The grating-structure of the microcline is now distinct, now vague. The acid plagioclase (albite-oligoclase) is partly finely laminated, party without lamellae. Here and there perthite-fibres are found in the potash feldspar. All the colourless chief-components have a most irregular shape. All of them show undulose extinction so that signs of pressure are of some importance. Besides biotite, muscovite is present as frayed crystals. Among the accessories some yellowish epidote of doubtful genesis is found; the crystals are not idiomorphic. Grains of apatite and zircon are rounded-off. A few grains of ore pass into titanite. In one of the pieces of epidote a small orthite-grain is enclosed.

Very conspicuous is the parallel texture in a granite-gneiss from the King Frederick William IV fall, Upper Courantyne (Y. 270), as shown by the sample (Pl. 20 fig. 1). The biotite shows absolutely parallel orientation and is heaped up on numerous planes which lie close together, so that fine, dark coloured bands alternate with light ones (see upper part of photo Pl. 20 fig. 1). In some places a lens of colourless minerals occurs (on the left, a little below the centre, see photo) and occasionally a rounded-off phenocryst-like feldspar-grain (middle right). Microscopically the rock shows again the same mineral combination, microcline, plagioclase, quartz, biotite, titanite, ore, apatite, zircon and orthite. The colourless minerals diminish in quantity in the order in which they are given. The plagioclase (oligoclase-andesine), often but slightly twinned, is sometimes found together with myrmekite. The microcline, with distinct grating-structure, and the quartz, do not show any trace of

[1]) W. Bergt. **45.** p. 115—118.

crystallization-sequence. The boundary-lines between the minerals are partly angular, partly wavy. Accessory titanite occurs locally pretty frequently, showing pale-brown tints. Sometimes it shows diamond-shaped sections, mostly, however, it is irregularly oblong. Irregular ore often forms the core of the titanite as if demixture had taken place. The ore may be octahedral; more often it is irregular. The apatite is oblong and rounded off, sometimes indistinctly column-shaped. It may be enclosed in titanite and the same holds good for the rounded-off zircon. The orthite is sometimes twinned according to (100). Practically no signs of pressure are present. Apart from parallel texture the components are regularly distributed, except the microcline which is heaped up locally, which phenomenon does not attain such a degree that the rock may not be regarded as an ortho-gneiss.

Closely related to this type, also with distinct parallel texture, is a granite-gneiss from the Upper Courantyne (Y. 304). The biotite has a striking chestnut-colour and is rich in pleochroitic haloes. It is remarkable that with the exception of a very few zircon-grains, there are practically no accessory minerals.

A granite-gneiss from the Lower Lucie river (Y. 285 B), is as rich in biotite as those mentioned before; the structure however is slightly different. The sample is fine-grained and shows distinct parallel texture. Locally lens-shaped masses of a fine-grained, aplitic material which is distinguished by pale pink colour occur. Microscopically quartz, potash feldspar, acid plagioclase, and much biotite, and also a slight quantity of muscovite are seen. Of the accessory minerals apatite is the only one worth mentioning; ore, partly as pyrite, is hardly present. The colourless main-components are strikingly oblong in shape, show parallel trend, so that they contribute considerably to the parallel texture of the whole. The acid plagioclase (oligoclase) shows hardly any lamination. The potash feldspar is generally untwinned; here and there, however, a vague grating-structure (microcline) is observed. The brownish biotite is partly chloritized. The crystals are often frayed. The apatite occurs in rounded-off, oblong grains. Owing to the distinctly oblong, almost scaly forms, of all the main components, the rock shows a resemblance to some lepidoblastic schists (Pl. 39 fig. 2). The rock has been considerably influenced by pressure, all the components are undulose, the mica is bent, and besides some micro-faults cross the parallel texture, along which mylonite-structure is developed. The coloured minerals in those places have been pulverised, the mica has changed to dust.

c. *Types with streaky texture.*

This type has only a single representative. It is from our trail which connects the Gran-rio and Lucie rivers (Y. 164). It is a fine-grained rock with biotite-granitic mineral-combination. The biotite shows in the sample distinct equal orientation, with a slight undulation in the texture. Besides there are string- and lens-shaped masses which contain hardly any biotite and which join the general texture. These strings have aplitic composition. The microscope shows quartz, microcline, plagioclase (oligoclase), biotite and as accessories muscovite, hornblende, apatite, zircon and ore. The microcline shows distinct grating-structure. The plagioclase is only here and there twinned. In a few places myrmekite formed by plagioclase and quartz is present, bordering on microcline. The colourless main-components have no idiomorphism; typical structure of ortho-gneisses prevails. The brown biotite is strongly pleochroitic; it shows many haloes. The basal face is often developed. The green hornblende, which is hardly of any importance, is characterized by strongly perforated structure, not unlike forms of corrosion. The same may be said of some pieces of biotite, which lie near it. The other accessories are of little importance. The undulose extinction of quartz points to pressure.

d. *Eye-gneisses of granitic mineral combination.*

These gneisses are very rare. They are found on the Coppename river, above Tomolin creek, where inter alia they form the Leguan rock. Some samples from there have been described already by Bergt. In the sample the rounded-off microcline-phenocrysts are conspicuous; they may have a size of 4 cm. and are twinned here and there according to the Carlsbad-law (V. 2353, 2354, 2355, 2356; B. 25, 26). These "phenocrysts" lie in a groundmass of granitic texture, in which biotite is heaped up in groups. Microscopically the groundmass appears to have granitic mineral-combination. As colourless minerals microcline (with microperthite), plagioclase and quartz are present. The quantitative relations of these vary; the potash feldspar sometimes being almost wanting in the groundmass (e.g. B. 25). In all the rocks we observe more or less distinctly rounded-off oblong feldspars which repeat the macroscopically visible ones (V. 2356, Pl. 39 fig. 3). They turn out to be practically invariably plagioclases (oligoclase to oligoclase-andesine), hence unlike the coarse microcline-phenocrysts. Twinning is vague or wanting; in one single rock (B. 25) there is quite a number of inclusions, amongst which appear beautifully shaped epidote-grains, illustrated in fig. 33 p. 180. The borders of the feldspar-eyes are irregularly impeded by the adjacent grains of the groundmass, while fine biotite-leaves sometimes form thin wreaths around the eyes. Between large plagioclases there is a mixture of quartz, microcline, plagioclase, biotite, with or without hornblende and primary epidote, with apatite, ore, titanite, zircon and orthite as accessories. The colourless minerals among these show no sequence of crystallization, but irregular crystalloblastic structure. They may be equal-sized, blunting each other polyhedrically (in V. 2356) with parallel trend of the maximum length of their sections, or they are unequal in size. The plagioclase is indistinctly laminated and microcline-microperthite is present. In a few rocks no essential difference exists between the eyes and the groundmass but the former pass into the latter by diminution in size. Myrmekite frequently joins the coarser microcline. The greenish-brown biotite is often accumulated, with or without green hornblende, and in that case the mineral-combination is that of biotite hornblende granite (V. 2353: B. 25, 26). The structure of these minerals is slightly idiomorphic as is usual in granitic rocks. The mineral-combination of these rocks may be compared with that of the Gran-rio granites; the feldspar-eyes and the structure of the groundmass justify the designation of eye-gneisses.

Bergt assumes that pressure is responsible for the structure. Were this really the case, these rocks would have to be treated together with the gneisses formed by pressure (see chapter on "Allo-metamorphism" page 334) Bergt says (l. c. 138): "Die mikroskopische Struktur trägt besonders bei No. 25 und 26 augenfällig den Charakter der porphyrischen Trümmerstruktur an sich, die makroskopisch stellenweise Anklänge an die Augengneissstruktur hat. Die bereits an den einsprenglingsartigen Körnern besonders des Feldspäten erwähnten optischen und mechanischen Druckwirkungen erstrecken sich bis in die Bestandteile der Grundmasse." Indeed in some rocks significant pressure-phenomena are present: bending of the plagioclases, crushing of the quartz; on the other hand, however, others have been influenced but little and the same eye-gneiss-structure may even be present (in V. 2356), without any sign of important pressure. The coloured minerals are not disturbed in any of the rocks, while in the eye-gneisses discussed in the chapter on "Cataclastic gneisses" we shall see that the biotite is bent and frayed. The lack of crushing (V. 2356) points to the fact that the eye-structure here is not a result of pressure, although intense pressure-action of the same nature as we often meet with in the Surinam granitodiorites has been superimposed on a few rocks here also. In my opinion the eye-gneiss-structure here, is of a primary nature.

B. *Bi-mica granite-gneisses.*

Ortho-gneisses which besides biotite contain also a more or less considerable quantity of muscovite are rarely found. We have mentioned a few in our description of the granite-gneisses of the Marowyne river.

C. *Hornblende granite-gneisses.*

This type occurs but seldom. Excellent gneiss-structure is found in a hornblende granite-gneiss of the Litanie river (V. 1086 Pl. 39 fig. 4). The fine-grained sample shows distinct parallel texture. The colourless minerals are quartz and acid plagioclase (oligoclase) in equal quantities and very little microcline. The indistinctly laminated plagioclase shows no trace of idiomorphism, but is oblong-shaped, with and undulating course of the boundary-lines. This holds good also for quartz and microcline. The parallel-texture in the sample is due to the equal trend of these minerals, and less to the hornblende, which is only partly orientated in the same way. The hornblende is the usual green one. Some big crystals show perforations. Many are irregular in shape. The accessory minerals are octahedral ore, rounded-off apatite, grains of zircon, titanite and an occasional biotite-leaf. Judging from the mineral-combination the rock may be called a hornblende granite-gneiss, which, however, owing to the slight percentage of microcline does not differ much from diorite-gneisses.

D. *Aplitic granite-gneisses.*

This type is very rare. The aplite-gneisses of the Nickerie river, Blanche Marie fall (V. 1987) and higher upstream (V. 2020), are medium- to fine-grained rocks. The principal colour is pale red. Parallel texture is poorly developed. Sparse biotite-grains and somewhat coarser quartz-grains are visible macroscopically. Seen through the microscope the rocks appear to consist of potash feldspar and quartz. The other components, biotite, zircon and ore are generally of little importance (except V. 1987 which locally contains a not insignificant percentage of ore). The potash feldspar is orthoclase or locally betrays a vague indication of microcline-structure (See V. 1987). There is a good quantity of microperthite. On close observation V. 1987 shows some vaguely twinned plagioclase, of a very acid type. The size of the main components is now almost uniform (V. 2020), now variable (V. 1987). The minerals are without any idiomorphism, the boundary-lines are irregular, in part also undulating. One of the samples shows a tendency to parallel texture because the mineral-grains are equally oriented with their greatest length in the thin section (V. 1987). In that rock drops of quartz are frequently enclosed in the potash feldspar. Undulose extinction points to pressure. Similar aplitic-gneisses occur also on the Lucie river (V. 3486).

II. D i o r i t e - g n e i s s e s.

A. *Quartz mica diorite-gneisses.*

A diorite-gneiss of this composition, from the Coppename river between Anjoemara- and

Planga creek has been described by Bergt (B. 26; V. 2360) [1]. He considered this rock to be a typical gneiss. The structure is crystalloblastic. It may be mentioned by the way that this rock contains no orthoclase; what is plagioclase without lamination was evidently mistaken for orthoclase.

Typical also is the gneiss of the extreme upper-course of the Lucie river (Y. 180). Equal orientation of the biotite causes distinct parallel texture in the sample. Seen through the microscope the following components are detected: quartz, plagioclase, biotite. Some microcline is found here and there which proves distinct relationship with the granite-gneisses. The plagioclase (oligoclase), partly vaguely twinned, partly without any lamination shows no idiomorphism towards quartz; the structure is typically that of ortho-gneiss. The greenish biotite is also irregular in shape, more or less frayed at the edges. Traces of microcline are seen, with hardly developed grating-structure, and some perthite. The ore is irregular in shape. Among the accessory minerals a few short prismatic zircon-grains occur, whilst haloes are found in the biotite around very small grains, probably of the same mineral. Apatite shows rounded-off grains. Undulose extinction may be developed here and there.

The following gneisses are of more basic composition owing to the larger biotite-percentage. The first great fall below the Sir Walter Raleigh fall in the Upper Courantyne is formed by a gneiss which is very rich in biotite (Y. 308, 309). The sample seems to contain as much biotite as gray feldspar and quartz. The biotite, for the greater part equally oriented causes distinct parallel texture. The microscope shows that the rock consists of plagioclase (oligoclase-andesine), quartz, biotite, apatite, ore, zircon and very little muscovite and microcline. Both the coloured and colourless minerals contribute to the parallel texture of the whole. The quantities of plagioclase and quartz are about the same. As has been mentioned, also these minerals contribute to the parallel texture. Only a few plagioclases suggest idiomorphism by their general shape, mostly, however, the crystals are quite irregular; the rock has typical gneiss-structure. Some muscovite suggests primary character. Ore, without distinct crystal-shape, seems to be magnetite. Zircon is present as rounded-off grains, apatite only in traces. Signs of pressure are limited to some undulose extinction in quartz. (Pl. 39 fig. 6).

B. *Quartz mica hornblende diorite-gneisses.*

These gneisses are somewhat more basic than the types rich in biotite which have just been described. Besides biotite, green hornblende occurs. A gneiss from the Upper Courantyne, collected between the mouth of the Lucie river and the King Frederick William IV fall (Y. 288) shows slight parallel texture. The biotite and hornblende are somewhat coarser (1—2 mm.) than white feldspar (1 mm.) and quartz, which is present in small quantities. The sample is dappled with coloured minerals. Microscopically we observe biotite, hornblende, plagioclase, quartz, some titanite, apatite and ore. The plagioclase (oligoclase-andesine) is considerably superior to the quartz in quantity. The colourless minerals impede one another mutually without any sequence of crystallization. The plagioclase frequently has a polyhedral form; the lamination may be bent and show wedging out of the lamellae. The sparse quartz is, however, only coarsely crushed and undulose. The hornblende is present in somewhat larger quantities than the biotite. The hornblende is irregular in shape and sometimes perforated. The biotite now has an irregular shape, now the base is well-developed. Pale-brown titanite appears in the form of irregular pieces; where they adjoin the biotite the latter shows a pleochroitic zone. Apatite is sometimes found enclosed in titanite. The ore is partly octahedral, partly present in the form of rounded-off grains. Zircon is not found. Secondary modifications, except the mechanical disturbance of quartz and plagioclase are not present.

On the English bank, at about the same latitude, an ortho-gneiss was collected (V. 3502) agreeing entirely with the former, except for the following details. Both the coloured and colourless minerals have a distinct tendency towards parallel trend, giving the sample distinct parallel texture. Part of the plagioclase, quartzes and hornblende have irregular oblong forms, devoid of any idiomorphism; the smaller mineral-grains are irregularly granular in form. The biotite is decidedly flattened according to the base. With an otherwise similar mineral-combination this rock differs from the former by typical primary epidote. The latter possesses characteristic idiomorphism, and signs of corrosion where bordering on the colourless minerals. The signs of pressure are the same.

Closely related to each other are two gneisses, the one of the Upper Courantyne above the Sir Walter Raleigh fall (Y. 316), the other of the New river above the Ashiru fall (Y. 302). These rocks may be compared with the corresponding gneisses of the "diorite facies" because they contain primary epidote and also orthite. The rocks are from medium- to fine-grained, rich in greenish-brown biotite and green hornblende, and show indistinct parallel texture. When seen through the microscope plagioclase and a much smaller quantity of quartz are to be found. The twinning of the plagioclase is now distinct, now vague. It is

[1]) W. Bergt. **45**, p. 114—118.

oligoclase-andesine. The plagioclase and quartz show no sequence of crystallization but irregular boundary-lines, giving the rock typical ortho-gneiss-structure. In one of the rocks (Y. 316), owing to the fact that the grains are almost isodiametrical, the structure is not unlike mozaic.

The biotite is strongly flattened to the base and this face may be developed or not. Hornblende on the other hand is always without any idiomorphism, often oblong-shaped. Primary epidote, where bordering on biotite, cuts the latter straight and so is idiomorphic towards it (especially V. 316). The epidote encloses orthite-grains which are more or less idiomorphic. The other accessories are irregularly shaped ore, titanite of a pale-brown colour, apatite, zircon and occasionally some pyrite, which is intergrown with the ore. The zircon has short prismatic shape. Signs of pressure are hardly worth mentioning. A gneiss of the same type, but without any primary epidote, orthite or titanite, is found on the Upper Courantyne (V. 3497).

A quartz mica hornblende gneiss of St. Maurice du Maroni (V. 1711) has another habitus. The normal-grained sample, rich in coloured minerals, shows well-defined parallel texture. Microscopically we see typical gneiss-structure. The plagioclases (oligoclase-andesine) show no idiomorphism towards quartz but irregular and in parts curved boundary-lines. Where a number of small plagioclases touch each other, they mutually blunt each other polyhedrically. The twinning structure is well-defined but with few lamellae per crystal. The plagioclase crystals, the clear quartzes and the coloured minerals not the least, on the whole, clearly show parallel direction with their maximum length. The hornblende appears in irregular crystals. The number of twins is striking, several frequently occurring in one and the same grain. Besides this the hornblende reveals another pleochroism than was ever seen in the granitodiorites, namely from almost colourless to sea-green, with conspicuously regular distribution of the tints. The biotite is also of an unusual colour, ranging from a bright-yellowish brown to bright cinnamon. The crystals are decidedly flattened according to the base, occasionally the latter is developed. The accessories are restricted to some rounded-off oblong zircons and apatite, both producing haloes in the biotite; ore occurs only in traces. The rock has undergone little change. Traces of pressure are restricted to very slight undulose disturbances in the quartz. Some sericite and zoisite-like material in the plagioclase appears here and there.

It is surprising that Du Bois regards this rock as "gequetscht" [1]. I look upon the parallel texture as primary and this also applies to the gneiss-characteristics.

C. *Quartz hornblende diorite-gneisses.*

Gneisses containing this combination of minerals occur very rarely; there are only two, which differ much in habitus.

A gneiss of the Cassipora creek, a tributary of the Lower Suriname river (V. 1487) is fine-grained, with distinct parallel texture in the sample. It is rich in hornblende. Several zones are also rich in biotite, and this, together with the texture may cause the rock to be mistaken for a mica schist (as is the case in Du Bois's list) [2]. Microscopically, however, we see more plagioclase (oligoclase-andesine) than quartz, much green hornblende, a little brownish-green biotite, much ore as accessory and some apatite. The structure is about equi-granular. The coloured and colourless minerals both contribute to the parallel texture. The quartz shows undulose extinction, for the rest the rock has remained unchanged.

Quite another type is presented by a quartz hornblende diorite-gneiss of the Upper Courantyne between "Point right about" and the New river (Y. 305). The sample is practically massive. The green hornblende contrasts distinctly with the white feldspar. The hornblende is present in somewhat smaller quantities than the feldspar. Judging from its habitus we should take the sample for a diorite. The grains vary in size from 1—4 mm.; in places, however, we observe much coarser skeleton-like hornblende-crystals, sometimes attaining to a size of 3 cm. There is, however, no question of a well-defined shape of these hornblendes, but quite a number of white feldspar-grains are enclosed at the sides, particularly in the coarser pieces. Several of these indistinct phenocrysts occur in the sample. Microscopically we observe plagioclase, hornblende, quartz, and primary epidote, their relative quantities being given in the order mentioned. The shape of the colourless minerals, plagioclase and quartz, is partly irregular, partly polyhedrical; the latter shape is especially shown by the smaller grains, so that not the least sequence of crystallization is to be recorded. Larger plagioclases, however, by their general form remind us here and there of idiomorphic types but neither the crystal faces nor the angles are sharply defined anywhere. Some chloritized biotite also appears. The plagioclase has approximately the composition of andesine; the lamination is distinct, sometimes slightly bent and wedging out. The considerable percentage of primary epidote, showing traces of corrosion, is worthy of note.

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[1]) G. C. Du Bois. **40.** p. 29.
[2]) l.c. Nr. 10b, p. 15.

SOME CHEMICAL DATA ON THE "REMAINING" GRANITO-DIORITES.

Table 28 gives the chemical composition of some of the types. The Niggli values have been added.

The first three columns of the first table give three granites typical of the Central Wilhelmina mountains (see description p. 280—281). The first two are aplitic granites, characterized by very low values for c and high ones for k.

The columns 4 and 5 give a diorite and a diorite-gneiss, which though occurring far removed from each other illustrate the fact that the gneisses may be the complete chemical equivalents of normal igneous rocks, which again proves the ortho-nature of the gneisses (the mineralogical composition is to be found on p. 295 and p. 285). The rocks range from the peléeitic to normal-dioritic magma type of Niggli.

The last two gneisses are types that have seldom been met with in Surinam; they seem to be confined to the area that we have discussed as Upper Courantyne in a wider sense. As has been stated a great variety of rocks occurs there. When reading the Niggli-values of Y. 305 the high value for k strikes us; it reminds one of granites, but does not go well with the high value for fm. This rock does not contain any free potash feldspar, but the large biotite-percentage accounts for the k-value. The chemical composition agrees with that of quartz monzonites (Niggli's opdalitic magma-type) [1]. The last type, however, differs from our rock by a higher value for c.

The granite-gneiss (Y. 270) shows similar peculiarities. Here the k-value is very high and cannot be caused by the percentage of potash feldspar, in connection with the very low si-value. Also here the potassium percentage must be caused in large measure by biotite; a very large amount of biotite is present also in this rock. Considering the rather low value of si together with the relatively low value of fm and c, it is clear that the composition of this gneiss does not fit any igneous magma, the magma of some lamprophyres excepted (Chemically odinites may be very much alike, see Niggli-Beger p. 268 no. 154 I). It is obvious, however, that our rocks have nothing to do with the lamprophyres.

With reference to the abnormal composition doubts might be raised in the case of the last two rocks concerning the ortho-nature of the gneisses. Later on, however, we purpose to dwell on a hypothesis which may perhaps interpret their deviating composition, and in which their ortho-nature is accepted (p. 353).

Geographic distribution of the "Remaining" Granitodiorites.

The geographic distribution will be discussed in the following sequence:

1) The Lower Marowyne river.
2) Between the Lower Marowyne and the Lower Suriname rivers.

[1] P. Niggli, P. J. Beger. Gesteins- und Mineralprovinzen. Berlin 1923. I. p. 117.

TABLE 28.

	Aplitic granite Y. 216	Aplitic granite Y. 290 [1]	Biotite granite silicic type Y. 199	Quartz mica hornblende diorite Y. 175. B.	Quartz mica hornblende diorite-gneiss Y. 316 [1]	Quartz mica diorite-gneiss Y. 305 [1]	Granite-gneiss very rich in biotite Y. 270 [1]
SiO_2	76.31	75.18	72.05	54.83	57.58	64.10	57.12
Al_2O_3	12.23	13.42	14.74	18.71	17.65	15.23	19.04
Fe_2O_3	0.91	1.27	3.09	0.75	2.56	3.13	3.68
FeO	0.19	0.18	0.08	6.14	4.73	4.41	3.08
MnO	0.01	—	—	0.18	0.13	0.33	0.19
MgO	0.53	0.28	0.59	3.24	3.08	2.93	1.73
CaO	0.20	0.62	1.30	7.12	6.32	4.12	3.80
Na_2O	2.96	4.30	3.67	4.09	3.59	1.92	3.09
K_2O	5.49	4.52	1.68	1.96	2.01	2.47	5.80
H_2O+	0.27	0.29 (H₂O+ and H₂O−)	0.02	0.62	0.66 (H₂O+ and H₂O−)	0.48 (H₂O+ and H₂O−)	0.29 (H₂O+ and H₂O−)
H_2O-	0.02		0.00	0.07			
TiO_2	0.47	0.16	2.78	1.67	0.74	0.60	1.37
P_2O_5	0.12	0.04	—	0.47	0.32	0.12	0.53
	99.71	100.26 [1] 0.08 SO_3	100.00	99.85	99.37 [1] 0.02 SO_3	99.84 [1] 0.06 SO_3	99.72 [1] 0.02 SO_3
Anal.	Dr. S. Parker Zürich	Koning & Bienfait Amsterdam	Dr. K. Brauer Cassel	Dr. S. Parker Zürich	Koning & Bienfait Amsterdam	Koning & Bienfait Amsterdam	Koning & Bienfait Amsterdam

	si	al	fm	c	alk	k	mg	Section
Aplitic granite Y. 216	509	48	8.5	1.5	42	0.55	0.61	2
Aplitic granite Y. 290	438	46	9	4	41	0.41	0.28	4
Biotite granite Y. 199	401	48	18	8	26	0.23	0.27	4
Quartz mica hornblende diorite Y. 175 B.	159	32	31	22	15	0.24	0.46	5
Quartz mica hornblende diorite-gneiss Y. 316	177	32	32.5	21.0	14.5	0.27	0.44	4
Quartz mica diorite-gneiss Y. 305	232	32.5	39	16.5	12	0.46	0.41	3
Granite-gneiss (very rich in biotite) Y. 270	189	37	27	13.5	22.5	0.55	0.32	4

Y. 216, Y. 290, Y. 199 — Central Wilhelmina mountains.
Y. 175 B — Upper Lucie river.
Y. 316 — Upper Courantyne, third rapid above the Raleigh fall.
Y. 305 — Upper Courantyne, above the New river.
Y. 270 — Courantyne, King Frederick William IV fall.

3) The Lower Suriname river.
4) The Lower Saramacca river.
5) The Lower Coppename river.
6) The Nickerie river.
7) The Middle Courantyne river and the Kabalebo river.
8) The Upper Lucie river.
9) The Central Wilhelmina mountains.
10) The water-shed of the Amazon.
11) The source-rivers of the Courantyne (Sipaliwini- and Cutari).
12) The Upper Courantyne in the widest sense.

The Lower Marowyne river.

From the confluence of the Tapanahony and the Lawa along the Marowyne downstream we find an extensive formation of metamorphic sediments, the graywacke-formation. This goes on as far as below the Armina falls. Although we find two local areas of granitic and gneissic rocks marked on Du Bois's map, one near the mouth of the Joeka creek, the other near the Armina falls and Apatoe kondre, neither of them are to be discussed. For we only know crystalline graywacke and mica quartzite from there, which both in the sample and in the field sometimes look much like fine-grained granitic rock, and Du Bois was probably mistaken.
The first rocks of granitic mineral-combination are ortho-gneisses from below the Guidala islands on the Dutch bank below the Aschendagana creek. From there downward we chiefly meet exposures of the same composition separated by great spaces of open water. They continue down to near the mouth of the Wane creek, at least on the French bank. As Du Bois has already recorded [1]) all of them show gneissose structure. This, however, is not to be seen in the sample. We have given an extensive description of these gneisses on p. 281; and also of the quartz mica hornblende diorite-gneiss of St. Maurice du Maroni, which is not only a special type among the rocks of the Lower Marowyne, but which is quite unknown elsewhere in the Colony (see p. 286).

Between the Lower Marowyne and Lower Suriname rivers.

Some regions marked as granitic by Du Bois ought to come in here; namely the tract between Guidala on the Marowyne and the Peninica (a tributary creek of the Commewyne river); the watershed between the source creeks of the Cottica and Patamacca in the North and the branches of the Tempati creek and Marowyne in the South; and also a granite-region at the sources of the Atie creek (right hand side creek of the Tempati creek). As, however, there is no material present from this area for microscopical examination and the geology of these very poorly exposed regions is not clear, we may pass them in silence. This also applies to rocks from a small granite-spot on Du Bois's map near the Man-a-Sam placer (Upper Commewyne) (V. 1739: Du Bois No. 327), which, microscopically, appear to be a crystalline graywacke.

The Lower Suriname river.

We come across the first and local exposures of granitodiorites on the Suriname river between Carolina and the first great bend above Phedra. At the landing-place of Carolina, we find a normal-grained, non-porphyritic rock, outwardly a granite, but microscopically, judging from its structure, an ortho-gneiss (V. 1484) with copious microcline and little plagioclase (oligoclase) and quartz. Primary muscovite occurs by the side of biotite. The rock has undergone little change, an initial stage of opalization of the plagioclases seems to be present. The rock is quite the same type of ortho-gneiss as is found on the Lower Marowyne. Next follow intensely weathered granites collected near the Joden-Savannah on the right bank by Martin, and inland in the hinterland of Gelderland. The biotite granite rich in microcline from Cassipora creek (V. 1486) which contains some muscovite and crushed quartz is fresh. By the side of apatite and zircon as accessory minerals, monazite is possibly also present. On the Cassipora creek quartz hornblende gneiss also occurs (V. 1487, see p. 286). The next exposures are near Worsteling Jacobs. Here we find fine-grained granite (V. 1447 and 1488). The first sample is a biotite granite with some muscovite and ill-developed sequence of crystallization; it shows nothing in particular; the second, on the contrary, as Du Bois has already recorded, bears garnet. Structurally this granite, which is poor in plagioclase, is very closely related to the ortho-gneisses. Going towards the interior another granite has been collected by Martin (V. 1446), bearing hardly any micro-

[1]) G. C. Du Bois. **40.** p. 29.

cline but very much plagioclase. The normal-grained rocks show a decided, fine, vermiform perforation of biotite described on page 182. As accessory minerals there are some hornblende and irregularly shaped titanite, apatite, zircon and ore, but also a trifling quantity of primary epidote. These rocks, too, show slight signs of pressure: slightly undulose quartz. Quite close, near Morea, we have a couple of granite-gneisses (V. 1489 and 1490) both normal-grained. Both are rich in microcline and bear primary muscovite by the side of biotite. V. 1490, especially, is of the same type as the ortho-gneisses on the Lower Marowyne. The rock V. 2468 from the same place is a quartz mica diorite, showing traces of free microcline and moderately well-defined sequence of crystallization. Next follow near Phedra a biotite granite (V. 1372) and a granite-gneiss (V. 1373). Primary muscovite next to biotite occurs in both; V. 1373 has a bi-mica granitic mineral-combination. These rocks, too, show signs of slight pressure. The above-mentioned rocks, in so far as the contrary has not been mentioned elsewhere, petrographically show no essential differences from the granites and quartz mica diorites which are classed elsewhere with the "Gran-rio granites" and the "diorite facies" of the latter; the fine- to normal-grained granites are of the same type as those which we find between the Lawa and Tapanahony, which is equally true of a few of the ortho-gneisses with granitic mineral-combination, while the only quartz mica diorite mentioned is of the same type as occurs farther upstream. Granites and diorites are also present above Phedra according to Martin and Du Bois. Locally in the Carolina creek (Upper Para river) viz. normal-grained biotite muscovite granite occurs (V. 1742), which, by its almost complete lack of sequence of crystallization approaches the ortho-gneisses. The granite above the island near Brokopondo on Martin's map is represented by V. 1529; I have classed it as an gneissose diorite of the "diorite facies". Here we come to the area discussed in connection with the diorite facies.

The Lower Saramacca river.

From the regions W. of the Saramacca we have but a few samples to record, namely a granite from West of the Mendrinetie creek (from the Montana mine, V. 726) and a rock of granitic appearance, from the same region (Du Bois No. 358). The latter proves, however, not to be a biotite granite but a metamorphic-clastic rock. For the rest we possess no material at all from the Lower Saramacca belonging to the rock groups in discussion which is the more surprising since this region may be easily reached.

The Lower Coppename river.

From the Lower Coppename we have a large number of granitic rocks, partly discussed already by Essed [1]) and in Bergt's petrographic descriptions [2]). While on the Raleigh falls and the neighbouring Foengoe island Gran-rio granites are present belonging to the great granite-massif, quite a number of metamorphic sediment-rocks, partly contact-metamorphic, follow downstream as far as below the Pireen creek (branch-creek from the left). They alternate locally with igneous rocks which we must hold responsible for their contact-metamorphism. From here we have a normal-grained biotite granite, non-porphyritic (V. 2401). Of the rest of the granites and gneisses occurring locally, which, according to Essed, alternate with the metamorphic sediments, there is no material available and they must be left out of consideration, as it is uncertain what these rocks would reveal on being microscopically examined. Not until between the Pireen- and Pomo creeks do we seem to come to a region of granitic rocks, forming the predominating formation as far as the deserted Bushnegro-village of Copenkrissie. First come a number of rocks of quartz mica dioritic composition, which structurally vary from normal diorites (V. 2359, 2361, 2366) and gneissose diorites (V. 2362, 2363, 2364, 2365) to ortho-gneisses with corresponding composition (called by Essed biotite gneisses, amphibolites etc.; in his identifications of rocks and consequently also in the geological relations recorded by him there is great confusion).

Next follow downstream a number of rocks of granitic mineral-combination, now real porphyritic granites, now eye-gneisses with coarse rounded-off feldspar-crystals. They appear already above Tomolin creek, and together with others, form the Leguan- and the Kaaiman-rock. Microscopically the groundmass now shows the features of gneiss, now the structure of granite, or an intermediate form, and as no essential mineralogical difference is present among all these forms, a connection between the eye-gneiss types and the porphyritic granites is probable. The granite forming the Kaaimanrock (V. 2348 and B. 27) is distinctly porphyritic with beautiful microcline-phenocrysts up to a size of 6 cm. showing a good crystal-shape. The dark mauve phenocrysts are flattened according to the base and partly twinned according to the Carlsbad-law. The normal-grained groundmass shows some parallel texture in the sample. Microscopically it appears to be biotite granite with rather poorly defined sequence of crystallization between plagioclase and quartz, while microcline (with microperthite) and quartz show no sequence at all; apatite, ore, and zircon are the accessories.

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[1]) E. Essed. **105.**

[2]) W. Bergt. **45.**

The plagioclases show antiperthite fields of oblong, almost rectangular, sections, in large numbers, having their maximum lengths directed parallelly to the intergrowth-faces of the poorly defined lamellae. This copious antiperthite is of the same type as we have already discussed in the rocks of the Nickerie-region. As Bergt has already stated (l.c. p. 138), pressure is quite of minor importance. This rock corresponds to porphyritic Gran-rio granite. The rest of the rocks, the eye-gneisses, are notable for the oblong rounded-off microcline-phenocrysts, which sometimes attain to a size of 4 cm. and are twinned here and there according to the Carlsbad-law (V. 2353, 2354, 2355, 2356; B. 25 and 26). These gneisses are described in detail on p. 283.

It is not certain in how far these rocks link up with those of quartz mica dioritic composition upstream, or with the ortho-gneisses which follow directly downstream. A couple of these ortho-gneisses (V. 2340 and 2342), from the hills to the North of Zonvisch creek, microscopically show mylonite-structure and locally undisturbed ortho-gneiss features. Besides we have a normal biotite hornblende granite (V. 2341) from the same hills. We further have a biotite granite rich in microcline from near Neti creek (V. 2333) with sericitized plagioclase. The last solid rocks are visible 200 m. below Copenkrissie (according to Essed) disappearing there under recent deposits.

Pieces of weathered granite are recorded by Essed to occur farther downstream at the Timmerman mountain, and he even marks on his map granites and granite-gneisses down to not far above the mouth of the Tibiti because of the occurring of weathering-products.

The Nickerie river.

In this region the granitodiorites vary strongly, both in structure and in mineral composition. Besides the "remaining granitodiorites" we have here a series of gabbros, pyroxene-bearing diorites and pyroxene gneisses which belong to a special series which we have already discussed separately. Of several rocks belonging to the "remaining" granitodiorites no thin sections are available; for these the identification of Beekman [1]) is followed here.

The rocks were collected along the Nickerie river up to the Blanche Marie fall, along the Fallawatra creek and along a trail that was cut from there to the water-shed with the Saramacca river. They are mostly granites and granite-gneisses of biotite granitic mineral-combination. It is remarkable that potash feldspar is now developed as microcline, now as orthoclase, whilst the latter mineral is only exceptionally found in the Surinam granitodiorites.

The rock from Bigi Santi (V. 2127) is a porphyritic biotite granite with a few microcline-phenocrysts in a normal-grained groundmass of quartz, plagioclase (oligoclase), microcline, biotite, and brown titanite, apatite, ore and zircon as accessories (the rock contains no orthoclase as Beekman states). The plagioclase shows idiomorphism towards quartz but its structure is generally disturbed by intense cataclasm. The quartz has been completely crushed and reduced to aggregates. Displacements of parts of the rock mutually must have taken place judging from the bent biotite which has slid off, and the ore which has, in parts, been crushed.

A granite from above the Blanche Marie fall is rich in granophyre of quartz and potash feldspar (V. 2022). Some bi-mica granites are present (e.g. 1943, 1944, 1945, 2138). Some granites are pegmatitic (V. 1983, 1984). Of the rocks of which no thin sections are available and which, according to Beekman are mostly granites or acid diorites, the numbers are mentioned here (V. 1907, 1936, 1937, 1961, 1983, 1984, 1987, 1993, 2032, 2037, 2038, 2051, 2085, 2091, 2108, 2109, 2136, 2137, 2141, 2143, 2175, 2177).

We have a fairly large number of ortho-gneisses from this region. Aplitic-gneisses occur now and then (V. 1987, 2020, see p. 284) but mostly biotite gneisses (V. 1952, 1961, 2027, 2030, 2070, 2078, 2101, 2103, 2116). Also in these rocks the feldspar is now orthoclase, now vaguely laminated microcline (V. 1987, 2020, see p. 284). In the acid plagioclase antiperthite occurs; sometimes also myrmekite is seen. Mineralogically these rocks show as a rule nothing remarkable. One of these rocks, however, has a small percentage of colourless minerals and contains a considerable quantity of red garnet (V. 2056); this rock was entitled a Leptynite [2]) by Beekman.

A couple of rocks from the Lombok fall (V. 1939/40 and 2027) have a biotite granitic mineral-combination with a certain percentage of hornblende. One of them (V. 1939/40) has very poorly developed sequence of crystallization of the colourless minerals and is a gneissose granite. The second through lack of crystallization-sequence has ortho-gneiss structure; besides this the latter shows some parallel texture. These rocks prove the connection between the two types, because they are from the same locality and have similar mineral-combination. Potash feldspar is developed as microcline once more and accompanied by myrmekite. In V. 2027 some epidote of the primary type is present.

Undulose extinction shows that pressure has influenced these rocks generally, while in some rocks also bending and crushing of the minerals is to be seen (e.g. V. 1961, 2070, 2116).

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1) E. H. M. Beekman. **63.**
2) l.c. p. 166.

Besides rocks of granitic mineral-combination there are also some of acid dioritic combination. They are quartz mica diorites (V. 1921, 1927, 1964, 1972, 2034). Mineralogically they do not show a single new component. Antiperthite is often present in the plagioclase. One of these rocks contains hardly any quartz (V. 2034). The structure of these rocks differs but little from that of ortho-gneisses owing to trifling crystallization-sequence of the plagioclase and quartz. Also here important signs of pressure are to be seen.

The acid diorite-gneisses have quartz mica dioritic composition and are aplitic (V. 1991, 1992). They are massive, and normal- to fine-grained. Typical is the fine-grained rock from Paradijs creek (V. 2028), showing undulating course of the boundary-lines between the colourless main components. Besides biotite it contains a considerable percentage of ore and some potash feldspar.

Whilst in the former rocks there are signs of important pressure, still stronger pressure is the cause of the formation of another type of gneisses, now of granitic (V. 1982), now of acid dioritic mineral-combination (V. 1978). These "cataclastic" gneisses are quite like the types which will be described in detail on p. 334 to 337. Moreover we have typical mylonites, viz. boulders from the Blanche Marie fall, which were considered by Beekman to be "Porphyre pétrosilicieux" (l.c. p. 108) (vide p. 338).

The Middle Courantyne and the Kabalebo river.

Now let us turn to a vast region of granite, along the Courantyne from the first great fall below the mouth of the Lucie river, downstream to the mouth of the Kabalebo, where the solid rock disappears under the latest deposits. On the South-side this region is in no sense sharply separated from the granitodiorites, ortho-gneisses and other rocks occurring upstream, which will be found separately discussed. Downstream the first great fall downstream the mouth of the Lucie river (the "King William" as it is called by the Balata-bleeders, probably in confusion with the "King Frederick William IV fall", higher up) one comes to an apparently uninterrupted granite-region. Instead of the rocks with more or less decided parallel texture frequently seen in the ortho-gneisses upstream, those with massive texture chiefly occur. This fact already struck Barrington Brown and he rightly separated the two regions into "schists and gneisses" upstream and "granites" downstream; even though he drew the line of demarcation somewhat differently from me. Judging from the appearance of the rocks in the field and from the samples available, this region is to be regarded as more or less equivalent to the Gran-rio granites. The reason, however, why they are discussed with the "remaining" granitodiorites is to be found in the fact that there are so few samples available, hence petrographic comparison based on a thorough microscopical research is out of the question. In quite a number of places the grain of these granites is comparatively coarse not exceeding five millimetres, however; in several places coarse microcline-phenocrysts occur, and in that case the granite is to be compared in its entirety with the Gran-rio granite, in its typical form consisting of quartz, microcline and plagioclase, the latter not being very acid (oligoclase-andesine or oligoclase) with biotite, and with or without hornblende. The fairly frequent primary epidote, quite in accordance with the well-known type, is of much importance for the comparison with the said granite. Titanite is sometimes present. The porphyritic type occurs at the Lord Stanley falls and also near the Plum- and Twirl-round rapids over a distance of about 10 km. Near the first falls it forms a very wild and rocky landscape of rounded-off granite-blocks of some m^3 in size, with numbers of islands.

Here follow some details. The first sample below the great fall found below the mouth of the Lucie river, is a normal-grained, red, decidedly cataclastic, aplitic granite (Y. 326). Next follows a rock from the small mountain on the left bank, not far from there (V. 3505). It is a coarse granite with grains in parts coarser than 5 mm.; it shows abundant quartz and less idiomorphic oligoclase and microcline. Traces of primary epidote occur. There are many striking filiform inclusions in the quartz. The accessories are apatite, ore, and zircon. Pressure has crushed the quartz. Not far downstream, a normal- to fine-grained massive biotite granite was collected (Y. 327). Of the accessories we must mention the idiomorphic titanite and, in particular, the primary epidote, which shows signs of magmatic corrosion. Muscovite, often rosette-shaped, seems to be of secondary origin. Granite rocks continue for about 15 km. in the river; then, however, more or less well-defined parallel texture appears in the rocks, finding clear expression in rounded-off masses, which seem to cross the river with a varying trend: NNW.—SSE. and East—West with a dip of about 45° to SW. and S.; the trend and dip are caused by equal orientation of the biotite. These rocks must either be gneissose granites or ortho-gneisses, which only can be ascertained by microscopical investigation. Material is, however, not available. The same phenomenon may repeatedly be more or less distinctly observed in a region of approximately 15 km. long (near the long island at the mouth of Awara-balli river) but a gradual transition to granite is undoubtedly present. Brown has also pointed out the latter fact [1]). On his

[1]) C. B. Brown. **10.** p. 224.

map he has marked gneisses here. The English map [1]) moreover gives gneisses throughout the region below the Lucie river, as far as 40 km. below the mouth of the latter.

Next follows massive granite again, forming quite an archipelago, as far as the Wonotobo falls. The first sample (Y. 328) (taken from above the region of rapids marked on the English maps as the Tiger falls) is a biotite granite with ill-defined sequence of crystallization. In the Lord Stanley falls and the Plum- and Twirlround rapids occur typical porphyritic granites as has been stated: we can observe the porphyritic structure even in the small samples (see Y. 333; V. 3516); the latter sample bears primary epidote. The rock (V. 3515) is somewhat divergent owing to porphyritic structure with idiomorphic microcline and plagioclase (the latter filled with epidote and sericite), in a fine groundmass. After passing a region of quartz porphyry the same normal-grained granites though non-porphyritic, occur again in good exposures down to past the Wonotobo falls. The plagioclase, which shows a distinct tendency towards idiomorphism is filled with secondary epidote-microlites and sericite (V. 3517, 3513; Y. 337). All these rocks show but moderate traces of pressure: undulose, slightly crushed quartz. Below the Wonotobo falls first come comparatively few exposures for more than 20 km., where rounded-off granite rocks appear but here and there. The exposure increases as we approach the Governor falls. Quartz porphyry, indicated by Brown near the lower rapids of these falls, was not seen by me, but I could only examine the region very superficially. The sample coming from there (V. 3508) is a biotite granite, relatively rich in quartz. The beautifully idiomorphic plagioclase, in so far as it is not filled with epidote-microlites and sericite, has the composition of oligoclase. Traces of primary epidote seem to be present. Idiomorphic titanite is present in significant quantities. The rock does not differ essentially from the granites near and above the Wonotobo falls.

Near the last island of the complex that in a wide sense corresponds to the Governor falls, we see, directly above the last rapid (indicated on Käyser's map [2])), near the English bank, a large, rounded-off rock. It is about the place, where Barrington Brown marks sandstone. Judging from its appearance, we should certainly take the dense gray-greenish rock for quartzite, in which some weathering-grooves are to be seen. Veins of pegmatite, a few centimetres thick, cut the rock in different directions, as if they filled cracks in the rock. The rock itself consists of very fine-grained aplitic granite (Y. 340). Microscopically we observe quartz, microcline, plagioclase (oligoclase), little biotite and muscovite, some epidote, ore, apatite and grains of zircon; the plagioclase contains grains of sericite and epidote. Plagioclase and microcline are present in approximately equal quantities, while the former, and sometimes also the latter, may show idiomorphism towards quartz; hence, sequence of crystallization is present. The average size of the grains is 0.25 mm. It is not certain whether this rock forms a dyke or not; the extremely fine grain renders it not improbable; if so, this dyke should not be much less than 10 m. in breadth. The exposure, however, does not allow us to ascertain this, because the rock is surrounded by water.

Past the sharp bend to the NE. which then follows, granite-exposures occur again down to past the second Temehri rock, over a distance of about 6 km. The rock V. 3509 from here is a biotite granite bearing titanite; it corresponds to the rock of the Governor falls (V. 3508) in detail. Below this point we saw no more exposures until we came to the next bend (towards the East), but the English map [1]) indicates sandstone here; I have no data at my disposal. Going further, however, we come to a region where local granite-exposures are pretty numerous, which keep on as far as about 5 km. above Sika island (Wanuto island on the English maps). Among others we see rounded-off rocks near the Assipoya and Maipoeri islands, between the latter and the Paka island, and near the Cow falls, the last insignificant rapids in the Courantyne; here the water flows among coarse, rounded-off blocks of granite. We observe the same near the Mawarli or Flat Rock island (not marked on map VI), and near the Alapalisso island and rocks of that name in the next bend. Not far below these the English map indicates sandstone again, which cannot be correct, as I saw quite a number of normal-grained granite rocks above water all the way from the last-mentioned islands to about 3 km. above Sika island and as I also collected material from them.

Let us now describe the few granite-samples collected in this granite-region. From below the Maipoeri island (near Mataway, a deserted village which is not marked on map VI) we have a sample (V. 2952). It is a normal-grained biotite granite containing microcline; in the acid plagioclase copious idiomorphic grains of epidote and sericite-scales occur. Close to here a normal-grained biotite granite was collected (V. 3510), with poorly developed microcline-phenocrysts in the sample, which may be regarded as equivalent to the Granrio granites. The plagioclase shows idiomorphism towards quartz and microcline. Relatively coarse idiomorphic titanite is present. Besides we have a sample of Voltz's (Vtz. 825) from near the Cow falls. This normal-grained rock, rich in microcline, also abundantly shows the same inclusions in the plagioclase here, and relatively coarse and twinned microperthite in the microcline. Both rocks show some signs of pressure viz. undulose quartz, while the plagioclase is sometimes bent. Lastly there is the sample Y. 341; it is a normal-grained granite consisting of quartz, microcline, plagioclase and biotite. The quartz and the

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[1]) F. Fowler. **82.**

[2]) C. C. Käyser. **80.**

plagioclase are, in parts, somewhat coarser. Microscopically there appears to be copious bi-pyramidal quartz, often enclosed in the coarser plagioclases and microclines. Greenish biotite is frequently perforated particularly by the quartz; as accessories some idiomorphic titanite, partially idiomorphic ore, and some apatite and zircon occur. Traces of pressure are present. Samples collected by Van Drimmelen in this region in 1898 and briefly described by Beekman [1]), I have not investigated microscopically. Some granite is said to occur near the mouth of the Tomatay creek (= the Toepoeroe creek) and near Marwarli island. These are the last granites exposed in the Courantyne.

From the Kabalebo, the right tributary of the Courantyne, we have but a few scattered data at our disposal (Courantyne Expedition and Voltz). Voltz's sample Nr. 868 from the former settlement at Itafé, is a fine- to normal-grained granite, poor in biotite. Part of the abundant microcline, and less so, the plagioclase show larger crystals with a conspicuous tendency towards idiomorphism, to which the quartz conforms. The microcline bears irregular microperthite, the plagioclases are full of idiomorphic epidote-microlites and sericite. The quartz is crushed, which betrays intense pressure. Some greenish biotite, some ore, zircon and, what is remarkable, also a very slight quantity of orthite remnants, surrounded by little rims of epidote, are the accessories. A thin vein of secondary epidote intersects the sample. Beekman [1]) mentions two more granites from the Kabalebo river, however, no thin sections are available at Delft. From far upstream in the Kabalebo near the so-called "Champion fall" there is a small sample of mylonised granite or rather of granite-gneiss; it is not impossible that it is in part penetrated by pseudo-tachylyte; the small dimensions of the sample and the state of the material do not allow us to judge of this with certainty (see V. 3511).

The few data from the Kabalebo indicate that granites are widely distributed here too, although the fragmentary material does not admit of any further conclusion; on the other hand it is well-known that gabbros, at any rate on the Avanavero falls, are certainly pretty widely distributed.

The Upper Lucie river.

From this region we have the data of our Expedition to the Wilhelmina mountains, supplemented by a few samples from the Courantyne-Expedition.

This region is linked up directly with the Gran-rio-massif at the low watershed between the upper-course of the Lucie river and the Gran-rio. [2]) A sharp line of demarcation, caused by a marked difference in composition, is not to be fixed between the two regions. The bi-mica granites on the rtail between the two rivers on the East-side of the watershed have been discussed with the Gran-rio massif. Towards the West we find a continuation of the same hilly country with few exposures. Granites are to be seen here and there, e.g. a normal-grained biotite granite (Y. 160), locally showing an abnormal accumulation of muscovite not to be compared with the regularly distributed muscovite in the bi-mica granites. Other rocks from the neighbourhood (Y. 161, 162, 163) seem to be a mixture of sedimentary material and igneous rocks; they do not come up for discussion here.

In one of the creeks intersecting the trail a rounded-off rock surface of granite-gneiss is exposed, the gneiss has streaky texture (Y. 164, see p. 283). Another sample (Y. 165) somewhat coarser of grain but for the rest of about the same composition, structurally, had rather be called a granite than an ortho-gneiss. The plagioclase and here and there also the microcline are irregular in shape and, locally, show poorly-defined idiomorphism. It is remarkable that both rocks were collected at but a few m. distance from each other on the same rock-surface; they illustrate how greatly structural features may vary within a very short distance, from which follows again the geological connection between the ortho-gneisses and the corresponding normal igneous rocks. Other exposures within a km. distance, show normal- and fine-grained biotite granite (e.g. Y. 166). Farther Westwards, at a few km. from the Lucie river we again meet with granite-exposures, now in the creeks, now on the slopes of the hills. Generally, however, they occur here in the form of coarse loose blocks. Such for instance is a biotite granite (Y. 167) which is indistinctly porphyritic on account of the appearance of oblong, rounded-off microcline phenocrysts, a few mm. in size, and which, because of the shape of the latter reminds us of an eye-gneiss. Microscopically, however, granite-structure appears to be present. Another granite-type, bearing hornblende (Y. 168), may, on account of its porphyritic structure with coarse microcline-phenocrysts of more than a cm. and the normal to coarse grain of the groundmass, be compared with a Gran-rio granite. Yet another sample shows the same composition, but no phenocrysts (Y. 169). Y. 170 is fine-grained and bears pseudomorphs according to cordierite (?). Again another type (Y. 171) is likewise fine-grained and almost aplitic on account of the slight percentage of biotite. The variation in the size of the grain and in the percentage of coloured minerals is significant here. All these rocks bear potash feldspar in the form of microcline, mostly with microperthite. Signs of pressure are of little significance. Not far above the place where our trail joined the Lucie river, a boulder was collected of fine-

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1) E. H. M. Beekman. **63.** p. 173—174.

2) Vide Map V.

grained granite, consisting of microcline, acid plagioclase, quartz, little biotite and some ore. Of the colourless minerals quartz only shows idiomorphism, occurring as numerous small bi-pyramids (Y. 172).

The exposures in the Lucie river itself are bad. Only where the said trail comes to the river do we see some small rapids formed by rounded-off rocks and also on the left bank not far in the bush, rocks come to light. They are all biotite hornblende diorites bearing quartz. They are comparatively basic and of an infrequent type, hence a more detailed description follows. In the sample (Y. 174, 175, 175 B) we see many white and grayish-white plagioclases, pretty much biotite and hornblende and little quartz, the size of the grain varying from 1½ to 5 mm. The coloured minerals especially strike the eye by their being coarser than the colourless ones. A few attain to dimensions of more than 5 mm. and show corrosion-cavities filled with colourless minerals. The texture is massive. Microscopically the rocks appear to consist of plagioclase, hornblende, biotite, quartz, ore, apatite, titanite, zircon, and pyrite. Plagioclase (andesine) is present in much larger quantities than quartz. Quartz conforms to plagioclase, is cut up into angular pieces and apparently crystallized last. Traces of zonal structure occur. The quantities of green hornblende and biotite are about equal and both are often accumulated. Irregular cavities occur in the hornblende (corrosion?). The colour of the mineral is yellowish-green, grass-green or brownish-green. Apatite is present in abundance, often enclosed in biotite, around which pleochroitic haloes sometimes appear. The apatite is older than the irregularly shaped ore and pyrite, for it is sometimes found enclosed in both. Irregularly shaped titanite and a few rather coarse rounded-off grains of zircon are quantitatively without significance. Signs of pressure are restricted to slight undulose extinction of the quartz. The analysis of this rock is to be found on page 288.

For the first few km. downstream, the exposures continue to be meagre. In the flat swampy ground no outcrop is to be expected. Only a single exposure of a normal-grained bi-mica granite (Y. 176) was seen a few km. farther down the river. The muscovite in this rock is of primary nature. Next follows a small waterfall of normal-grained biotite granite with a considerable biotite-percentage (Y. 177). A little farther downstream we come to the spot where the trail of the Suriname- and Courantyne-expeditions must once have joined the river. On these trails two samples of biotite granite were collected (V. 1898 and 1899). Going downstream, granite rocks are visible again here and there, in spite of the swampy condition of the banks. V. 3468 is a normal-grained rock without parallel texture, showing nothing worthy of note. In the same stretch of river, however, we also see rounded-off rocks with well-defined parallel texture, the biotite having parallel trend; e.g. below the place, where the latter sample was collected, and not far above the latter. An example of the type with parallel texture is yielded by the acid diorite-gneiss (Y. 180) described on p. 285.

Next follows a normal- to fine-grained bi-mica granite with some idiomorphism of the acid plagioclase (Y. 181). This granite shows but slight signs of pressure. It forms a smooth rounded-off rock on the right bank. When we have passed the hairpin-bend that now follows, a small waterfall or rapid comes into view, in which flat rock-surfaces are visible. The rock is a fine-grained, gray granite, with a significant percentage of biotite and hornblende and devoid of any parallel texture. Microscopically we see porphyritic structure, the oblong plagioclases (approximately oligoclase-andesine) being of larger dimensions than the groundmass, and showing idiomorphism. They are more or less zonal in structure. Black dust is enclosed in large quantities (probably ore) and, next to this, also rounded-off specks of biotite and other microlites occur. The edges are often impeded by bi-pyramidal quartz-crystals. The latter occur in large numbers in the groundmass, which contains microcline and plagioclase. As coloured minerals biotite and green hornblende are present. There is some epidote possibly of primary origin (Y. 182). Less than a km. farther downstream we again come to a rapid with granite rocks: normal-grained, without any parallel texture, and with a significant percentage of coloured minerals. Microscopically they appear to be biotite hornblende granites. The plagioclase (oligoclase-andesine) which is present in abundance, shows strikingly well-defined idiomorphism towards quartz, which has clearly crystallized out as a rest between the plagioclase. Microcline is present in small quantities. The hornblende and biotite show a tendency to idiomorphism, the latter with a well-defined base. Some idiomorphic titanite occurs. This rock also shows slight signs of pressure. We also observe the same rock in the next rapid. The exposures here leave nothing to be desired; in quite a number of places rounded-off granite rocks crop out. At the end of the next hairpin-bend a normal-grained granite rich in microcline was collected (V. 3469). In the first small fall or rapid below the mouth of the East river (a tributary flowing from the right) we observe a normal- to fine-grained quartz mica diorite, rich in coloured minerals. The plagioclases form sparse phenocrysts, which, microscopically, appear in greater number (see Y. 186). They lie in a groundmass of quartz and plagioclase with biotite. The small plagioclases in the groundmass occasionally also show some idiomorphism. The quartz has partially developed into bi-pyramids. The green biotite contains sagenite. Dark inclusions or streaks rich in epidote, biotite and hornblende are present in this rock.

Further downstream to where the Lucie river approaches the Wilhelmina mountains nearest, the exposures are satisfactory and granitic rocks crop out in quite a number of places. A couple of aplitic rocks collected on the bank and in the bush on the right-side of the large island above our main camp are remarkable (Y. 189 and 192). Both the rocks are of pale flesh-coloured tint. The first sample is extremely fine-grained to dense and does not allow of a single mineral being recognized: it has quartzitic habitus. The second is also fine-grained and shows very fine sparse specks of coloured minerals. Both rocks are quite massive. Microscopically they appear to be granite-aplites. They consist of microcline and quartz, with very little acid plagioclase. The minerals show no sequence of crystallization, except the quartz which shows a tendency to assume a bi-pyramidal shape. The microcline is richly provided with microperthite. Octahedral ore is the only accessory to be recognized. Pressure-action is wanting. In the field, the geological relation of the rocks was not clear. Rocks of granitic composition continue to appear until we come to the main camp mentioned.

During our expedition the Lucie river could be examined downstream as far as here at low water, and the exposures were, at least for the greater part, sufficient to conclude that the bed of this river must consist chiefly of granites. Whereas we could ascertain this fact in the dry season, we went down the river some months later, when circumstances were unfavourable (at the close of the long rainy season) and very few rocks were to be seen. For the first 30 km. rounded-off rocks of granitic composition were visible here and there, mostly biotite granites without any parallel texture (V. 3474). Idiomorphic epidote-microlites, appearing in the plagioclase, are remarkable. It is questionable whether they are of primary or of secondary nature.

Farther downstream we repeatedly saw rounded-off granite rocks again, in spite of the high water, and this kept on as long as the river continues to run SW. and also for a short distance along the part of the river running due West. Hence we may once more assume that this district is chiefly occupied by granites. There are a few samples available. V. 3476 is a normal-grained granite, which in a prevailing tint of pale red, shows sparse biotite. Ill-defined parallel texture is present. Microscopically it appears to be rich in microcline; besides it has a normal quartz-percentage and contains but few acid plagioclases. Both the microcline and the plagioclase have a tendency towards idiomorphism. Strings of green biotite wind themselves among the feldspars; of the accessories we may mention ore surrounded by rims of titanite. The quartz has been crushed by pressure. The rock was collected by the Courantyne expedition about a km. towards the interior on the left bank. Just above the first important group of islands a pale flesh-coloured, fine-grained, massive, aplitic biotite granite was collected. Intense pressure-action is present, seeing that the quartz is crushed and the plagioclase-lamination is bent (Y. 272). Below the first large group of islands, consequently about 12 km. below the large tributary river coming from the Käyser mountains, we meet with a normal- to coarse-grained granite which, owing to its coarse potash feldspar phenocrysts, corresponds almost entirely to the Gran-rio granites in porphyritic form. Sometimes the phenocrysts show parallel trend. The same granite seems to continue for about 6 km. to at least, past the next group of large islands. The only material present is a piece of biotite granite rich in microcline (V. 3477). In this area exposures must be very good in the dry season, judging from the many rapids.

With these rocks the region where the "remaining" granitodiorites are found distributed along the Upper Lucie river, closes; for further data concerning the exposures downstream see page 305.

The Central Wilhelmina mountains [1]).

It appears that the Central Wilhelmina mountains consist almost exclusively of granites. Exposures, as everywhere else in the Surinam mountains, are poor, much worse than we generally meet with in the upper rivers. Besides, the nature of the exposures is different: whereas in the latter every rock almost invariably belongs to the bed-rock, in the mountains this is rather the reverse: boulders are frequent, having been conveyed over a shorter or longer distance, and even if rocks of larger dimensions are found it may be doubtful whether we are concerned with an outcrop of the subsoil or not. In the broad valleys the bed-rock appears only, in the small rivers and creeks, causing rapids or small falls. In the hilly country exposures are practically entirely wanting; on the steeper hills, however, rocks sometimes crop out on the slopes and on the summits and also in the narrow valleys, often at the most unexpected points. On the slopes of the higher mountain-ridges we seldom meet with the bed-rock until close to the summit, where it is very often seen. Quite a number of ridges and summits in the Wilhelmina mountains exhibit granite-exposures as rounded-off and bare faces, often some dozens of metres broad. Similar bare rock-surfaces occur here and there in the valleys, in places where the solid rock comes to the surface and the soil has been washed away. Pl. 4 fig. 2 shows an instance of this. Boulders are to be found everywhere. In the valleys we often encounter huge blocks of granite of many cubic metres and more or less rounded-off. Now they lie on the ground in the forest, now have partly sunk into it, or they have been washed loose from the laterite by the brooks, and they may even occur in the swamps. Enormous accumulations of boulders may occur on the slopes of the higher countain-ridges. The rocks are invariably fresh only being covered by a thin weathering-crust.

[1]) Vide Map V.

In my opinion the principal ridges and mountains of the Wilhelmina range not only almost exclusively have granitic composition but the same is equally true of the intervening hilly country and just as much of the subsoil of the valleys. It might be suggested that the deepest depressions are a result of quicker weathering of rocks of a composition differing from that of granites. This opinion must be positively refuted for where the circumstances are favourable for outcrops, granites are always found. That the whole is cut up so capriciously, must, therefore, be a consequence of primary differences in the granites on the one hand and conditions of erosion differing locally on the other hand.

The granites of the Wilhelmina mountains in general are of an acid type, containing a small percentage of coloured minerals and abundant feldspar and quartz. On the one hand granites with a rather slight quantity of biotite are common, on the other hand real aplitic granite also occurs, in which biotite is practically wanting; both types seem to be linked up by transitions. We have described both types already (p. 280—281).

Let us start with the Central Wilhelmina mountains which have top 1280 as their highest point. When we go down the Lucie river, we catch sight of only two small mountains of the whole range, lying near the left bank (see sketch-map V, 650 and 710; see ditto for the rock-numbers quoted). The lower one has a bare granite-surface on the West-side (Y. 191). This pale rose granite shows accumulations of quartz and biotite-specks in the sample. Microscopically the quartz appears to be crushed into aggregates, which are crossed by strings of liquid inclusions. The microcline shows well-defined lamination and perthite. This mineral, too, is crushed. A secondary supply of quartz and fluorite seems to have taken place, which minerals have settled particularly in the microcline (see page 324). There is little acid plagioclase present showing some tendency to idiomorphism. By the side of biotite appears some hornblende and the accessories are titanite, apatite, zircon and ore.

Following the main trail of our expedition from the head-quarters on the Lucie river, we first pass almost flat ground for several km., i.e. the plain of the Lucie river. The first exposure is a normal-grained granite poor in biotite, in the wide creek dissecting the trail near the river. Farther up, near km. 3½, we come across a considerable accumulation of boulders of some cubic m. leading us to suppose that there is granite underneath. This granite has the same composition as that which near km. 5.5 forms the first small mountain.

Next follow a couple of cross-ridges which we traversed. On the two ridges and in the valleys running parallel to them, quite a number of exposures of granite and scattered or amassed granite-blocks are found. Here we meet with both the types of granite mentioned above next to each other: acid granites, relatively poor in biotite (Y. 193, 196 B, 197 F, 199) and, collected close to these, aplitic rocks (Y. 194, 194 B, 196, 198). In one of these rocks both feldspars are idiomorphic (Y. 196 B); titanite may be present (Y. 199). Some rocks show fine (Y. 194) or coarse (194 B) granophyre.

Next the remarkable rock-plate near km. 12 of our trail is to be mentioned (Pl. 4 fig. 2). It is a rock-surface of some hundreds of metres in diameter divided into a number of fields by groups of bushes. Its undulating surface is formed by the aplitic pale rose type of the granites (Y. 201). A few narrow veins of a dm. broad and of the same composition, intersect the rock. From the rock-surface we get a beautiful view, among others of top 910 (Plate 1). This mountain forms the western end of a long ridge trending WSW.; at the western extremity this ridge ends abruptly in a bare rocky face shown by the photo. A second summit of the same ridge (1030) also has a bare granite-face, and the ridge consists practically wholly of the same rock. It is the acid type, here variegated with chloritized biotite, rose potash feldspar, and yellowish-green plagioclase, with normal grain and again quite massive (Y. 200); locally it makes room again for the aplitic form (Y. 202). In the latter the quartz and potash feldspar have partly intergrown to granophyre. On a second ridge there are several blunt rounded-off summits (830, 850 and 1030), which here and there show bare granite-faces. Reconnoitring in that direction teaches us that the whole of this ridge, too, cannot but consist of the same granite-types. We observe that the same granites crop out also in the valley between the two ridges mentioned. The granite-type appearing there is again variegated with yellowish-green plagioclase, but with a somewhat larger percentage of biotite than usual (Y. 203). Even in the sample the plagioclases show idiomorphic shape.

The neighbourhood of summit 1280 consists for the greater part of variegated and acid, normal-grained granite poor in biotite, witness the many loose boulders found along the sides. Summit 1280 proper, forming a steep precipice on the South side, shows a small, bare surface of granite there. The main summit is of a different composition to its surroundings. It is a normal-grained biotite hornblende granite. Microcline-structure is well developed. The relatively coarse, dark brown titanite is remarkable, being irregular in shape and sometimes enclosing apatite and ore and even small hornblende crystals. The smallest titanite-crystals, however, are idiomorphic. Pressure-action, just as with the preceding rocks, is of small moment, and restricted to the undulose quartz. This rock, on account of hornblende and the percentage of all the coloured components, has a more basic composition than the rest of the granites of the Wilhelmina mountains (Y. 209).

The important ridge running NNE., joining top 1280 and also the ridges branching from it and forming the broad foot, once more consist, to a large extent, of the acid granite-type relatively poor in biotite. On this ridge we see coarse granite-boulders in a number of places and just as much on the sides. Also the aplitic type is represented again (Y. 216);

it is composed entirely of quartz and potash feldspar here. The same rock has been collected on the small mountain more to the SW. which again has a bare granite-face (Y. 222). The main-ridge from top 1280 to the NNE. preserves the same character over a distance of about 5 km., but is then interrupted by a deep depression. The ridge runs on for about another 5 km., at first NNE.; farther up, NE. We ascended this ridge from the West in two places and continued for some time over the crest. In a number of places we find brushwood and bamboo, between which bare granite comes to light. This mighty ridge again, in so far as it could be examined, consists partly of the acid biotite granite-type (Y. 232), partly of the aplitic one.

To the West of this important ridge there is a rather large group of summits linked up with the ridge mentioned by a cross-ridge. This cross-ridge forms part of the watershed between North and South. All these summits together enclose a depression, which is open to the SW. and in which a large creek flows, forming a great number of waterfalls. Downstream it is crossed by our main trail (near the so-called Bruggenkamp). Granite, relatively poor in biotite, is to be seen along this river, sometimes also the aplitic form occurs again (Y. 229).

The mountain-group mentioned above, W. of the valley, consists in part of granite, but diabases and gabbros, too, have a considerable share in its upbuilding (see p. 119). The SSE. and SW. side of this group, however, consist of granite, in so far at least as the exposures allow us to judge of this. Numbers of boulders indicate that there, too, the acid granite, with yellowish-green plagioclase and pale red potash feldspar and a relatively slight percentage of biotite is distributed widest. On the S. and SW. side (near our "Uitzichts-kamp") granite-faces scantily covered with vegetation, occur on the steep slope, all of aplitic granite (Y. 236, 237, 239). Y. 237 shows a few bi-pyramidal quartzes of larger dimensions. Microscopically they appear to consist chiefly of microcline and quartz granophyrically penetrating one another. Another acid granite consists of normal plagioclase (albite-oligoclase), microcline, and numerous bi-pyramidal grains of quartz; it is the type discribed on p. 280. All these rocks again have been subjected to very little pressure-action.

In the broad valley between these mountains and the large ridge crowned by tops 1060 and 1065 here and there granite crops out in the creeks, and often boulders are found. The large ridge N. with top 1065 as its highest point is cut longitudinally by a gabbro dyke. (see page 116). The flanks and the main mass, however, consist of granite again. It is of a granite-type, differing from the preceding ones. It is a normal, sometimes almost coarse-grained granite (Y. 242). Pale flesh-coloured phenocrysts of microcline about a centimetre in size appear locally, which are partly twinned according to the Carlsbad-law. Microscopically we find much plagioclase in the groundmass (albite-oligoclase), showing idiomorphism towards quartz and microcline, copiously filled with epidote-grains and sericite. The quartz and microcline reveal some inclination to intergrowth. The chloritized biotite is accumulated together with secondary epidote. Some idiomorphic titanite, apatite and ore form the accessories. This granite does not differ essentially from the Gran-rio granite in its porphyritic form.

This last-mentioned ridge is the most westerly part of the Central Wilhelmina mountains that we visited. Let us now turn to the East group. It is separated from the central group by a wide depression, through which the Oost river flows. Going up the Oost river we meet with a few small rapids over granite; the exposure in this small river leaves much to be desired. Commonest is a normal-grained biotite granite (Y. 252). The sample mentioned microscopically shows much acid plagioclase, idiomorphic towards quartz and microcline. The appearance of an oblong piece of orthite is noteworthy, for this mineral is met with nowhere else in the rocks of the Wilhelmina mountains. Y. 251 is quite different, it shows numerous grains of bi-pyramidal quartz, it is again the type described on p. 280. Microscopically it appears to be rich in quartz and extremely acid plagioclase, with mylonite-structure. All the components are disintegrated and bent, especially the plagioclases. It is a cataclastic acid granite. In so far as the exposure allows us to judge, the bed of the Oost river is for the greater part also occupied by granites.

The only group of mountains of some importance in the Eastern Wilhelmina mountains is that crowned by summit 1040. On the plain on the West side we meet with granite-boulders here and there, but here, too, exposure is very meagre. Not until we mount the Western foothills does the subsoil appear to consist of granites in as far as we can ascertain with certainty. One of these foothills shows again a bare surface of granite. There are several peaks in the main ridge, which runs NNE. The highest, 1040 m., has very steep slopes and an enormous mass of granite forms the apex. On the Southern extremity of the ridge we encounter a still larger bare mass of granite, bearing a gigantic granite-boulder (which may be distinguished 15 km. away; we saw it for instance, from the isolated hills in the West lying quite close to the Lucie river). The bare rocks of the highest peak consist of normal-grained granite, (Y. 290), aplitic, much coarser than that in the Central Wilhelmina mountains. Pale brownish feldspars form a strong contrast with brillant quartzes and vary in size from 2—5 mm., the rock is relatively coarse. These are the only components which allow of being distinguished in the sample. Microscopically we observe beautifully laminated microcline, quartz and very acid plagioclase (albite-oligoclase). The sequence of crystallization is restricted to indistinct idiomorphism of plagioclase. Relatively coarse perthite appears in the microcline, showing albite-lamination. Some biotite occurs in places. Some epidote and ore form the accessories. Traces of pressure are present. On our trail from the Oost river to the Table mountain we found granites of different types, besides quartz porphyry and granite porphyry which have been described elsewhere. Granites form the core of many hill-groups. They are normal-grained, massive rocks with a percentage of biotite such as appears in normal biotite granites. In one of the small rivers which flow to the Coppename, just where we traversed it, normal to coarse-grained biotite granite crops out. It shows potash feldspar-phenocrysts of 1½ cm. long; this granite does not differ from the typical Gran-rio granite, judging from its macroscopical habitus.

The water-shed of the Amazon.

From the water-shed we have some rock-samples collected by the Tumuchumac-Expedition (1907) along an Indian trail running from the Paloemeu (source-river of the Tapanahony) to the West, passing the water-shed in two places and ending at the Sipaliwini (source-river of the Courantyne). Between the Paloemeu and the place where the trail passes the water-shed for the first time, we know a series of 4 biotite granites, with microcline-phenocrysts (V. 1271, to 1268) attaining at times to some cm. in length (V. 1269). Microscopically microcline and plagioclase show a tendency to idiomorphism in relation to quartz. The rocks are on the whole somewhat more acid than the typical Gran-rio granites, but may quite well be related to the granites on the Paloemeu (V. 1270, 1271). They are all more or less characterized by signs of intense pressure.

In the neighbourhood two rocks were collected of which one (V. 1267) has been described by Grutterink [1]) as piemontite-bearing porphyrite. In my opinion, however, both are quartz mica diorites rich in acid plagioclase which have been modified owing to extremely strong pressure into mylonites (see p. 337). Next beyond the water-shed follow seven samples, of which six appear to be granites again. Two (V. 1265, 1264) are porphyritic biotite granites, with a groundmass rich in quartz, of an acid type to partly titanite-bearing. Both show considerable signs of pressure. After that come four non-porphyritic granites, which in the groundmass partly show a tendency to granophyric intergrowth of quartz and potash feldspar (V. 1263, 1262, 1260, 1259).

Along the same trail, after having passed the water-shed once more, returning to Surinam territory, some granites, partly porphyritic (V. 1258, 1253) and containing titanite were collected. Another rock (V. 1254) is fine-grained, non-porphyritic and microscopically shows a wealth of microcline. V. 1258 again bears titanite. The last rock (V. 1252), collected on the Sipaliwini, is a fine-grained biotite granite. Some signs of pressure are present in all these rocks. Besides these there is still a single sample of normal-grained biotite granite collected by the Courantyne-Expedition close to the water-shed, on a trail, beginning at the Sipaliwini (V. 3491).

The rather frequent occurrence of porphyritic biotite granites which do not differ essentially from the typical Gran-rio granites, among the sparse data available, make it very probable that the Gran-rio massif extends as far as here.

The source-rivers of the Courantyne (Sipaliwini and Cutari).

The Sipaliwini river has been mapped by the Courantyne-Expedition and it is also to the latter that we owe the only geological data available. The Cutari has been explored by Barrington Brown (1871) and by our expedition.

The samples from the Sipaliwini point to the fact that granites are widely distributed there. The data from farthest upstream link up with those already discussed. The first sample (V. 3487) is a light-coloured rock of schistose habitus, which, through a pocket-lens, shows oblong lens-shaped quartz-masses with parallel trend and feldspar. Microscopically it appears to be a mylonized granite which, through pressure, has assumed parallel texture. Oblong, rounded-off microclines and less numerous acid plagioclases filled with sericite lie in a fine-grained groundmass of pulverized quartz and feldspar. The ore, too, has been crushed to powder. Epidote has been formed from the coloured minerals. The next rock downstream (V. 3492) microscopically appears to be a perfect granite mylonite, epidotized, of the type described in the chapter on allo-metamorphism (page 337). Next follow downstream three biotite granites (V. 3488, 3489, 3490), which, although not developed into porphyritic form, might be called granites of the Gran-rio type. They conform to the normal-grained type, but are relatively coarse, and completely massive. They contain microcline, while primary epidote occurs in the first two samples and occasionally coarse titanite too. The microcline is as usual provided with microperthite. The plagioclase is of the same moderately acid type as that of the Gran-rio granite: oligoclase-andesine, or oligoclase, with a tendency towards idiomorphism. A trace of hornblende appears in V. 3488. The primary epidote is partly idiomorphic, enclosed in biotite (see V. 3488), partly irregular in shape on account of corrosion. Pressure-action is confined to the cataclastic quartz. Possibly we are here in the continuation of the Gran-rio granites. It is striking in this connection that a similar granite occurs on the Cutari at the

[1]) J. A. Grutterink, **73.**

highest point reached by our expedition. It is a normal- to coarse-grained granite, with twinned microcline-phenocrysts. Microscopically it appears to be a biotite-granite bearing hornblende, showing well-defined idiomorphic plagioclase (oligoclase) and much titanite. The latter is beautifully idiomorphic and is visible in the sample. Next to this a flesh-coloured granite occurs, which has an almost aplitic composition (Y. 322). Some km. downstream we meet with a very large loose block in the middle of the river, of normal-grained biotite granite showing the sequence of crystallization of plagioclase (oligoclase) towards quartz and microcline (Y. 320).

The Upper Courantyne in the widest sense.

Now we may pass to the discussion of the ortho-gneisses and granitodiorites of *the Upper Courantyne in the widest sense*. In the widest sense, for besides the exposures in the Upper Courantyne (Curuni) those in the Lucie river from its mouth to 90 km. upstream and those in the New river up to about 20 km. upstream (i.e. as far as we went up the latter) will also be discussed. By the "Upper Courantyne" we mean the main river downstream as far as the first large fall, approximately 15 km. below the mouth of the Lucie river. This fall bears no name on any map. [1])

We wish to point out emphatically that the subjoined geological data were gathered by schematic reconnoitring during our expedition and that a detailed and systematic survey is quite out of the question. We went down the Lucie river at the end of the rainy season, when the water was high. We went up the New river for some way and up the Upper Courantyne or Curuni to its source. Through the exposures were favourable here, their exploration had to be somewhat superficial on account of the nature of the expedition. I was not able to collect material in abundance, because the expedition was already overburdened.

The boundaries of this region do not correspond in any way with a sharp geological or petrographical delineation; on the contrary, many rocks of the basal complex which are also exposed in the adjacent region, are met with here again. The area, however, is distinguished for intense local interchange of the various components. There is no other part of the Colony, where the changes from granitodiorites to ortho-gneisses occur so frequently as here, and because of this it is undoubtedly one of the most interesting areas of the Colony.

The components known are the following:

1) Ortho-gneisses and granitodiorites.
2) Para-schists.
3) Venites.
4) Pegmatites.

The ortho-gneisses and granitodiorites are quantitively decidedly much more important than all the others together. As far as we are in a position to judge, the ortho-gneisses and the normal igneous rocks seem to show the same geological relation as they do in the rest of the Colony; they form a geological whole, and are both structurally and texturally different facies of the same igneous complex, hence they are approximately of the same age. On the other hand here, too, we are acquainted with a few gneisses, the gneiss-characteristics of which are the result of intense pressure.

The most striking feature of the ortho-gneisses in the field is the extraordinarily great change within narrow confines both of their mineralogical composition and of their parallel texture. This same phenomenon occurs, too, elsewhere in the Colony, but nowhere as distinctly as here. Within a distance of few dozen metres fairly basic rocks occur next to rather acid ones, now with well defined parallel texture, now practically of massive habitus, and yet, linked up by transitions. We may consider as metamorphic sediments mica schists. They seem to be confined to the Curuni proper. We only know they are present; concerning their extent and relation to the ortho-gneisses etc., nothing is known. Some hornblende gneisses are considered by me to be metamorphic basic igneous rocks except in one single case, in which we are concerned with a para-gneiss. Besides we know some venites here. Pegmatites, some of considerable dimensions, occur locally in large numbers. Brown [2]) has called them "granite veins".

Parallel texture in the rock, the result of parallel trend of the coloured minerals, is to be observed in quite a number of places. If the parallel texture is constant and the schistosity well-developed, it finds expression in the weathering, too. Less distinct parallel texture expresses itself by the occurrence of rounded-off masses of rock with constant trend. I collected a number of data on trend and dip particularly on the Upper Courantyne (Curuni). Several facts should not be lost sight of in appreciating them. First that they bear on rocks of different nature, of which but a small number have been examined more closely. As, however, the ortho-gneisses appear to be by far the predominating ones, most of the

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[1]) By the Balata-bleeders it is called "King William fall", apparently owing to confusion with the King Frederick William IV. fall higher up.

[2]) C. B. Brown. **10.**

observations must of necessity refer to them. Secondly that, as has already been remarked, trend and dip are not always strongly pronounced, so that the measurements can only be guesswork. Thirdly that observations taken while sailing are but estimations.

Place of Observation.	*Strike and dip.*
In the Courantyne:	
about 10 km. below the mouth of the Lucie river.	N. East, dip steeply towards the S. East.
5 km. below the mouth of the Lucie river.	N. East, perpendicular.
A few km. below the mouth of the Lucie river, among the islands.	N. 60° East, dip approximately 55° towards the N. West.
The Upper Courantyne, Dutch bank, not far above the mouth of the Lucie river, near the "Pearlfalls" on the English map.	N. 85° East, perpendicular.
Between the mouth of the Lucie river and King Fred. William IV fall, extreme right riverchannel.	Well-defined parallel texture, steep dip; locally: N. 65° West, dip 85° North.
King Fred. William IV fall: Dutch bank.	Strictly parallel texture trending East, steep dip.
First fall above the King Fred. etc.	N. 55° West, steep dip.
Below the mouth of the New river.	N. West, dip 60° N. East.
In Curuni opposite second mouth of the New river, going downstream.	N. N. West steep dip.
New river, near the Andira fall.	Trend approximately N. East.
Below the Waiwois fall.	Trend various, steep dip.
In the Curuni:	
Goodalls falls.	N. 80° West, dip 60° North.
Beginning of the long stretch of river running E. N. East.	N. N. East, dip about 65° West.
In the next important group of rapids above the Goodalls falls.	N. 60—70° East, dip N. West, steep.
Below the next large island lying in the middle of the river.	Trend East-West, i.e. parallel to the river.
In the next stretch of river running N. East—S. West.	N. 80° East.
About 3 km. above "Point right about".	Slabby rocks, dipping steeply.
About 9 km. above the same point.	Trend S. West, dip about 40° N. West.
About 13 km. (as the crow flies) above "Point right about".	Indistinct trend in rounded-off rocks: S. West. dip towards the West.
In the next bend, where the river comes from the E.S. East.	Plan-parallel shaped rocks, owing to decided schistosity, dip about 30° North.
Farther upstream, in several places.	Indistinct trend and dip; N. East, dip S. East, in rounded-off rocks.
Below the first fall of some significance (as the crow flies) lying a good 40 km. above "Point right about".	S. East, dip 45° N. East.
In the same fall.	W. S. West, dip 70° South.
Just below the small mountain on the right bank (as the crow flies) about 14 km. farther.	W. N. West, dip towards the North.
In the first rapid above this.	S. S. East, dip 50° East.
Some km. farther up.	N. N. East, dip 60° East.
In the next small rapid.	Trend S. S. East.
About 82 km. (as the crow flies) below the mouth of the Malawini creek.	S. East, dip 45° East.
A few kilometres higher upstream.	ditto.
In the second rapid of the first group below the Malawini creek.	Distinct plate shape of the rocks: N. 60—85° East, dip 65° North.
About 2 km. below the Malawini creek in several places.	S. S. East, dip about 45° East.
In the fourth rapid (going upstream) below the island there.	S. S. East, dip about 70° East.
In the rapid above the same island.	N. 85° West, dip about 70° North.
About one km. higher up.	North-South, dip 45° East.
In the first rapid of the next group of rapids (10 km. below the mouth of the Malawini creek).	Nearly North-South, dip about 65° East.

Above the same rapids.	S. East—N. West, dip about 65°.
About 5 km. below the mouth of the Malawini creek.	S. East—N. West, dip about 45°.
In the large fall past the big island past the Malawini creek.	N. 50° West, dip 55° N. East.
About 6 km. above the mouth of the Kamani.	N. 70° West, dip South.
Past the large island about 2½ km. past the Sir Walter Raleigh fall.	N. N. West, steep dip.

From the above it follows, therefore, that in quite a number of places dip and trend may be measured, even if there be a good deal of estimation in it. The trend varies considerably although in places it is fairly constant over great distances. The preponderating very steep dip of the parallel texture is striking, most of the rocks showing a dip of 45—90°.

Let us see what other observations and petrographical data are known, to begin with the Courantyne, above the large fall found 15 km. below the Lucie river, and upstream to the source. The first rocks are of granitic composition, locally showing parallel texture. About 5 km. below the mouth of the Lucie river a granite-gneiss was collected, the gneiss-features of which are entirely due to intense pressure, hence it is a cataclastic gneiss (see p. 334). Among the numerous islands lying below the mouth of the Lucie river we observe alternation of parallel texture and absence of it. Although no material is available, it is probable that there are transitions from granitic rocks to ortho-gneisses here. Above the mouth of the Lucie river, we notice a small fall near the Dutch bank, about 2 km. upstream, over a dark-coloured diorite-gneiss (Y. 287), forming a rounded-off rock, which, however, on knocking off a piece, shows inside a parallel trend of N. 85° E., and a steep dip. The fine-grained rock appears microscopically to be a cataclastic-gneiss, the gneiss-features of which are due to pressure (see p. 335). Just above this the river suddenly becomes very much wider. Our expedition followed the Dutch bank; the Courantyne-expedition has mapped out the English side. Here and there on the Dutch side gneiss is to be seen; an ortho-gneiss of quartz mica hornblende dioritic mineral-combination was collected (Y. 288; see p. 285). This normal-grained gneiss forms rounded-off rocks. Here we find the important King Frederick William IV falls with a total descent of 15 m. On the English side they form a series of steps, on the Dutch side the falls are concentrated into two steps close together, followed up by a channel with raging torrents, of nearly a km. long. Even before we reach the mouth of this channel we see a fall on the right hand side (going upstream) in a narrow entrance between the islands. Here rocks of varying habitus occur. Among others we observe fine-grained hornblende-gneiss, with steeply dipping texture, probably a metamorphic sediment (Y. 289, see p. 380). Close by rounded-off rocks appear; biotite granite-gneiss without any parallel texture of importance (Y. 298 B).

Along the above-mentioned channel on the Dutch bank, rocks crop out in quite a number of places. They are gneisses with a varying percentage of coloured minerals. The stream follows the texture of the gneisses especially in the lowest part of the channel (Pl. 2 fig. 1). The rocks there have a parallel texture East-West and dip steeply N. A description of this granite-gneiss will be found on p. 282 (Y. 270). In the field this fine-grained gneiss appears to be linked up by transitions with types of coarser grain and smaller biotite-percentage, which remind us more of a granite with primary parallel texture. Both types vary considerably within a distance of a few dozens of metres. These ortho-gneisses are cut by flesh-coloured aplite-veins attaining to a few dm. in breadth running parallel to the gneiss-texture. The latter is also cut by an irregularly-shaped mass of the same aplite, at least 10 m. in diameter. These aplites are composed almost exclusively of red microcline and less quartz (Y. 292). The two components form no granophyric intergrowth, but both are irregular in shape and vary greatly in the size of the grain, so that a few veins here and there show microcline-crystals of some cm. in size and be called pegmatites. See p. 160. Microscopically some crushing appears to be present in these veins. At the end of the channel going upstream there is a large waterfall consisting of two steps (Pl. 2 fig. 2). It flows over an eye-gneiss, with potash feldspar-eyes up to 2 cm. having a rounded-off oblong form. Some parallel texture both in the direction of the eyes and of the groundmass, is sometimes to be seen.

The gneisses continue above this fall-complex, now with more or less distinct parallel texture, now practically massive, hence it is not certain in how far they will microscopically turn out to be normal igneous rocks.

Following the Dutsch bank we see at the Werekitto fall an eye-gneiss with countless plagioclase-eyes and coarse orthite crystals which may be recognized macroscopically (Y. 297, p. 336). There is some parallel texture in the rock, N. 55° W. and very steep dip. We are concerned with a cataclastic eye-gneiss. Above this fall as far as the mouth of the New river there is again a variation in the degree of parallel texture; the rocks are now rounded-off and have the appearance of normal igneous rocks; now gneissose texture is present; the composition is unknown. Just above the Maopityan fall (this unimportant fall is opposite the middle of the mouths of the New river on the Dutch bank) we come across a gneiss, which, on account of the irregular distribution and structure of the minerals (microcline, acid plagioclase, quartz and biotite) and on account of garnet, sillimanite and some cordierite pseudomorphs, seems to be a para-gneiss. (Y. 298, see p. 368). Opposite the second mouth (going downstream) of the New river, a cataclastic gneiss of quartz mica dioritic mineral-combination was collected, which is described on p. 335 (Y. 299). Following the Upper Courantyne or Curuni upstream we see but few rocks exposed, rocks of gneissose appearance cropping out but here and there. Near the Goodall's fall between and above the island situated there, distinct parallel texture and dip is to be observed in the rock. Numerous steep slabs of gneiss project from the water or crop out on the banks, and show for a great distance trend N. 100° E., dip about 60° N. It is a granite-gneiss (Y. 304, see p. 283).

In the next series of important rapids we observe gneissose rocks of granitic mineral-combination, with pegmatite-veins of rose-coloured potash feldspar and quartz, running parallel to the texture. Somewhat farther up where the river flows from N-E. to S-W., a normal- to fine-grained granite-gneiss was collected (V. 3501) with slight parallel texture in the sample. From the same place, at any rate very close by, a para-gneiss was collected, poor in feldspar (plagioclase) and rich in quartz, biotite and muscovite (V. 3500). Gneiss-exposures follow here and there again. Among others, in the bowl-shaped expansion of the river gneiss was collected (Y. 305, see p. 286). Another sample was collected below the long island lying in the middle of the river farther up (Y. 306). It is of quartz mica dioritic composition and shows distinct sequence of crystallization (between the plagioclase and quartz). Hence here we have a case of the gneisses making way for a normal igneous rock. It consists of quartz, acid plagioclase, intense chloritized biotite and a significant percentage of secondary muscovite, which winds itself through the other minerals in the form of sinuous strings, with zircon, and traces of apatite as accessories. It has been influenced by pressure. Near and above "Point right about" few rocks are visible. About 6 km. above the latter point a few hundred metres inland, on the right bank, an exposure of hornblende gneiss, being a metamorphic basic rock (Y. 307) occurs. A sediment-gneiss appears 10 km. above "Point right about" (V. 3499). The rock has the appearance of a mica schist, splitting easily on account of the biotite and muscovite, separated by thin layers and lenses of fine-grained, light-coloured material (see p. 379). The distribution is quite unknown. It is not improbable that this rock occurs in many other places in this part of the river, at any rate, the same rock-type, was also seen farther upstream. 16 km. (as the crow flies) upstream above "Point right about", coarse pegmatite appears, with muscovite-crystals sometimes having a diameter of 8 cm. Exposure in this part of the river is comparatively slight; here and there gneisses of granitic and acid dioritic mineral-combination are seen. Such is e.g. the sample V. 3498. Concerning the composition of the gneisses upstream we know something but here and there. Most of them, judging from their habitus, are more or less acid ortho-gneisses. The sample V. 3497 is a fine-grained quartz mica hornblende diorite-gneiss. It is rich in coloured minerals, and has an amphibolitic habitus. The parallel trend is hardly visible. Microscopically we observe green hornblende, greenish-brown biotite, plagioclase (oligoclase-andesine) and quartz which is in the minority with respect to the latter mineral. Octahedral ore, apatite and some zircon form the accessories. Pressure-action is of trifling importance. The sample V. 3503 proves that also para-gneisses occur here. It is a fine-grained rock rich in biotite, which we might once more take for a biotite schist, microscopically, however, it appears to contain a significant percentage of microcline by the side of quartz (see p. 379).

A very small gneiss-sample (V. 3495) is of unknown origin, and was collected in the rapids at about a distance of 15 km. (as the crow flies) below the Malawini creek. It is a normal-grained biotite-gneiss, possibly a para-gneiss (see also V. 3496, and p. 379).

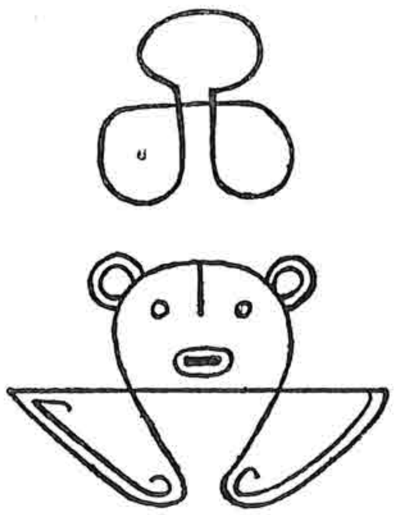


Fig. 46. Indian rock-drawing, 1/11.

Another rock, an amphibolite, forms steep slabs not far from here, trending N. 120—95° W., dipping 65° N., sometimes with strictly parallel cleavage-planes, due to the parallel trend of the minerals. On one of the slabs, the Indians have made a rock-drawing (see for this rock p. 437, Y. 310). In the same group of rapids, we come across coarse pegmatite-veins consisting of muscovite, potash feldspar and quartz; the muscovite may attain some cm. in diameter (Y. 311). Exposures here are abundant and it seems that we are chiefly concerned with ortho-gneisses, now with an acid, now again with a more basic (acid dioritic) mineral-combination.

Near the Malawini creek exposure is trifling. Not until we come to the next large fall, just above a large island, there is a vast outcrop of rock. The rocks are smoothly rounded-off, but on knocking off a piece, very distinct parallel texture appears, running N. 50° W. and dipping vertically. This is shown still more clearly at the foot of the fall, where the dip is 55° N. The variation in the percentage of coloured minerals in this quartz mica diorite-gneiss is great. We observe gneiss rich in biotite particularly at the foot of the fall (Y. 309, page 285). Injection with aplitic material is particularly striking. In the coarsest form veins of more than a dm. in thickness, intersect the gneiss, parallel to the texture, sometimes crossing it. They consist of red microcline which may show crystals of several cm. in size, and less quartz. Smaller veins diminish so much in thickness as to be visible as fine layers parallel to the schistosity of the gneiss: in the broad ones the size of the grain amounts to a few millimetres, but in the thinnest veins it is not coarser than that of the gneiss itself (1 mm. approximately) and it is there only the red colour of the microcline that makes it possible for us to discern the injection. The appearance of relatively coarse muscovite accompanies this injection (see Y. 308).

The very sparse material collected opposite the mouth of the Kamani (V. 3494) and 12 km. farther upstream (as the crow flies) (V. 3493) proves that gneisses may occur farther upstream. They are sillimanite-bearing biotite and muscovite gneisses. About 10 km. (as the crow flies) above the same river a hornblende gneiss (Y. 312) was collected, from a heap of boulders on the left bank. Exposure is better near the Sir Walter Raleigh falls and the neighbouring islands. The fall itself plunges over a mighty pegmatite-dyke (see p. 160, Y. 313 etc.). Above the main step of the fall follows a smaller one consisting of gneissose quartz mica hornblende diorite (Y. 314). The normal-grained rock shows some indication of parallel texture of the coloured minerals in the sample. These may attain to a size of some mm., and form a striking contrast with the gray feldspar and the quartz, which are present in smaller quantities. Microscopically its shows biotite, green hornblende, distinctly laminated plagioclase (oligoclase-andesine), less quartz, with irregularly shaped, brownish titanite, ore, apatite and zircon, and a strikingly large percentage of primary epidote. The latter shows idiomorphism and corrosion. Structurally this rock is a transitional form between a normal igneous rock with crystallization-sequence of the colourless minerals and an ortho-gneiss. Corresponding to this are two samples (Y. 315, 316) which were collected a few km. upstream. They are normal- to fine-grained, rich in coloured minerals (biotite and hornblende), and practically devoid of parallel texture. Structurally Y. 315 is a gneissose-diorite. The other sample, however, has perfect ortho-gneiss structure (see p. 285). The last three rocks mentioned were collected within a distance of 3½ km.: they bear evidence of the connection between the ortho-gneisses and gneissose types. At the place where the rock Y. 316 was collected we observe pegmatite-dykes breaking through the gneiss. They are approximately a dm. broad and cross the rock vertically. They consist of pale potash feldspar, quartz and among others of a few tourmaline-crystals. Pegmatite-dykes also frequently make their appearance upstream. From the numerous rapids below the junction of the Cutari and Sipaliwini no material is available; at the junction itself, however, a rock-complex, which shuts off the mouths of the two rivers at the same time, is above water in the dry season. It is a normal-grained rock with indistinct parallel texture standing vertically. Hornblende and biotite are present in abundance, by the side of brown-coloured feldspar and little quartz. It appears to be a quartz mica hornblende diorite (Y. 317), of a comparatively basic type on account of its large percentage of coloured minerals and scanty quartz. Hence it does not differ much mineralogically from the last two diorites discussed. Microscopically more hornblende than biotite appears to be present. Plagioclase (oligoclase-andesine) varies in shape; the larger crystals are partly idiomorphic. Twinning is poorly developed. The accessories are apatite and ore, the latter often being enclosed in hornblende. Pressure-action is restricted to undulose extinction.

Now we come to the basin of the Sipaliwini, which we have already discussed.

In the left source-river, the Cutari, we observe many exposures for the first 6 or 7 km. The rounded-off rocks have granitic or acid dioritic composition. A granite-gneiss was collected from the fall some km. upstream (Y. 318, see p. 282).

Near, and especially above the mouth of the Aramatau, exposure is very bad, and in the extreme upper-course we rarely catch a glimpse of any solid rock: rounded-off rocks of a granitic or acid dioritic mineral-combination. After going upstream for three days another sample was collected (Y. 319). It is a gneissose quartz bearing hornblende diorite. Grey feldspar attaining to a size of some mm. and in parts chloritized hornblende, make a richly variegated sample. Insignificant undulating texture is developed in the sample. Microscopically we observe strings of hornblende and chlorite (probably arising from biotite), with intervening fields rich in plagioclase among which quartz also appears. Not only do the hornblende and the chlorite generally show parallel direction, but also the coarser plagioclase. The plagioclase (oligoclase-andesine) shows some idiomorphic faces towards the quartz, but the greater part is irregular in shape. Considerable signs of pressure are present, the plagioclase often being bent and the quartz being cataclastic. Hence it seems that the region of gneisses and gneissose rocks continues along the Cutari for a very considerable distance. In the extreme upper-course, however, a few typical granites were collected, which have been discussed on page 299.

As a sub-section of the "Upper Courantyne region in the widest sense" we may discuss a few data from the Lower New river. The region of gneisses and gneissose rocks which is found at the Upper Courantyne continues there. Exposure between the numerous islands is very good. In quite a number of places more or less distinct parallel texture of varying directions, and dipping steeply is to be seen in the rocks. In the field it is easy to get lost among in the large number of falls marked with names on the English map, for they are nearly all rapids following each other in quick succession. In one of these, the

Andira fall, the cataclastic, quartz-bearing hornblende gneiss, described on p. 335, was probably collected (Y. 301).

Not far above the Ashira fall, an ortho-gneiss was collected of quartz mica hornblende dioritic mineral-combination (Y. 302, see p. 285). In several places we observe rocks with potash feldspar-crystals of more than a cm. in size, probably eye-gneisses of granitic mineral-combination. Such gneisses are seen at a place corresponding probably to the "Ita rapids" and farther upstream. In the large Zaruma falle we see coarse potash-feldspar-eyes, rounded-off, and lying parallel in a normal-grained groundmass. They are probably eye-gneisses. The venites cropping out on an island just above the Werinye fall are very remarkable. These rocks (Y. 303), the genesis of which is obscure, are found fully discussed on p. 317.

In a rapid a short distance above the Waiwois fall, we see a considerably folded biotite gneiss, which is interpreted as a para-gneiss (Y. 303B, see p. 317).

Let us now turn to the Lower Lucie river which also belongs to this region. Ortho-gneisses, granites and acid diorites, appear to be widely distributed and local vein-gneisses occur. Going upstream we observe rounded-off rocks of granitic composition in the narrow mouth near the left bank, at low water. Exposure upstream is trifling. About 8 km. (as the crow flies) upstream we followed a balata-line on the right bank, for some km., which line runs approximately in a NE. direction. On this trail we passed some hills among which, in places, there is some rock to be seen, mostly in the form of boulders. It is normal-grained biotite granite. We followed this trail as far as a bare rocky plate of some dozens of metres in diameter, lying on the N. side of a hill-top. From here we have a good view of the surrounding country, among others of the West-group of the Wilhelmina mountains. The rock-face consists of normal-grained biotite granite, with poorly-developed porphyritic structure on account of somewhat coarse potash feldspars. Above this trail some rocks are to be seen here and there in the river, e.g. the fine-grained granite-gneiss V. 3486. The pale red rock shows but sparse biotite with parallel trend in a very fine-grained groundmass. Microscopically the latter appears to consist of quartz, acid plagioclase and vaguely foliated microcline. These components do not show any sequence of crystallization. They have a tendency to parallel orientation, however. Some ore and zircon are the accessories. It is one of the most acid ortho-gneisses that we know from Surinam. At the head of the only large island here, an ortho-gneiss of granitic composition was collected (Y. 285 B, p. 283). The parallel texture is clear, the dip vertical. Band of a few cm. in breadth of light-coloured material, quartz and feldspar, run parallel to the general texture; this rock shows one of the few instances of banded texture. About 20 km. upstream from the mouth we come to a complex of rapids, falls and islands, which continues over a distance of 15 km. Here we find normal-grained, gneissose granites with biotite, and sometimes also some muscovite. Ill-defined parallel texture is sometimes visible in the rocks. Microscopically the plagioclase (approximately oligoclase) appears to be idiomorphic to a very small extent towards quartz and microcline, which mutually fail to show any sequence of crystallization (Y. 285; V. 3485, 3483). Y. 285 contains primary epidote. V. 3483 is a normal-grained, gneissose biotite hornblende granite with slight indication of parallel texture. Some primary epidote encloses a coarse orthite-remnant. Myrmekite accompanies the plagioclase. Traces of pressure are practically negligible. V. 3482 and 3481 have a corresponding composition; they were collected somewhat higher up in the same complex. Primary epidote is present in rather larger quantities; it shows corroded forms and may enclose orthite. In this part of the river we repeatedly observe pegmatite-dykes of some dm. in thickness breaking through the rock more or less vertically. Being harder than the surrounding rock, they appear as slabby masses. They consist of quartz and microcline sometimes intergrown to granophyre and may also bear muscovite (V. 3480, 3484).

Going upstream, the same rocks now with some parallel texture, now again massive, being either granites or acid diorites, continue over a distance of 20 km. in so far as the varying exposures allow us to judge. Material is only available from two places: a normal-grained, pale rose bi-mica granite (Y. 283), and a quartz mica diorite (Y. 282). The latter only calls for remark. By the side of brown biotite we see a significant percentage of muscovite, in places even surpassing the biotite, an unusual phenomenon for a quartz mica diorite, the more so as the muscovite is of primary nature. It is often enclosed in biotite and in parts intergrown with it in such a manner that secondary formation seems to be out of the question. Locally, however, the normal-grained diorite shows relatively coarse rounded-off quartzes up to 8 mm. in the sample and it is not impossible that the latter together with the material which has supplied the muscovite takes its origin from enclosed and resorbed material which may account for the abnormal percentage of muscovite. The rock shows poorly-developed sequence of crystallization of the colourless main components yet sufficiently so to be called a normal igneous rock. In the neighbourhood where the Lower Lucie river approaches the Curuni nearest, exposure is but moderate, at any rate, it was so when we visited it at high water. The sample Y. 281 from here is a normal-grained bi-mica granite. The biotite and primary muscovite are not quite equally distributed, and where these minerals are accumulated, some sillimanite also appears in the form of short needles: probably enclosed material was present in trifling quantities here too. Pressure-action in all these rocks is negligible.

A few km. upstream we observe on the right bank (the place marked by the letter "A" on the map) the remarkable venites (Y. 280), described in detail on page 316. The venites, however, appear to be a local complication, for both upstream and downstream there are rounded-off rocks of granitic or acid dioritic mineral-combination. Not far from here a quartz mica diorite-gneiss was collected, which besides biotite, also shows primary muscovite. The question is again whether the latter originated from resorption of enclosed material. Still a little farther there is a quartz mica diorite, rich in quartz (Y. 279), bearing chloritized biotite, secondary epidote and acid plagioclases. The quartz has been crushed. Besides this a breccia of granitic mineral-combination has been formed there by intense pressure (Y. 279 B, see p. 338).

Above the latter exposure, gneisses and gneissose rocks seem to predominate over normal igneous rocks, and in quite a number of places more or less distinct parallel texture is to be observed, dipping steeply. Locally there is also a beautiful venite to be seen again (the spot is marked "B" on map VI, see p. 318, Y. 277). Next to it a biotite hornblende gneiss is the only material present (Y. 276). The fine-grained rock shows some parallel texture. The mineral-combination approaches that of syenites, and is regarded as a variety of the granite-gneisses. The abundant microcline shows grating-structure and bears no microperthite of any importance; the crystals impede each other polyhedrically. Quartz is present in trifling quantities. Biotite and hornblende are the coloured minerals; the accessories are primary epidote which encloses most insignificant orthite-grains, a fair quantity of small, partly idiomorphic pieces of titanite, some ore and traces of apatite.

Although still a considerable distance must be covered upstream before one comes to the region of the Upper Lucie river, described already, we have no more material at our disposal, except a gneiss Y. 275, which is supposed to be of sedimentary origin. In the winding part of the river, and even more so in the stretch running pretty well due East-West, at high water, we observed rocks but here and there, some of them without any doubt being gneisses.

Summary of the "Remaining" granitodiorites.

The annexed sketch schematically gives the distribution of the "Remaining" granitodiorites and ortho-gneisses, as far as they have been discussed in this chapter. For comparison the area taken by the Gran-rio massif has also been given (fig. 47).

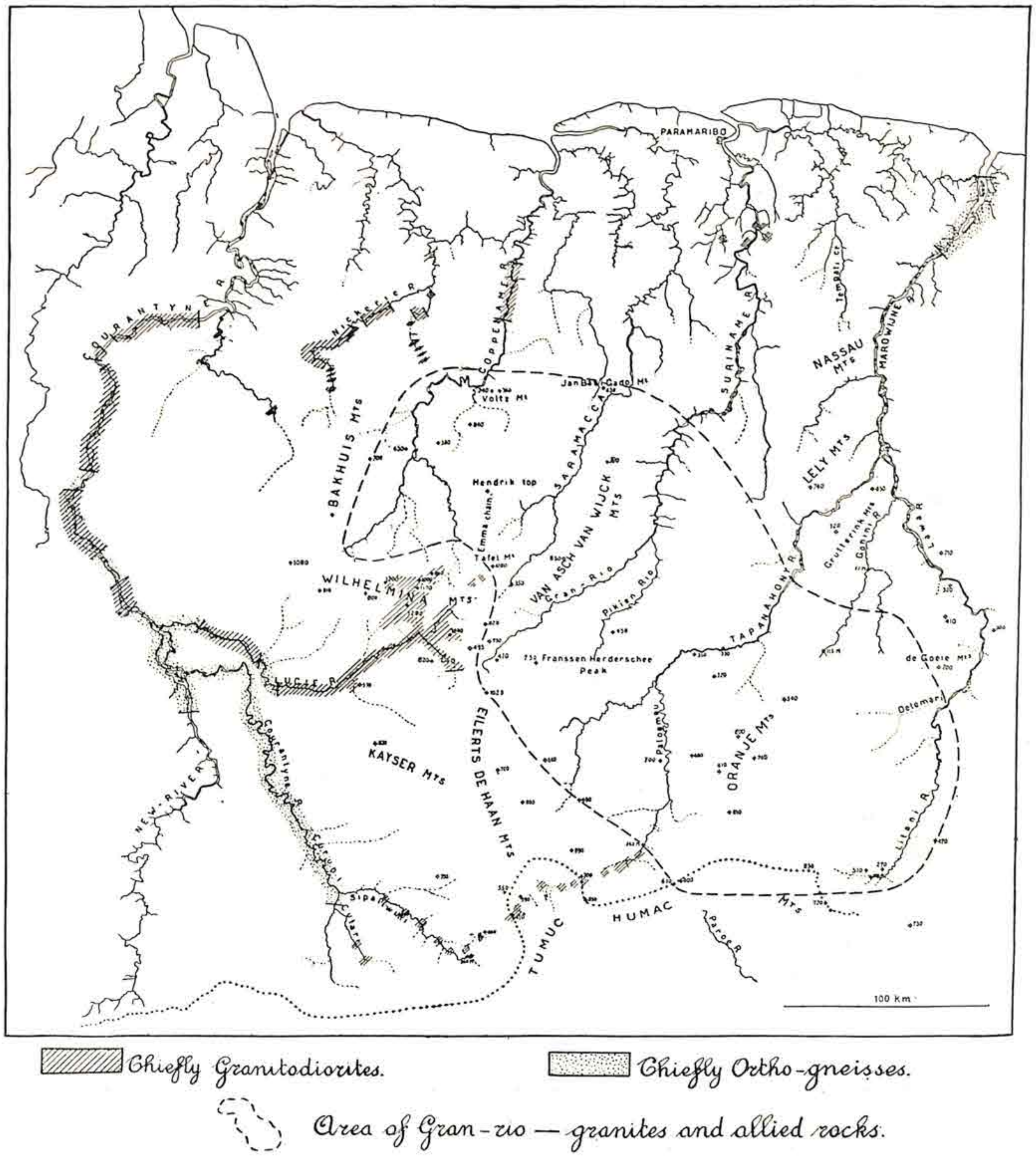
The Lower Marowyne river. Rocks of granitodioritic mineral-combination occur on the Marowyne only on the lower-course of the river, below Guidala island, and, as far as exposures allow us to decide, are found down the river all the way to the mouth of the Wane creek. They are almost all microcline-bearing biotite granite-gneisses; locally they contain muscovite to such an extent that they are bi-mica gneisses. They are massive or show indistinct parallel texture. A quartz mica hornblende diorite-gneiss from St. Maurice du Maroni is a local type as appears from the biotite and hornblende, which show deviating properties, unknown elsewhere in the Colony. Signs of pressure are trifling; a mylonized granite-gneiss is known (see p. 338).

Between the Lower Marowyne and Lower Suriname rivers. Some granites from here are reported in petrographic literature; samples are not available.

The Lower Suriname river. Local exposures of granitodiorites occur from Carolina to above Phedra, and also in the Carolina creek (Upper Para). They are normal biotite granites, quartz mica diorites, corresponding ortho-gneisses, and also gneissose rocks. Also bi-mica granite is known here. As accessories titanite, primary epidote and garnet rarely occur. All have no or indistinct parallel texture. Potash feldspar shows microcline-structure. Some types closely resemble the granite-gneisses of the Lower Marowyne, others differ not essentially from the rocks of the Gran-rio massif; a quartz hornblende gneiss is a type rare elsewhere. Signs of pressure are trifling.

The Lower Saramacca river. Some granites are mentioned in petrographic literature: from the placers on the Mindrineti creek and along the Colonial railway, but from here, and also from the river itself, we have only very scanty material.

Fig. 47.



The Lower Coppename river. The variability of the rocks here, especially structurally, is important. The ample material shows that granitodiorites occur from Copencrissi to Pireen- and Pomo creek upstream, where they make room for a crystalline graywacke-formation. Important is the relation between the normal rocks and the corresponding ortho-gneisses which are facial varieties of the same rocks. This is shown by a series of rocks of quartz mica dioritic mineral-combination, and also by typical eye-gneisses of granitic composition and porphyritic biotite granite, the latter differing not essentially from the Gran-rio granites. Moreover we know normal biotite granites, biotite hornblende granite and corresponding ortho-gneisses. Disturbances by pressure are variably present; locally mylonized rocks occur, accompanied by pseudo-tachylytes (which will be discussed in detail further on).

The Nickerie river. Next to a series of granitodiorites and gabbros which have been discussed separately, we know ample granites, acid diorites and corresponding ortho-gneisses from the Nickerie-region. Biotite granites prevail. It is remarkable that the potash feldspar in the granitic rocks is generally represented by orthoclase in contradistinction to the general rule in the Surinam granitodiorites. Some bi-mica granites occur. Porphyritic forms are rare. The crystallization-sequence in the granites and acid diorites is generally little developed; granophyre was noticed once. Myrmekite and antiperthite occur; the latter frequently. Among the granites only one is garnet-bearing. In a single rock also primary epidote occurs. Some aplite-gneisses are present. Generally the ortho-gneisses show more or less distinct parallel texture. It should be remarked that the rocks from this region generally have a smaller percentage of coloured minerals than the corresponding rocks from other regions. Disturbances of pressure are mostly present, often remarkably strong, causing also the formation of some cataclastic ortho-gneisses, and in one case a mylonite.

The Middle Courantyne with the Kabalebo. This region comprises the Courantyne up to the mouth of the Lucie river and the Kabalebo. Concerning the Courantyne we can say that starting from below the first large fall beyond the mouth of the Lucie river downstream, a mighty granite-region has developed. As far as samples allow us to judge, these granites are to be regarded as equivalents of the Gran-rio granites. They are commonly biotite granites, sometimes also biotite hornblende granites, partly with microcline phenocrysts, which may prevail over many miles. Primary epidote, and also titanite were found in several samples. The sequence of crystallization of the colourless main components is now indistinct, now moderately distinct, leaving the phenocrysts out of consideration. But also other rock-types are present. A single one shows bi-pyramidal quartz. Moreover we know an occurrence of aplitic granite. In the tract below the mouth of the Lucie river granite-gneisses occur; they have distinct parallel texture in several areas. In how far dioritic varieties occur, such as are seen in the Gran-rio massif, may only be ascertained by further research.

In the river-tract above the mouth of the Kabalebo, the granites appear to be more developed than the sandstones indicated on the English maps.

The few data from the Kabalebo point to a large distribution of granites, there too. Orthite and primary epidote were noticed in one of the rocks.

Signs of pressure are very differently developed in this large area. Cataclastic eye-gneisses are present in the area below the Lucie river; elsewhere some disturbances of pressure are fairly common; a mylonised granite is known from the Kabalebo.

The Upper Lucie river. The rocks exposed along this river and in the adjoining part of the water-shed with the extreme upper-course of the Gran-rio, are very inconstant in habitus, though the differentiation does not as a rule reach far. Biotite- and biotite hornblende granites, aplitic granites, quartz mica diorites and also ortho-gneisses of this mineral-combination, prevail. Changes in the size of the grains, varying distribution of the dark components through the sample, and differences in structure and texture are the cause that hardly two rocks are quite the same. Here and there porphyritic granites were found (containing microcline-phenocrysts) closely resembling the typical rocks from the Gran-rio region. In one area these rocks were seen over several km. distance exposed in the river-bed. In some rocks titanite and primary epidote occur.

Of the special types there should be mentioned a relatively basic diorite, rich in hornblende and biotite, quartz-bearing and showing massive texture together with excellent idiomorphism of the plagioclase. Though the rocks of the "remaining" granitodiorites not very seldom yield types of this mineral-combination, the texture and structure mentioned are seldom found combined with the latter.

A single granite shows bi-pyramidal quartz.

Though exposure was relatively bad during our investigation it may be assumed that granitodiorites make up by far the greater part of the bed of the Upper Lucie river.

The Wilhelmina mountains. The Wilhelmina mountains in as far as they were visited by our expedition appear to consist almost exclusively of granites. This holds good not only for the main mountains and ridges but also for the hilly country and the subsoil of the valleys between. The granites here are predominantly of two types. First acid biotite granite, poor in dark minerals (biotite) and accessories, and rich in quartz and feldspar (mostly potash feldspar, containing microperthite to such an extent that the microcline-structure is mostly unrecognizable, and very acid plagioclase). Secondly real aplitic granite (chiefly quartz and potash feldspar) which is connected with the first type by transitions. The crystallization-sequence of the colourless main components is variable, but rather often notably well-developed (acid granites); often also granophyre is present (aplitic types). Some acid granites with bi-pyramidal quartz occur. *Both the main types form mountains.*

Acid intrusions are limited to very small aplitic veins. Besides the main types biotite hornblende granites, porphyritic biotite granites (with phenocrysts of potash feldspar) and normal biotite granites were found; these rocks may form mountains too. They do not differ in habitus from the rocks of the Gran-rio massif. Orthite was noticed once. More basic related rocks do not occur. Ortho-gneisses are not present.

Signs of pressure are generally unimportant or entirely lacking. Locally a mylonized granite was found.

The water-shed of the Amazon. Along the water-shed between the Paloemeu (source-river of the Tapanahony) and the Sipaliwini (source-river of the

Courantyne), among the few samples available, rather frequent porphyritic biotite granites occur, which do not differ essentially from the typical Gran-rio granites. It is probable that the Gran-rio massif extends as far as here. The rest are mostly biotite granites showing nothing remarkable. A single mylonized acid diorite is present.

The source-rivers of the Courantyne (Cutari and Sipaliwini). The sparse data available from the Sipaliwini show that granites are largely distributed there. Partly they are of the same type as the (non-porphyritic) Gran-rio granites. Primary epidote occurs. Possibly we are here in the continuation of the Gran-rio massif.

At the source of the Cutari a rock of the same type occurs. The very sparse rocks exposed there are biotite- and biotite hornblende granites.

The Upper Courantyne in the widest sense. This area comprises the exposures in the Courantyne up from abt. 15 km. beneath the Lucie river, those in the Upper Courantyne (Curuni), those in the Lucie river to 90 km. upstream, and those in the New river to 20 km. upstream. The region is no distinct geological unit; many rock-types exposed in the basal complex here, are met with elsewhere also.

The local changes in normal igneous rocks and ortho-gneisses are extremely intense here. Ortho-gneisses and gneissic granitodiorites distinctly predominate. The last fact holds good for the Courantyne and the New river; in the Lower Lucie river, however, igneous rocks with normal structure seem to prevail. There are extraordinary changes, in their mineralogical composition, structure and texture within narrow confines in the field, of which many instances have been given above. *All these rocks are different facies of the same igneous mass,* and hence approximately of the same age: at least this is shown by the connection between different types in many places, but in other regions exposure was insufficient to ascertain this. The occurrence of pegmatites, cutting ortho-gneisses in many places, furnishes no evidence to the contrary; nowhere are they found connected with large igneous masses.

Besides we know here to a smaller extent metamorphic rocks, para-gneisses, hornblende gneisses derived from basic igneous rocks, and venites of which the geological behaviour will be discussed later on.

Among the ortho-gneisses and gneissose equivalents we find predominantly granite-gneisses (mostly biotite gneisses), quartz mica diorite-gneisses and quartz mica hornblende diorite-gneisses. Aplite-gneisses are rare. So they are generally acid to moderately basic rocks.

Several gneisses owe their gneiss-characteristic to intense pressure, among others the greater part of the eye-gneisses of granitic or acid dioritic mineral-combination. Some mylonized rocks also occur.

The corresponding rocks with normal structure have the same mineralogical composition: biotite- and biotite hornblende granites, quartz mica and quartz mica hornblende diorites and moreover bi-mica granites, the latter especially in the Lower Lucie river. A single rock has the composition of quartz syenite.

Here and there rocks occur with the same habitus as they have in the Gran-rio massif. This is the case with some diorite-gneisses, which contain primary epidote and orthite, especially occurring in the Lower Lucie river. In some rocks sillimanite, abnormal precentages of muscovite etc. suggest that enclosed material has been resorbed.

As has been mentioned already the texture varies greatly within short distances. In cases of clear parallel texture the trend may be constant over a considerable distance and may influence the course of the river. A list having reference to strike and dip shows that the trend varies considerably, though locally in the area under discussion it is fairly constant over great a distance. The dip is generally very steep: 45—90°.

VII. THE "REMAINING" GABBROS.

A. *Hornblende gabbros North-West of the De Goeje mountains.*

To the North-West of the De Goeje mountains gabbros occur locally, as well as some more acid rocks which petrographically are closely related to the rocks from these mountains. By analogy we might look upon them as basic differentiation of the Gran-rio massif, but the material is too scarce for us to decide on this point. These gabbros form part of a group of hills between the Emma river and the Assisi creek, which hills are briefly mentioned in the Report of the Government Mining Exploration [1]).

Without exception the rocks have undergone more or less important changes, which are analogous to those of the basic rocks of the De Goeje mountains. Most of them are normal or fine grained and have massive texture. They contain basic plagioclase and hornblende as principal components. The hornblende is very variable. Brownish and greenish hornblende, in patches, entirely makes the impression of being primary, on account of its structural relation to plagioclase. Besides, the hornblende may have coalesced with irregular pyroxene masses (V. 230, 308), or we see some pyroxene surrounded by rims of hornblende. By their side, however, there also appears greenish, or colourless hornblende, whose fibrous edges, if bordering on plagioclases, grow into them; this hornblende is certainly secondary, without being typical uralite therefore (Pl. 40 fig. 3). In other rocks again we observe monoclinic pyroxene, which changes into genuine uralite; the pyroxene may be almost entirely replaced by it (V. 296, 303, 305). The plagioclase in these gabbros is now intact, now again partly or entirely replaced by zoisite-like grains, epidote etc. (see V. 303, 305).

The original structure may as a rule be recognized, and is gabbroid; more often, however, the plagioclases cut pyroxene-remnants and hornblende, so that some tendency towards ophitic structure manifests itself; especially large (and primary?) hornblende-crystals often show this structure (V. 232 B, 233, 308).

These metamorphic gabbros with partly primary and partly secondary hornblende, may be called hornblende gabbro. Some of them, on account of their uralite-percentage show alterations analogous to the epidiorites of the later intrusive diabases and gabbros, which we have already discussed. Related to these hornblende gabbros are moreover some hornblende diorites with some quartz, whose mineral combination is of primary nature (V. 297, 232, 304); they may betray some signs of pressure. To this group of rocks belong the numbers: V. 227, 230, 232 B, 233, 291, 296, 303, 304, 305, 308, 509.

B. *The norites and troktolites of the Hebiweri mountain.*

More interesting are two norites and two troktolites, collected by the Coppename expedition.

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[1]) E. Middelberg 64, p. 15.

Plate 15.

Fig. 1. Ortho-gneisses in river-channel below King Frederick William IV falls, Dutch bank, Courantyne. Parallel texture in the gneisses causes vertical cleavage in the rocks.

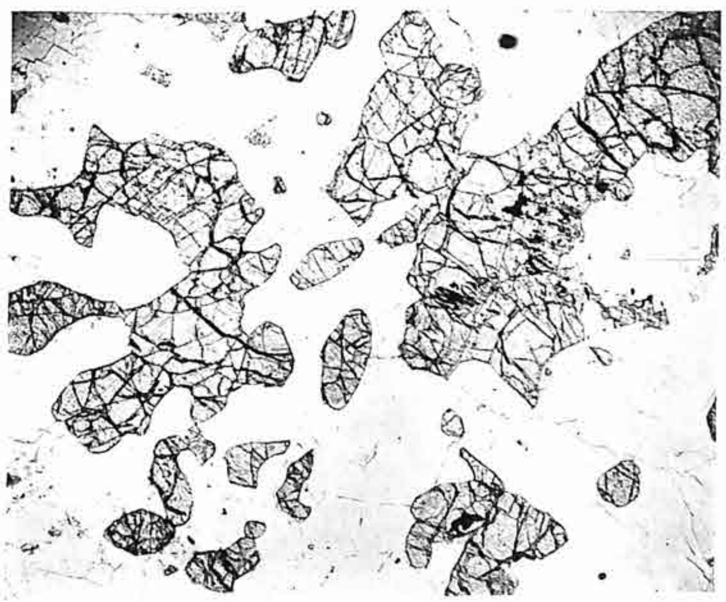

Fig. 2. Irregular shaped olivine crystals among clear plagioclases: in troktolite of Hebiweri mountain, Coppename river. × 20. (C. 94).

Fig. 3. Dendrite-like intergrowth of ore and hornblende (adjoining to olivine): in troktolite of Hebiweri mountain × 40. (C. 39)

On the left bank of the Coppename river, near the Tonckens falls, there is situated the Hebiweri mountain 450 m. in height, from which several ridges descend radially. This mountain-group, as appears from the samples collected, is formed by basic igneous rocks; their greater resistance has caused the relief. It is doubtful whether the rocks in the series of falls which are found at the foot of the Hebiweri mountain also partly consist of basic rocks; we have only a biotite-granite from there (C. 92).

The two norites, the one collected near the summit of the mountain (C. 95), the other at the North-East foot (C. 41) are mutually quite alike. They are massive, coarse-grained gabbros, showing dark brownish pyroxene and greenish feldspar. Microscopically the composition appears to be simple, we see hypersthene, plagioclase, traces of monoclinic pyroxene and some ore. The pieces of hypersthene are as a rule clearly developed according to the prism-zone; (110) cleavage and cross-fractures are conspicuous. Their pleochroism is always distinct, varying from pale wine-red (n α) to brownish (n β) and green (n γ). Systematically arranged leaves of titanomagnetite (?) are included. Some of the hypersthenes show feeble double refraction and display vague twinning-structure (C. 41). A very insignificant percentage of feebly refractive, monoclinic pyroxene may surround the hypersthene as a rim, and also occurs independently, conforming to plagioclase. The latter is distinctly twinned, and without exception turbid on account of innumerable little rod- or needle-shaped inclusions, which are arranged according to several systems. The plagioclase contains abt 55 % of anorthite. A few insignificant grains of ore occur, sometimes also patchy ilmenite. The structure is clearly gabbroid, with a tendency towards idiomorphism of the hypersthene.

The two troktolites are also mutually alike. They are normal- to fine-grained almost black rocks. The one was collected on the North-East side of the mountain-mass (C. 94), the other near the river (C. 39). Microscopically they appear to consist of much olivine, of plagioclase, and of an inconsiderable percentage of monoclinic pyroxene, a few traces of greenish hornblende, and some ore (Pl. 15 fig. 2). Monoclinic pyroxene is practically entirely wanting in one of the rocks (C. 94); so in that case we have to do with a combination of basic plagioclase and olivine, for which the name troktolite has been chosen. The bright olivine forms pieces and grains, always showing rough cracks. Olivine and plagioclase impede each other; there is no question of any sequence of crystallization. The oblong to isodiametric plagioclase contains abt. 55 % of anorthite. Monoclinic pyroxene, when present, crystallized later than olivine, and may in its turn be surrounded by a small rim of greenish-brown hornblende or be partly intergrown with it. Besides some pieces of pyrite and grains of ore we see a remarkable intergrowth of ore with hornblende; club- and worm-shaped bodies of ore penetrate the hornblende, without any system (Pl. 15 fig. 3). The norites as well as the troktolites show no trace of pressure.

TABLE 29.

SiO_2	46.85
Al_2O_3	23.90
Fe_2O_3	1.64
FeO	4.25
MnO	traces
MgO	8.96
CaO	11.74
Na_2O	1.96
K_2O	0.23
H_2O+ / H_2O-	0.44
TiO_2	0.36
P_2O_5	0.03
	100.36

Niggli-values

si	100
al	30
fm	39
c	27
alk	4
k	0.07
mg	0.74
Section	5

Anal. Koning & Bienfait, Amsterdam.

Table 29 gives the chemical composition of one of the troktolites (C. 39). The Niggli-values have been added. Chemically the rock is a typical representative of Niggli's ossipitic magma, characterized by the high value for al, which approximately agrees with the one for c, and by the high value for mg. It is distinghuised from the normal gabbroid magma-types by low fm-value and by high al, c and mg-values.

The norites and troktolites must be differentiations of the same gabbro massif. They show great similarity with the basic gabbros of the De Goeje mountains. The troktolites of the Hebiweri mountain are partly richer in olivine; the norites exclusively contain hypersthene with clearly recognizable pleochroism.

We can only guess in what relation this gabbro massif stands to the granitodiorites of the neighbourhood. Its resemblance with the rocks of the De Goeje mountains renders it likely, however, that here too, more acid differentiations will be found in future, which probably form transitions to the granitodiorites. Presumably they have no connection whatever with the later intrusive diabases and gabbros, though, like these, they show no sign of pressure.

We may casually mention the occurrence of gabbros at the extreme upper-course of the Lucie river. On the left bank, a few hundred yards upwards of the place where the trail of our Expedition touches the river, there is to be seen in the wood a smoothly rounded rock of some metres in diameter. It is a gabbro, just protruding from the laterite-covering, apparently cut by the Lucie river at one time. The fine-grained, massive rock (Y. 173) is composed of basic plagioclase, monoclinic, nearly colourless pyroxene, and very feebly pleochroitic hypersthene. Besides, green hornblende occurs in patches, together with a trace of biotite. Pieces of ilmenite are profusely present. Of the pyroxenes, hypersthene is the only one to show a tendency to idiomorphism, on account of its oblong form. The hornblende includes short, idiomorphic crystals of plagioclase. For the rest the structure is without any sequence of crystallization and typically gabbroid. In spite of the fact that not far from there acid diorites have been discovered, the geological relation to the latter is not clear.

VIII. SOME SYENITES.

Syenites seem to be very rare in Surinam.

A very fine-grained rock collected by the Coppename Expedition and classed in an earlier publication with the syenites must, in my opinion, be referred to granite (C. 7).

Beekman describes a quartz-bearing biotite hornblende syenite, collected in the Nickerie basin [1]). I have not found the rock in the collections.

The only material requiring description is a syenite from the Locus creek (a tributary-creek of the Suriname river) north of the "Stollnberg" [2]). The sample has got lost. Nothing is known of its geology.

The thin section (D.D. 1710. Delft) shows much microcline, green diopside and some quartz. As accessoria occur some titanite, apatite, and ore. Microcline is the main component. The crystals impede each other. Where some quartz is present the microcline may show some idiomorphic faces. The microcline is rich in microperthite. The latter may replace a considerable portion of the microcline. Sometimes polysynthetic twinning may be recognized in the perthite. The green diopside may show distinct prism zones. Other crystals have irregular shapes. The rock shows granitic texture. Small titanite-crystals tend to idiomorphism. Apatite and ore are of very little significance. The quartz shows some signs of pressure.

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1) E. H. M. Beekman. **63.** p. 108—110.
2) G. C. Du Bois. **40.** p. 20. Nr. 155.

IX. THE VENITES.

Venites were found by our expedition in several localities. in the basin of the Lucie river and in the Upper Courantyne. These rocks appear in areas where ortho-gneisses and granitodiorites of similar mineral-combination predominate. As I had an opportunity of studying some of the exposures in the field closely and of collecting material for microscopical examination these interesting rocks are going to be discussed in detail here.

The venites are characterized by very irregular texture. The photo of Pl. 16 fig. 1 refers to a rounded-off rock-face in the Lucie river, not far from the place where this river draws quite close to the Upper Courantyne (This point is marked on map VI by the letter A). Light-tinged aplite-veins are conspicuous by their intensely folded course. S-shaped windings are to be seen. Locally the veins gradually get narrower so that we can only follow them with difficulty. The same texture may be followed on other planes: it resembles fluidal texture. That the veins predominate locally is illustrated on Pl. 16 fig. 2, taken of the same rock-face. The parts rich in veins are there environed by a dark rock, viz. a quartz mica diorite-gneiss, rich in biotite. In some places this gneiss has massive texture, in other places we see parallel texture because the biotite-leaves all have the same direction and all follow the course of the veins. There is no sharp difference between the gneiss and the filling between the coarser aplite-veins. Between the latter we see in the sample now locally massive texture, now again detail-folded texture (Y. 280). Cords of a few mm. in breadth contrast by their white colour with the dark parts, rich in biotite. The relatively coarse cords can easily be traced, and again show the irregular texture of the chief veins. When looking sharply we detect that also here the biotite follows the texture of the veins; only where the latter are scarce, massive texture occurs. The boundary between the smallest veins and the interstitial material is not sharp: the veins divide and dissolve in the dark masses. The latter are locally somewhat richer in light-coloured minerals. The coarse veins are for the greater part filled up with quartz: the more quartz, the broader the veins are. Locally they widen to lenticular or irregular masses entirely filled up with quartz. These nests attain to a diameter of 6 cm.

Microscopical examination teaches us the following:
The dark ortho-gneiss in which the complications occur, is composed of quartz, oligoclase-andesine and biotite with primary epidote enclosing grains of orthite (see p. 188 to 189), irregularly-shaped titanite, and apatite, as accessoria; pleochroitic haloes occur round zircon; ore is not present. The rock exhibits all structural features of our quartz mica diorite-gneisses. The only thing worth mentioning is the relatively frequent occurrence of rounded-off quartz-drops in the plagioclases, not, however, to such a degree as to suggest para-gneiss. The dark groups which are present between the thinnest aplitic veinlets microscopically appear to agree with the description just given: except for the occurrence of some muscovite, with clearly developed base and intergrown with biotite in such a way as to presume it to be of primary nature.

In large thin-sections we see at the same time the material of the dark parts and of the smallest aplitic veins. The latter consist of some biotite and non-idiomorphic microcline, plagioclase and quartz. Generally microcline is of more frequent occurrence as we approach the centre of the veins. This holds good only in part, for in a vein, 10 mm. in thickness, the aplitic material which borders directly on the dark parts, consists in part of quartz and plagioclase, in part, however, also of more microcline than those two minerals together. Again, in other places, between the aplitic material (consisting of quartz and microcline)

Plate 16.

Fig. 1. Rock-face of venite with intensely twisted aplite veins. Lucie river.

Fig. 2. Venite with fold-like texture and numerous aplite veins, surrounded by dark biotite gneiss. Lucie river.

and the dark parts there is a transition zone containing microcline as well as plagioclase, quartz and some biotite. The boundary-line between the aplitic zones and the dark parts is not sharp at all there. The differences are still less striking, because the plagioclase in the narrow aplite-veins has the same composition (oligoclase-andesine) as that in the dark parts. Towards microcline the plagioclase is almost always surrounded by a rim of myrmekite protruding into the microcline. Microcline has vague grating-structure and is slightly undulose. Rounded quartz-drops and a few grains of apatite and biotite may be enclosed. Undulose extinction and some signs of pressure are to be observed. Nowhere do we see distinct corrosion-forms of which we might presume that they were caused by the aplitic material.

The thick veins, broader than 1 cm., consist for the greater part of quartz and also of some microcline. The coarse quartzes must at one time have occupied the whole breadth of the vein, which now consists of differently polarizing fragments. The undulose extinction of several fragments is intense. The microcline is far in the minority; oblong, rounded fragments do not show the least tendency to idiomorphism. The grating-structure is clearer than in the finest veins but is locally disturbed by pressure; some fibres of microperthite occur.

It is remarkable that the inclusions in quartz: dust and sporadic hair-inclusions occur constantly in all parts of the rock. This possibly points to genetic relationship.

A second occurrence of venites was seen in the New river just above what is called Werinye fall on the English map [1]). There we see against a small island a rock-face with intensely folded texture, illustrated by Pl. 17 fig. 1. Light-coloured veinlets contrast with a somewhat darker groundmass. This groundmass also partakes of the folding-texture of the whole, owing to the orientation of the biotite-leaflets. This enables us to recognize the folded texture in the rock-face also where the aplitic veinlets, which are never thicker than 1½ cm., diminish to the minutest dimensions or are not recognizable at all. These masses without recognizable veins, in their turn, pass into a fine-grained, all but massive rock, which on microscopical examination appears to be a biotite granite-gneiss. A coarser aplitic vein that shows no folding cuts through the whole mass (it is distinctly perceptible on the right side, but pretty well invisible on the left side of the photo).

Pl. 17 fig. 2 shows a polished detail rich in aplitic material (Y. 303). The veins are partly to be followed over the whole breadth of the sample, broadening and narrowing irregularly. Others are interrupted repeatedly and unite locally, so that the term vein is not quit adequate. All of them consist for the greater part of quartz. In the right hand part of the sample a few light-coloured veins, scarcely deserving that name, are distributed over the dark material in such a way that the transition is very gradual and no sharp boundary-lines can be drawn.

Microscopic examination of the sample shows the following.

Sections of the darkest parts of the sample show a granite-gneiss rich in microcline and dark brown biotite, the latter being amply provided with pleochroitic haloes. The biotite is conspicuously frayed. Some primary muscovite is present. Both in texture and in structure the rock has typical ortho-gneiss features. Where the dark material occurs between the smallest aplitic veins it appears to be far from homogeneous: in a section which has cut through a coarse aplitic vein and also through the adjacent dark rock, the latter is locally rich, locally poor in microcline, although for the rest the composition is the same. The differences are still more developed in another section, where spots occur chiefly consisting of microcline and coarser quartz, besides traces of biotite. The quartzes are crushed and show strings of dust. Near them and between them are lying numerous oblong microclines with sparse albite-fibres and which show vague, often strongly undulose grating-structure. They may enclose rounded quartz-drops. Here we seem to have to do rather with the material of the aplitic veins, distributed very minutely in the adjoining rock. These parts gradually pass into others richer in biotite. Locally we see moreover parts that do not contain microcline, and consequently have the composition of a quartz mica diorite-gneiss. These spots are a little richer

[1]) F. Fowler. 82.

in biotite than the others, and also contain some muscovite. All are united by transitions. Resuming we can say that the distribution of the minerals is irregular, especially in those places where the dark parts are finely distributed among the aplitic veinlets, and that there are transitions to the latter.

The coarse aplitic spots visible in the sample consist chiefly of quartz and less microcline. The quartz shows signs of pressure; in some places aggregate-polarization appears. Strings of dust and liquid inclusions cut these aggregates so that they must have belonged to larger quartzes. Locally hair-inclusions are seen in the quartz. It seems that the latter do not occur in the quartz of the dark groups. Microcline appears in the oblong pieces between the quartz. Some insignificant grains of apatite are the only accessoria present.

Another thin section has been cut in such way that the dark material is to be seen together with the finest aplitic material. Quartz is the chief component of these aplitic spots, next follows plagioclase (oligoclase-andesine), and after this microcline. The quartz is quite the same as that of the coarser aplitic veins, only it is small-sized. Some fragments are much larger than those in the dark rock, others again show aggregate-polarization of the grains, while strings of dust and inclusions intersect them. Locally there are bent hair-inclusions. Here and there irregularly shaped plagioclases occur, often showing bent and vague twinning. In some places microcline-masses with vague lamellation appear. The plagioclase has a myrmekite-margin towards microcline. Here and there biotite, muscovite, zircon and apatite occur in the aplitic material. As has been stated before, these aplitic spots are surrounded by material of varying composition and gradually pass into it.

An exposure of venites which show several points of difference with the former is found in the Lucie river at the place marked B on map VI. Pl. 18 fig. 1 illustrates a part of the rounded rock-face on the left bank. Careful inspection shows intense folding. Locally we see nests very rich in quartz, partly united by indistinct veinlets. These nests may have a diameter of one decimetre or more. The veins are often interrupted, and appear again farther on. The parts between the veins show the same texture, because of the orientation of the dark minerals. The texture in general is the same as the one described above, though less intensely twisted. A detail is shown on Pl. 18 fig. 2. In the polished sample aplitic veins are set off against a dark groundmass. The veins consist for the greater part of quartz-grains up to 6 mm. The size of the grains decreases with the breadth of the veins. The latter may still easily be traced when they are a few mm. in thickness. The finer ones, however, can be traced over a few centimetres then they vanish and may reappear farther on. The interstitial material is rich in biotite, which is oriented like the aplitic veins, and has partly accumulated to slightly bent cords. Here and there we also can distinguish coarse muscovite in the dark groups.

Microscopical investigation shows us a very irregular texture of the material between the aplitic veins: it might be para-gneiss. A section normal to the parallel texture shows cords of brown biotite and muscovite, and between them groups rich in quartz and microcline. The two micas are mostly intensely flattened after the base. Biotite shows pleochroitic haloes; in the muscovite, sillimanite (fibrolite) occurs. Both micas are often frayed on the outline. The quartz and microcline do not show any idiomorphism. Now the microcline forms larger pieces than the quartz and encloses quartz-drops, now again the two form an entangled mass. The grating-structure of the microcline is well-developed. Occasionally we observe also twinned plagioclase (oligoclase). Locally lenticular parts occur consisting mainly of quartz-grains polarizing differently. It is not clear whether these bright quartz-particles were formed by pressure from larger crystals showing "aggregate-polarization", or whether they crystallized separately. These lenticular quartz-groups contribute rather much to the irregular texture of the whole. There is some undulose extinction in all colourless minerals. There are only few accessoria. Ore and apatite do not occur at all. Zircon-crystallets of very small dimensions are present.

A thin-section of the coarsest aplite-veins of the sample shows almost exclusively quartz with some plagioclase, microcline and muscovite. The coarse quartzes are undulose and partly crushed. Hair-inclusions occur sporadically, these have not been observed in the quartz of the dark parts. The plagioclase is scattered irregularly. Some crystals show tendency to idiomorphism, others again are irregular in shape. The twinning is indistinct. The composition is that of oligoclase. Microcline is present only as a few scattered crystals between the quartz. This small amount of microcline is remarkable considering the large

Plate 17.

Fig. 1. Rock-face of venite-showing intensely folded texture. Near Wirinye fall, New river.

Fig. 2. A part of the same rock, polished. White aplitic masses are lying in dark biotite gneiss. (Y. 303).

amount of microcline in the adjoining rocks. Here and there we see muscovite and also biotite in the aplite. These minerals have the same properties as those in the adjoining rock. Accessoria have not been found in the aplite.

Speculations regarding the genesis of the Venites.

We shall begin with the discussion of the genesis of the two venites that we have mentioned first, and afterwards consider the last one.

As has been stated already, two venites form local complications in granite- and acid diorite-gneisses; gneisses such as we know in a number of places in the Colony. These ortho-gneisses constitute the chief material of the venites; they may be traced even between the aplitic veins. The problem of the genesis of the venites is, therefore, how the locally deviating behaviour of these ortho-gneisses is to be accounted for.

It should be emphasized that the gneiss-features of the Surinam ortho-gneisses are considered to be primary. Facts, showing that the first two occurrences of venites were caused by contact between the magma from which the ortho-gneisses crystallized, and older material, have not been met with in the field, neither were they discovered with the aid of the microscope: no relics of enclosed material or contact-minerals have been found. Only muscovite in the acid diorite-gneisses might be considered as an anomalous component.

Two possibilities, should be faced, viz. 1°. whether anomalous relations existed locally in the magma during the crystallization of the ortho-gneisses; 2°. whether their origin is of secondary nature. Let us view the latter possibility first.

The venites cannot have been formed by strong pressure only. For such pressure, would have caused crushing and habitus quite different from those of the rocks under discussion, if it had been active in the epi-zone. Neither can pressure, active in the deeper zones may have been the cause, for this would not tally with the quite undisturbed structure of the adjoining rock. We might also think of direct or indirect influence on the ortho-gneisses by an intruding magma; direct influence in the sense that the aplitic veins intruded and at the same time influenced the adjoining material, which would have resulted anomalous distribution of the minerals in the latter. This supposition is very unlikely, however, considering that veins of such small dimensions cannot have developed so great an activity, anyhow not under epi-, or meso-zonal conditions. Such activity of the aplites might be imagined, however, in the deepest zone, the ortho-gneiss being under such conditions that a slight rise of temperature, caused by the intrusion of the veins, brought about local recrystallization of the ortho-gneisses. The influence of indirect contact in the sense of Sederholm's [1]) palingenesis might also be accepted: an intruding magma refusing a rock and bringing it to renewed action. We might think of this possibility, though in a different sense from that proposed by Sederholm. In our case namely we have no arguments for an intruding magma of any significance. In how far Sederholm's ideas would have to be transferred to the Surinam venites,

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[1]) J. J. Sederholm. On migmatites and associated pre-Cambrian rocks of southwestern Finland. Part. I. The Pellinge region. Bull. Comm. géol. Finlande. Nr. 58. 1923. Do. Part II. The region around the Barösundsfjärd W. of Helsingfors and neighbouring areas. Nr. 77. 1926.

and in how far primary character of their genesis might come into consideration, had better be discussed when we shall have seen what genesis has been assumed for venites elsewhere.

As to the habitus our venites resemble those occurring in various parts of the world: f.e. the "Arterites" of Sederholm [1]) and the "Venites" of Holmquist. [2]) It is assumed by Sederholm that the aplite veins of these rocks are of igneous origin. The penetrated material is either of igneous or of sedimentary origin. This does not imply at all that the penetrating material has forced its way along coarse fractures. The great pressure that must have prevailed in the complex at the intrusion, must have prevented the opening of coarse fissures. Most likely the material intruded after the magma had heated the adjoining rock so strongly that solutions could make their way through it without crystallizing there by cooling. The intruding material opened numberless fine fissures, parallel to the schistosity, in which veins and lenticular bodies of intrusive material crystallized. This injection may have most delicate dimensions, the smallest being recognizable under the microscope only. If the schistosity of the initial material were distinct and if there were also a large difference between the injected and the injecting rock, there must have resulted a well-marked difference between bands and bandlets of primary and secondary material. The two groups are difficult to separate, however, if the difference in composition of the components is small, and, when the injection is intense, it is impossible to distinguish between them. In the last case the result is a rock of irregular texture with more or less streaky distribution of the minerals. If the stage is reached in which the intruding material constitutes the major part of the whole, a very considerable rise of temperature must have taken place. The whole mass may have moved in that case under the influence of the pressing intrusive magma, so that fluidal structure originated, which is so typical of venites.

This interpretation is given for the "Arterites" and "Injections-fältelung" in Fenno-Scandia by Sederholm, and for the "Injections-gneisse" near Laufenburg on the Southern border of the Schwarzwald etc. That similar injection-phenomena parallel to the schistosity have indeed taken place, is borne out by numerous studies of contacts by Sederholm in Southern Finland and Southern Sweden. Here pre-Cambrian rocks, as well ortho-, as para-rocks are intruded and enclosed by magmas, which coincides with intense injection and anatexis, resorption, and a mingling of the components (migmatites).

Holmquist (l.c.) assumes more complicated and divergent geneses for the venites. In his genetic classification he distinguishes two groups. The first comprises the "Syngenetische Venite". According to Holmquist these venites cannot be accounted for at all by the intrusion of aplitic material from the outside, because magmas responsible for its appearance are absent in extensive areas occupied by venites, in Sweden. For these regional venites Holmquist assumes recrystallization caused by deformation of massive rocks (e.g. granites) or of originally banded rocks (e.g. leptites), the texture of the latter being destroyed by intense folding (detail-folding) and flow-cleavage; the quartz-feldspar bands of the original banded rocks must have furnished the material of the aplitic veins in the venites. This type of genesis is supposed to occur in the deepest zones. Moreover "Epigenetische Venite" are assumed to arise from the filling-up of "Zerrungsraüme". The cavities are formed by detail-folding; filling takes place by material derived from the adjacent rock ("Lateralsekretionsvenite"). This must occur either at relatively low temperature as is assumed for the material in the bends of the folds in the upper parts of mountain-systems uninfluenced by magmas, or under the influence of high temperature namely owing to regional pegmatite-palingenesis ("Ultrametamorphe Lateralsekretionsvenite"). Venites of this origin must be found in areas of highly metamorphic gneisses of Sweden. In how far the group of the "Lateralsekretionsvenite" can be distinguished in the field or in samples from the first type of the syngenetic venites, seems to me to be an open question; probably it would be better not to introduce such an excessive theoretical division of venites.

In conclusion Holmquist distinguishes among the "Epigenetische Venite" two more divisions, both having originated by magmatic injection combined with detail-folding. Both are called "Injektionsvenite" or real "Arterite". In the first division the injected material must have originated by "Pegmatitpalingenese", and this division (according to Holmquist) must occur together with the "Ultrametamorphe Lateralsekretionsvenite" mentioned already. It is puzzling to me how they can be distinguished from the latter.

The second division of the "Injektionsvenite" is more sharply defined; the material of the aplitic veins comes directly from deep-seated magmas at the contact zone of the intruding magmas. The latter group may therefore genetically be compared with the Arterites of Sederholm.

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[1]) J. J. Sederholm. Über eine archäische Sedimentformation im Südwestlichen Finnland. Bull. Comm. géol. Finlande. Nr. 6. 1899. Do. Om granit och gneis etc. Nr. 23. 1907.

[2]) P. J. Holmquist. Typen und Nomenklatur der Adergesteine. Geol. Foren. Förhandl. XLIII. 1921. p. 612.

Plate 18.

Fig. 1. Folded quartz-nests in venite, Lucie river.

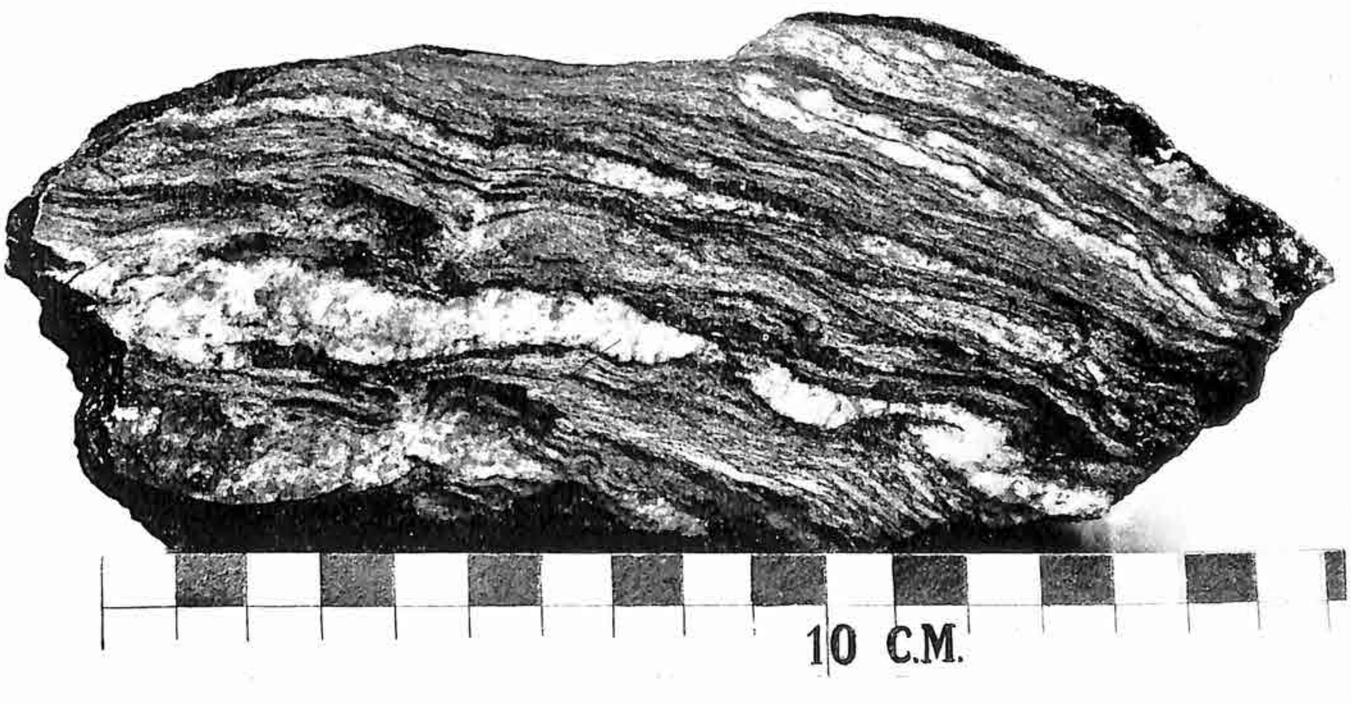

Fig. 2. Polished sample of venite showing light aplite veins in dark biotite gneiss. (Y. 277).

Now let us return to the Surinam venites. For reasons enlarged upon in the foregoing our first two venites cannot be considered as the product of injection, like Sederholm's arterites, unless one is ready to accept that an igneous rock responsible for the phenomena, is hidden beneath or was not observed by us because of incomplete field-work.

We might assume that our ortho-gneisses, in which the venites occur, came again under the influence of high pressure and temperature, after having sunk back into deeper parts of a still fluid magma; there, parts of the gneisses which had sunk in, might have become active again, splitting off as aplite veins; at the same time the highly heated and pressed mass might have assumed its strongly folded and tangled texture under the influence of magmatic movements. These suppositions are closely allied to Sederholm's palingenesis, with this difference that the activity resulting in the transformation is not caused by an intruding magma, but arises from the deeper parts of the same igneous complex. It should be observed, however, that in our case, contrary to what is surmised by Holmquist for this group of venites, we have not to do with a regional phenomenon, but with a local one. It is moreover very doubtful whether the conditions, here assumed as being the cause of venite-formation, will indeed engender a similar splitting in material that has regained its semi-fluidity. This does not refer only to our suppositions but also to Holmquist's speculations.

The third exposure of venites, the one in the Lucie river, higher up, has been left out of consideration here. Whereas the two other exposures show rocks bearing the characteristics of being derived from ortho-gneisses, this is not probable for the latter. Microscopical examination suggests that the material penetrated by the aplitic veins, is a para-gneiss, judging from the texture of the components etc. Also the texture of the whole is less irregular than in the two previous cases. It is not impossible that the genesis of this venite is quite different from that of the two previous ones and that here we have to do with intense injection into para-schists or gneisses, so with a case of Sederholm's "Injektionsfältelung".

Summing up we may say that the genesis of the Surinam venites is still a matter of conjecture, in accordance with what is mostly the case with these remarkable rocks elsewhere.

X. AUTO- AND ALLO-METAMORPHISM OF THE GRANITO-DIORITES AND ORTHO-GNEISSES.

In this chapter phenomena will be treated which are ascribed to post-magmatic changes, with regard to all granitodiorites and ortho-gneisses. In discussing these post-magmatic changes we have tried to bear in mind the very divergent causes of the different phenomena. The undermentioned work-scheme will be followed:

I. Auto-metamorphism.

Under this heading fall processes still belonging to the magmatic crystallization-process, but not essential to the formation of igneous rocks: important changes, however, may be caused by them.

These processes may be subdivided as follows:

A. Auto-metamorphism, directly following the magmatic phase.
B. Pneumatolytic changes caused by gases and vapours.
C. Hydrothermal processes, i.e. post-magmatic changes caused by watery solutions.
D. Those weathering phenomena which are difficult to distinguish from the hydrothermal processes; these may be discussed together with the latter.

II. Allo-metamorphism.

Under this heading fall all other changes in the rocks which are no longer concerned with the igneous process itself. As to these we only have to discuss phenomena which have been caused directly or indirectly by pressure-action. For the sake of completeness let it be repeated here that the gneiss-features of most Surinam ortho-gneisses are regarded as primary, hence we shall not find their origin discussed in this chapter. We shall, however, treat a number of gneisses here, whose gneiss-features are of secondary nature, and which have been formed by dynamic action. We may best discuss the products of allo-metamorphism in view of typical examples forming together a series representing increasing pressure-action:

A. General phenomena of cataclasm.
B. Cataclastic gneisses.
C. Mylonites.
D. Pseudo-tachylytes (= Ultramylonites).

I. AUTO-METAMORPHISM.

A. *Auto-metamorphism, directly following the magmatic phase.*

It seems to be generally accepted that the processes of auto-metamorphism are influenced by falling temperature following magmatic crystallization. Some petrographers reckon among autometamorphism those processes, which act before the last parts of the magma have quite solidified. At this stage (according to them) some of the minerals already formed try to adapt themselves to the changing chemicophysical conditions without altogether succeeding, for they only change at the edges; corona-structures (reaction-rims) are formed, which appear particularly in basic rocks. Probably the myrmekite and symplectite and other structures, which are "synantetic" in the sense of Sederholm, also belong to this period.

Myrmekite viz. the intergrowth of vermiform quartz-bodies and plagioclase, which has taken the place of potash feldspar, is generally distributed in Surinam rocks (p. 180). The intergrowth of quartz or feldspar with biotite (symplectite), in which the quartz, at any rate, in the Surinam rocks, seems to penetrate into the biotite, is possibly to be regarded as a phenomenon of earlier corrosion.

Signs of demixture are supposed to belong to a subsequent phase of cooling: the formation of sagenite in biotite; the demixture of titanomagnetite, characterized by rims of titanite around the ore-crystals; possibly, too, the hematite-leaflets and other fine inclusions in the plagioclase; and the appearance of microperthite. All these phenomena are very common in the Surinam rocks. We are partly concerned here with demixture of solids, at any rate, in the case of microperthite, [1]) hence this phenomenon does not belong to the liquid-magmatic phase.

Certain phenomena of metamorphism are revealed by the gabbros from the De Goeje mountains (see p. 259). Similar phenomena are also shown by some gabbros and diorites occurring N.W. of these mountains (see p. 312). The unmodified gabbros have developed into normal gabbros, olivine gabbros, norites etc. A number of these rocks show margins of hornblende round pyroxene, besides independent crystals of hornblende. It is obvious that this hornblende is of primary nature. Secondary hornblende is found in a number of the gabbros. In part it is colourless hornblende, with frayed edges. The fibres of this hornblende have clearly penetrated into the adjacent plagioclases. Consequently the demarcation between the plagioclase and hornblende is not so sharp as in the primary hornblende. Another type differs from the primary one by its pale-greenish tint. The centre of the crystals is almost colourless; the margins however, are pale-greenish. Besides, this hornblende at the edges sometimes shows vermiform or club-shaped appendages penetrating into the adjacent plagioclase (see V. 509, 518, 688). In the latter case the structure resembles the one described by us with regard to the outmost rim of the kelyphitic zone which may occur round olivine in the gabbros (see p. 244). The remains of pyroxene occurring in the colourless as well as in the greenish hornblende afford an indication of the secondary nature of the hornblende (V. 503, 509, 513, 514, 518, 698 A). In some cases, however, it is not certain whether the hornblende-rims, occurring round the pyroxenes, have arisen from the replacement of pyroxene by hornblende, or whether we have to do here with primary rims. Most of the rocks alluded to have been

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[1]) c.p. E. Dittler and A. Köhler. Zur frage der Entmischbarkeit der Kali-Natronfeldspäte und über das Verhalten des Mikroklins bei hohen Temperaturen. Tscherm. Miner. Petrogr. Mitt. XXXVIII. 1925. p. 229.

subject to epidioritization. It should be remembered that on account of the uralite-like hornblende a number of these rocks are to be termed epidiorites, or (on account of the homogeneous structure of the hornblende), secondary hornblende gabbros, or amphibolites. Here, then, we have transitions to the ortho-schists. The texture of the rocks is, however, not clearly schistose. It follows that pressure cannot be answerable for their metamorphism.

Let me add a few remarks about the kelyphitic zones of the gabbros of the De Goeje mountains. As has been said, the olivine exhibits a synantetic double zone. This zone consists of an outer rim of green, myrmekite-shaped hornblende, and an inner-rim of tremolite (?). Considerable modifications are noticeable in many cases. The outer hornblende-rim increases to the detriment of the material inside. First the tremolite disappears, subsequently also the olivine passes into hornblende. The outer hornblende-rim retains its green colour and its structure, and seems to expand outwards while repelling the adjacent plagioclases. However, where olivine has been replaced, the secondary hornblende has another habitus: we observe a fibrous hornblende-mass, all but colourless, in which ore-dust may occur. The process may be very well traced in a rock which, judging from the relics of olivine and pyroxene in it, was previously a norite rich in olivine (V. 503). However, also the well-known serpentine pseudomorphs to olivine may occur (V. 698 A). These modifications are, therefore, of a different nature to the formation of biotite from olivine, which process has been observed in the later intrusive diabases.

We do not know by which kind of auto-metamorphism all these changes were caused, and provisionally we have classed them with the group "A".

B. *Pneumatolitic changes.*

Next, under the influence of volatile elements, new minerals may wholly or partly replace the primary minerals. Fluorite, topaz, tourmaline and cassiterite are considered as such. Fluorite is to be found in a couple of granites of the Central Wilhelmina mountains as irregularly shaped crystals (Y. 191, 233). The granites have been influenced by pressure, which has caused aggregate-polarization of the quartz, and crushing of the microcline. In the latter strings of quartz occur along cracks. The fluorite also is arranged along the cracks; consequently the fluorite and quartz seem to have appeared after pressure-action took place and to have replaced the original minerals here and there. Small pieces of fluorite also appear in the plagioclase.

An insignificant quantity of topaz together with chlorite and epidote appears in a quartz mica diorite (bearing some microcline) from the Litani (V. 1078). The topaz is not idiomorphic and occurs near cracks and mineral boundaries. A rock, which, according to the description of Vélain[1]), by the side of topaz also bears tourmaline, wolframite, fluorite and cassiterite has the features of a real greisen. It was collected by the famous traveller Crevaux on his expedition along the Marowyne and over its watershed (Tumuchumac mountains) to

[1]) M. Ch. Vélain. 22. p. 474.

the Yari (tributary of the Amazon). It is a rose-gray rock, consisting of quartz and mica with small pieces of wolframite, tourmaline and little veins of tinstone; as in the "granulites métallifères" in Cornwall and Saxony. All these minerals are to be distinguished macroscopically; microscopically we see, besides these, rutile needles enclosed in quartz and a few large titanite-crystals, while the cassiterite is not only confined to the little veins, but is found spread throughout the rock; further fluorite is present. This rock must, indeed, be a typical "greisen", as it is characterized by quartz and mica (the latter mineral has replaced feldspar) and as the rock bears a whole series of pneumatolytic minerals, which are typical satellites of tinstone.

Tourmaline, as a pneumatolytic mineral, is of very little importance in the granites. Here and there we sometimes see an extremely small tourmaline-rod (mostly shorter than 0.1 mm.), or somewhat coarser, irregularly shaped pieces, with bluish to brownish and olive-green pleochroism. [1]) In so far as they are solitary and not confined to cracks, they may be of primary nature as well. In a biotite granite from the Gran-rio (V. 1876) a single string of tourmaline occurs (in the thin-section), winding through the coloured minerals, together with some muscovite. The granite shows signs of pressure and it is probable that the tourmaline settled in the rock before pressure-action took place, for the tourmaline-rods do not occur near cracks and are broken themselves.

Secondary muscovite is very common, but since the origin of the material has already been discussed in detail, we refer to p. 184.

C. *Hydrothermal processes.*

It is supposed that in further cooling exhalations of CO_2 and H_2S, and supply of alkalies, supply of SiO_2 and of sulfides take place; while ionized water causes hydration. These processes and especially the supply of alkalies and sulfides are, however, of more importance to peri-magmatic contacts in adjoining rocks. Typical examples of hydrothermal processes are of little importance in the Surinam rocks.

Very often colourless mica-scales, which may be called sericite, occur in the plagioclases. Mostly the leaflets have a well-defined base, hence sections vertical to the latter are oblong and sharply defined, while crystal-shape of the prism-zone is wanting. We are only referring here to material that is plainly recognizable as colourless mica and not mica-like material too fine to be identified. Our mica is invariably restricted to the plagioclases and never appears in the potash feldspar. This is true to such an extent that we are often able to see directly, whether feldspar is plagioclase or not. In many cases the plagioclase itself has sometimes been almost entirely replaced by it. The mica-leaflets mostly lie jumbled up together, but sometimes they show a tendency towards regular arrangement in accordance with some system, with respect to the enclosing plagioclase. [2])

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1) e.g. V. 740, 744, 1883.
2) Much of this mica is seen among others in: V. 79, 80, 313, 413, 475, 478, 591, 594, 840,

Various origins of this mica might be considered.

1. The mica is formed by weathering.
2. It is a phenomenon of demixture.
3. It is a new formation formed with the add of pressure.
4. It is a product of a pneumatolytic-hydrothermal origin.

We shall see that the last origin may be accepted. Its being a weathering-phenomenon may be dismissed at once, for this mica occurs just as well in quite fresh rocks. We may not assume that the occurrence of the mineral is connected with pressure-phenomena, for signs of pressure may be entirely absent in rocks containing mica. The following observations are decisive. It may be noticed that mica not always occurs throughout a plagioclase crystal; in a number of acid diorites it is found only in an irregular marginal zone of the plagioclase (fig. 48). Furthermore the mica-free field has other optical pro-

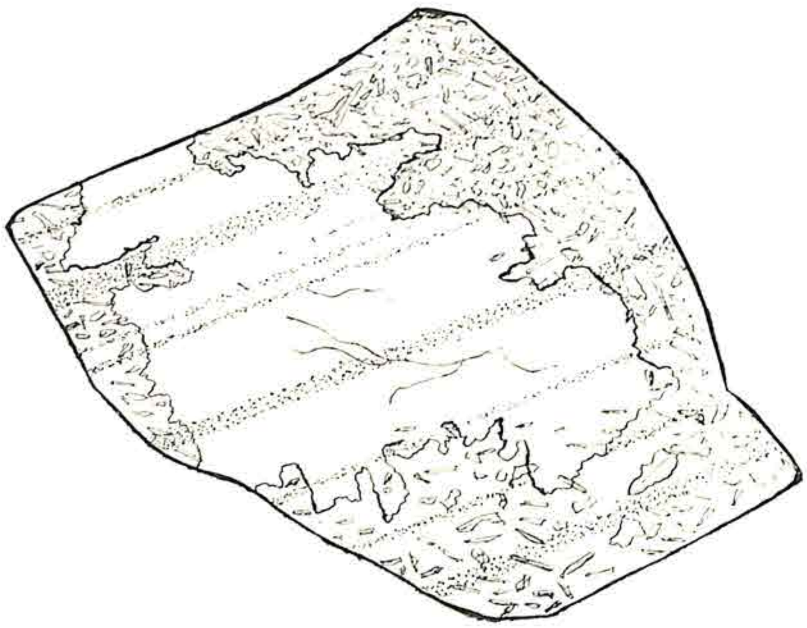

Fig. 48.

perties, showing here and there stronger refraction and another extinction than that of the margin. It must be emphasized that the phenomenon has nothing to do with zonal feldspars of concentric structure, because the line of demarcation between the field and the edge-zone is extremely irregular.

The field need not to be in the centre of the feldspar and besides, in large plagioclases, several such fields may appear, while in others we see quite a number of irregular mica-bearing fields extending from the edges into the plagioclase. [1]) The parts bearing mica, on the whole, show clearer twinning than those free from mica, but the same lamellae continue through both parts.

862, 995, 996, 1058, 1411, 1565, 1572, 1585, 1623, 1627, 1631, 1632, 1633, 2298, 2299, 2311, 2312; Y. 1, 7 B.

The same mica but coarser, hence comparable with fine muscovite, we find e.g. in: V. 122, 142, 200, 201, 474, 476, 805, 824, 829, 841, 1413, 1416, 1420, 1555, 1557, 1564, 1622, 1664, 1667, 1680, 1688; Y. 3.

[1]) For this process see e.g. V. 130, 842, 1410, 1679.

These twinning-lamellae show a maximal difference in extinction of 5°, in the zone vertical to (010), in the two parts. While the mica-free parts contain about 20 % of anorthite, the mica-bearing ones contain about 15 % of it. The penetrating of the mica from the edges towards the centre points to the fact *that we are concerned with a secondary phenomenon, which is accompanied by a diminution of the anorthite-percentage of the plagioclase.* These combined phenomena may continue to such an extent that the whole of the plagioclase is crowded with mica, in which case the index of refraction of the whole crystal is equally reduced. In a number of the most acid members of the "Diorite facies" (group IV) and of biotite granites containing plagioclases completely filled with mica, it is obvious that the acid composition (albite-oligoclase to approximately albite) is connected with the formation of mica, and that the original composition of the plagioclases was somewhat more basic (approximately oligoclase). It is clear that the material for this mica cannot have been supplied exclusively by the original plagioclases; this holds good no matter whether the mica is rich in potash (muscovite) or rich in sodium (paragonite), for in either case the anorthite-percentage would have been augmented during formation of the mica and not the reverse. Besides it may be remarked that a plagioclase unpurified by potash could never contain sufficient of potash to saturate all mica.

By the side of this mica another secondary mineral sometimes appears in the plagioclase, namely idiomorphic epidote which must have been formed at the same time as the mica, because its mode of occurrence is the same. Usually they appear together, but the epidote as well as the mica may also occur alone. The epidote microlites [1]) excel mostly by beautiful crystal-forms (fig. 49) and are now found in clusters, now scattered throughout the whole plagioclase-crystal and may almost completely replace it (Pl. 40 fig. 1). We may sometimes observe that the microlites appear especially in the centre of the plagioclases, a thing never seen in the case of the mica. The shape is the same as that of the idiomorphic epidote microlites described on page 180, hence it is sometimes difficult to make out with which type we are dealing. The secondary one, however, invariably appears in extremely acid plagioclase so that it is likely that the anorthite-percentage was consumed during formation of the epidote. The secondary type has a tendency to grow out into irregular masses and pieces, which may entirely replace large parts of the plagioclase. When secondary epidote-grains together with mica appear in large quantities, they sometimes betray their presence macroscopically, giving the plagioclases a yellowish and greenish colour (granites of the Central Wilhelmina mountains) [2])

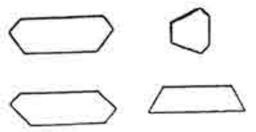

Fig. 49.

In a few cases the sericitization is not restricted to the plagioclase, but affects other minerals too. In a porphyritic biotite hornblende granite from the Koesi-

[1]) see e.g. V. 81, 475, 478, 862, 871, 1410, 1564, 1755, 2298, 2299, 2952, etc; Y. 3, 7 B, 8, 9, 11, 13.
[2]) e.g. Y. 193, 196 B, 200.

kamba fall, Suriname river (Y. 42), plagioclase, green hornblende and ore have partly been replaced by sericite, while microcline, quartz, titanite, apatite, and coarse zircon remain unaltered and biotite has passed into chlorite. The plagioclase, partly developed as myrmekite, is filled with sericite to such an extent that the lamellae are hardly to be recognized, while accumulations of epidote appear locally. Both the epidote and the mica are devoid of crystal-shape. In the hornblende, which does not look very fresh, fissures form an irregular network; for the greater part they are filled with mica-scales and epidote in the form of dust. The coarse pieces of ore are, as to their general form, still intact, but they are equally traversed by fissures filled with sericite, chlorite and another colourless mineral, possibly quartz, in varying percentages (Pl. 40 fig. 2). It seems that the ore was in part carried away, the secondary minerals having established themselves in the cavities; in any case there is no question of weathering. The rest of the minerals are fresh, only microcline being traversed by some streaky quartz-aggregates, but quite free from mica.

We have several instances [1]) of the replacement of ore by sericite, chlorite etc.

In the same connection, calcite also may appear. In many acid diorites and granite rocks, we observe irregular pieces of calcite, concerning the secondary origin of which there is no doubt. They only occur in fissures and replace the adjacent minerals. [2]) Neither need we be concerned with a weathering-phenomenon; this is evidenced by some quite fresh rocks.

All these secondary minerals together, the mica in the plagioclases of the type mentioned above, the epidote microlites and the calcite with or without epidote formations, are therefore to be regarded as a result of pneumatolytic hydrothermal action. They may be present in such quantities, that it is no easy matter to recognise the original rocks. [3])

A secondary change, which very probably has been affected by hydrothermal processes we see in the granite of Semoisi, Suriname river. At the landing of this Bushnegro-village a coarse-grained biotite granite crops out in the form of rounded-off rocks. Rose-coloured microcline-phenocrysts are very numerous. They attain to a size of 2½ cm. while the groundmass is composed to a large extent of sulphur-yellow epidote, with chloritized biotite-crystals and quartz. Part of the sample is cut by a coarse-grained quartz-vein in whose neighbourhood there is distinct enrichment of quartz. Hence the rock must have become impregnated with quartz. Microscopically the rock appears to be composed of the granitic mineral-combination of quartz, microcline, plagioclase and biotite. Considerable complications are to be seen; first in the plagioclase. This is extremely acid, approximately albite. The twinning is well-defined. Always epidote-microlites occur in the plagioclase. They are coarser than the microlites described above (0.1—0.2 mm). They appear scattered throughout the plagioclases, but also in the quartz and the microcline, while large quantities of these small crystals are intergrown to masses. The epidote causes the yellow spots in the sample. It is probable that the anorthite-percentage

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[1]) see e.g. V. 377 and 594.
[2]) V. 78, 79, 592, 593, 594, 1058, 1511, 1565, 1571, 1627, 1655, 1689; Y. 7 B.
[3]) e.g. V. 870, 995, 1632, 1635, etc.

of the original plagioclase was consumed during the forming of the epidote, leaving behind a very acid plagioclase, unusual for the Gran-rio granites. Secondary quartz is important. In the sections rich in plagioclase (see Y. 60 A) we observe, where plagioclase and quartz adjoin, that the quartz penetrates the plagioclase in the form of a network (fig. 50 near a). The network of quartz polarizes in the same way as the adjacent quartz-crystals and is nothing but a continuation of them. In the network quite a number of small pieces of plagioclase have been left intact which in their turn polarize in about the same

Fig. 50.

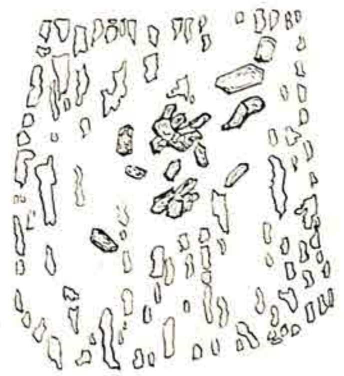

Fig. 51.

way as the plagioclase-crystals. This process of replacement goes on to such an extent that of the plagioclase-crystals nothing may be left but a number of relics, which however, all together, reproduce the shape of the former plagioclase-crystals (fig. 51). The relics are directed with their maximum length parallel to the original twinning of the plagioclase. The epidote microlites remain intact at this process.

We observe the same where quartz and microcline border on each other (see especially Y. 60 B). The process goes on in the same way, but the remaining fields of potash feldspar are smaller and mostly distinctly oblong and all show parallel orienting. The replacement begins not only at the edges of the crystals, but in the larger microclines we also observe patchy masses of quartz scattered about.

If the replacement is intense, it is difficult to decide whether the rock was once a plagioclase or a potash feldspar, the remnants of both showing very low refraction. In the case of complete replacement it may be possible to trace what belongs to the primary quartz and what to the secondary, in spite of the equal orientation of the material. For the primary quartz shows strings of dust, liquid inclusions etc., which are wanting in the secondary quartz.

The replacement of one single feldspar-crystal may proceed from several primary quartz-crystals at the same time; in that case the secondary fields may come into contact with each other, the polarization of each field being the same as that of the quartz-crystal, from which it proceeds.

One more complication appears in the same rock. The biotite has entirely passed into chlorite with anomalous double-refraction, without revealing anything special. In the secondary quartz, however, we see chlorite, looking quite different. Countless fine sphaerolites of chlorite-fibres with a negative main zone and distinct pleochroism ranging from sea-green to pale-green are found in the quartz. The spherolites are often not complete but form sausage-shaped bent ring-segments (Pl. 40 fig. 4).

Locally these spherolites are accumulated in the secondary quartz and therefore it is probable that their formation took place contemporaneously with the appearance of the secondary quartz while possibly their material was taken from the biotite. In my opinion the united processes are the consequence of hydrothermal-pneumatolytic action operating as follows: first the calcium-percentage of the plagioclases diminished, accompanied by the formation of epidote microlites and possibly also even of masses of epidote: then supply of quartz began which was accompanied by the formation of the fibrous chlorite in the secondary quartz. The epidote microlites remained intact during the growth of the quartz.

This rock is one of the few instances of silicification. Besides insignificant strings of quartz, which cross some rocks along cracks, no other instances are known (V. 1199, 1219).

D. *Weathering-processes which are difficult to distinguish from the hydrothermal processes.*

Other phenomena may with a less degree of certainty be ascribed to hydrothermal processes, because the same changes may also have been caused by weathering. It is generally accepted that in the final stage of magmatic activity, kaolinization, zeolite-formation and metasomatic opal-formation may be caused by the activity of the "juvenile" water. Indeed the plagioclase has been replaced by opal in various granites, in acid diorites and in corresponding ortho-gneisses. Instead of the doubly-refracting lamellae we observe opal in that case. [1]) The first traces of change are very fine fissures filled with isotropic material forcing their way along the intergrowth-plane of the lamellae. These tiny channels soon attack the lamellae themselves, too, and riddle the whole crystal: at last only the frayed remnants of the substance of the plagioclase are left, the edges holding out longest. In conclusion complete pseudomorphs also appear. It is remarkable that the adjacent minerals are not affected in the least, not even the potash feldspar. Sericite-scales formerly present in the plagioclase, also remain intact in the pseudomorph. Considerable variation in the refraction of the opal is caused by the varying proportion of water. The opal may be not wholly isotropic (V. 1223). If the opal is present in abundance so that practically complete pseudomorphs of plagioclase appear, we can even distinguish it more especially as a sort of brittle substance which, when rubbed, easily produces a gray-brown powder, which gives the impression that the rock is weathered to a marked degree. Unlike their macroscopical

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[1]) Y. 115, 142, 151, 160; do., among others V. 107, 381, 392, 764, 765, 850, 1213, 1223, 1358, 1484, 1895, 1897, 1944, 2116.

appearance the rocks microscopically often appear to be fresh: biotite and potash feldspar may have remained unchanged (V. 1897); so in all probability we are not concerned with a weathering-phenomenon.

In connection with the fore-going a few more changes in the granitodiorites may be discussed, in which it is also difficult to decide whether they belong to auto- or to allo-metamorphism. Secondary epidote and chlorite are found very frequently. It is uncertain whether the water required for the formation of these minerals was of magmatic origin or penetrated into them through cracks and fissures during weathering. In the latter case we should not be concerned with metamorphism in a narrower sense.[1]) In the handbooks on petrography the formation of chlorite and epidote in igneous rocks is, in many cases, put down to weathering. In this connection it is striking that our rocks collected from river-beds are sometimes chloritized and epidotized, whereas others, which were probably in the same circumstances, do not show this change. It is possible that the former rocks had already been influenced by thermal processes which made them highly accessible to weathering. On the other hand it is a fact that boulders that have long been exposed to weathering show chlorite and epidote in the outside zone, around an unmodified core. Hence both origins should be borne in mind.

In this connection bastite originating from pyroxene in the rocks of the Nickerie region may be mentioned, and also leucoxene originating from titanite and from ore, besides the change of orthite into an isotropic modification etc. Probably veins of epidote in so far as they do not occur in rocks showing strong signs of pressure are to be ascribed to auto-metamorphism. Of doubtful origin are extremely fine grains also belonging to the epidote-group and showing very strong pleochroism ranging from sky-blue to clear yellow with intense refraction and double refraction, which are very sparsely met with together with microlites in granites (Y. 182 B, 337). They are usually somewhat smaller than 40 μ.

Zeolites were only found in a biotite granite from Aurora, Suriname river (Y. 54). Their optical properties correspond to those of desmine.

II. ALLO-METAMORPHISM.

A. *General phenomena of cataclasm.*

Pressure-phenomena are of great importance in the structure of the Surinam granitodiorites. They are repeatedly referred to in publications. Those of Kloos[2]) and Du Bois[3]) give scanty details. In the provisional descriptions of rock-samples collected by several expeditions, Molengraaff,[4]) Moerman,[5])

1) c. p. P. Niggli, Die Gesteinsmetamorphose, p. 179 : 2. „Metamorphose ist die Summe des Prozesse, durch welche einzelne oder alle der drei Faktoren Mineralbestand, Struktur und Textur einer als ganzes erhalten bleibenden Minerallagerstätte eine wesentliche Änderung erleiden, wobei jedoch gewisse, an die Grenze-zone der Lithosphäre mit der Atmosphäre und Hydrospähre gebundene Erscheinungen (Diagenese, Zementation, Verwitterung, Halmarolyse etc.) nicht einbegriffen sein sollten".
2) J. H. Kloos. **28.**
3) G. C. Dubois. **40.**
4) G. A. F. Molengraaff. **44.**
5) C. Moerman. **54.**

Thie,[1]) and Duyfjes,[2]) give brief references to pressure-action. Grutterink[3]) goes more into detail. He compares the pressure-phenomena in the granites from the Tumuchumac mountains with those of the "protogines" of the Alps. The great distribution of cataclasm in the Nickerie-region is discussed by Beekman.[4]) Also in Bergt's[5]) description of material from the Coppename and the Nickerie-region we find on nearly every page details about „Druckwirkungen".

The mineral that reacts to pressure first is quartz, showing undulose extinction, followed by crushing (Pl. 40 fig. 5; Pl. 41 fig. 1). Strings of liquid inclusions running undisturbed from one fragment into the other prove that we are concerned with fragments of one and the same crystal. Undulose extinction may indicate fields which are not separated by cracks. It seems as if we are concerned here with a healing of cracks so that the fields grow together, but the polarization-disturbance remains. Sederholm[6]) accepts this explanation for analogous cases in granites of the Pellinge region, South-West Finland. For the Surinam rocks, at any rate, this does not hold good. On eliminating the nicols and diminishing the intensity of light extremely fine lines of demarcation may be observed here and there, and, moreover, in preparations showing intense pressure-action, there is no question of this so-called recrystallization, but of intenser disintegration. Another product caused by pressure is the so-called "Streifen quartz"[7]). It has already been recorded as occurring in the granites of the Tumuchumac mountains[8]) and the Coppename.[9])

Disturbances of plagioclase begin with undulose extinction. The plagioclases are evidently less brittle than the quartz, for bending is predominant and crushing only appears when the whole rock has been strongly influenced. The bending of twinning-lamellae is often accompanied by their wedging out (Pl. 41 fig. 2). The wedges of one lamella-system often come to a dead end in a field that polarizes homogeneously or undulosely. This field is identically oriented with on system. Such comb-like ending of groups of lamellae is frequent.[10]) As the lamellae in that case are always more or less warped, their wedging out is probably the result of torsion. Should this be so, we must also assume some plasticity of the plagioclase, for otherwise breaking would have taken place. The lack of lamellae in plagioclases, therefore, may be result of the wedging out of the two systems. New formation of lamellae in pressed plagioclases, as described by Van Werveke,[11]) is of very little importance. Beekman, however, says: „Le plagioclase renferme quelquefois des macles secondaires, différant des

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1) A. Thie. **57.**
2) H. N. Duyfjes. **58.**
3) J. A. Grutterink. **73.**
4) E. H. M. Beekman. **63.**
5) W. Bergt. **45.**
6) J. J. Sederholm. On migmatites and associated pre-cambrian rocks of south-western Finland. Part. I. Bull. Comm. géol. Finlande. No. 58. 1923. p. 114 etc.
7) Y. 9, 10, 234; V. 851, 1939, 1940, 2027.
8) J. A. Grutterink. **73.**
9) W. Bergt. **45.** p.p. **147, 148.**
10) Y. 33, 36, 83, 106, 124, 125, 288, 317.
11) L. van Werveke. Eigenthümliche Zwillingsbildung an Feldspath und Diallag. Neues Jahrb. Miner. 1883. II. p. 97.

macles primaires par leur caractère inconstant, et qui sont une résultante du dynamométamorphisme". (l.c. p. 88).

In microcline pressure-action manifests itself in the form of fractures and cracks and not by bending as in plagioclase. Even a slight shifting of the fragments betrays itself by the corresponding parts of the system of lamination no longer joining each other. Shifting along the intergrowth-plane of twins also often takes place. In imitation of Rinne some petrographers ascribe the microcline-structure in the Surinam rocks to pressure-action. Bergt [1]) assumes that in some cases this is undoubtedly so, but says at the same time that the structure of non-pressed microcline is primary [2]). Beekman assumes secondary origin in a few cases. [3]) The present writer cannot share this view. In his opinion the microcline-structure in the Surinam material is always of primary nature. In view of Rinne's publication [4]) no proofs for secondary nature could be gathered. According to Rinne where tensions assert themselves, microcline-structure is produced, while this is wanting where tensions have been neutralized by breaking. In the Surinam rocks we observe the most beautiful lattice-structure just exactly in the slightly pressed types, particularly in the numerous phenocrysts of the porphyritic Gran-rio granites, in their groundmasses, and in numbers of other slightly pressed granites. In some intensely pressed types, and in slightly pressed ones, lamination is only local and vague; hence, there is an inverse connection between the development of the grating-structure on the one hand and the degree of pressure-action on the other hand. In crushed rocks yet to be treated, however, grating-structure is practically wanting. We may often observe with plagioclase and microcline that crushing takes place at the edges of the crystal, while a rounded-off core is left, often oblong-shaped, showing the well-known "eye-structure".

Of the micas, biotite and muscovite, the last-mentioned is the first to be affected. Sections approximately vertical to the cleavage show bent cleavage-lines and the crystals are often undulose. Shifting of part of the crystals along the cleavage-planes especially occurs with biotite.

With pyroxenes, and this applies especially to the rocks of the Nickerie-region, pressure causes bent cleavage, mostly together with undulose extinction. Crushing begins particularly at the edges by the breaking off and carrying away of minute fragments, an irregular piece of pyroxene being left. These phenomena are shown both by orthorhombic pyroxene and monoclinic pyroxene.

It is remarkable that in hornblende, besides some undulose extinction, disturbances of some importance rarely occur, at least, rarely are recognizable as such. In some cases, however, this mineral is frayed at the edges or it passes into a mass rich in chlorite which adapts itself to transformation.

In case of still intenser pressure-action, when the rock partially passes into powder, ore and apatite are also affected. Ore is rolled out until it becomes black powder; apatite is only crushed.

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1) W. Bergt. **45.** p. 134, 136, 137, 138, 139, 142.
2) do p. 134.
3) E. H. M. Beekman. **63.** p. 88 and 96.
4) F. Rinne. Ueber Mikroklinstruktur. Neues Jahrb. Miner. 1890. p.p. 66—70.

Of other phenomena possibly due to pressure we have yet to mention twinning-structure, namely in titanite and calcite.

If we recapitulate the sequence of general mineral-cataclasm we find that first quartz reacts by undulose extinction and aggregate-polarization; next plagioclase and microcline show undulose extinction, afterwards warping and wedging out of the twinning-lamellae and fractures. In the next stage the micas and pyroxenes also react, beginning with bending and undulose extinction and culminating in crushing at the edges of the pyroxene. The latter phenomena are accompanied by considerable strengthening of those mentioned first; the feldspars in that case may show eye-structure. The reaction of the accessories follows last.

B. *Cataclastic gneisses.*

When cataclasm has affected the granitodiorites to such an extent that gneisses have been formed, the rocks usually show parallel texture in the sample, the minerals and mineral fragments having parallel trend. Microscopically the structure is quite different from that of the non-cataclastic ortho-gneisses; both rock-groups have this in common that crystallization-sequence of the main components is lacking, but in the first group this was caused by mechanical deformation, in the latter group it is considered as primary structure. A structure, however, that has much in common in both groups is the "eye-gneiss structure", for the eyes may as well be the result of intense pressure on large crystals, as primary, poorly developed phenocrysts, in non-cataclastic gneisses.

It should be emphasized here that the forming of new minerals, and recrystallization are unimportant. I never found indications showing that crushing may be accompanied by recrystallization as was suggested by Van Hise [1]) and Grubenmann [2]).

Primary structure may wholly or in part have been rendered unrecognizable by cataclasm, and in the first case it is difficult to say whether the rock under consideration was once a rock with normal crystallization-sequence, or a gneiss with primary gneiss-characteristics, on which cataclastic gneiss-structure was superimposed. Indeed rocks of both groups appear to have been the primary material of our cataclastic gneisses, as is proved by the remnants of primary structure.

It appears that all the cataclastic gneisses which we have at our disposal are derived from igneous rocks; the broken and crushed minerals together always form a combination typical for ortho-rocks. Besides, it is known that they occur in the field together with less disturbed equivalents. So there is no doubt about the origin of these rocks.

The changes in structure caused by pressure are the same as we have discussed already in view of the minerals separately, and it is only their frequency and intensity that stamps the rock as a cataclastic gneiss; besides

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1) c.p. C. R. Van Hise. A treatise on metamorphism. Washington. 1904. p. 738—740.
2) U. Grubenmann. Die Kristallinen Schiefer. Berlin. 1910. p. 61.

the rocks may be crushed in such way that locally mylonitic parts occur, quite of the type that will be discussed farther down.

Here follow some typical representatives.

A rock, having the mineralogical composition of a hornblende diorite, but showing unmistakable gneiss-structure, was collected on the Andira fall, New river (Y. 301). The grain is but ½ mm. and even smaller. Here and there coarser feldspar-crystals, up to 2 mm. occur. The mineralogical composition is green hornblende and plagioclase whilst ore and apatite are present in relatively large quantities. Brown biotite is very much in the minority. All of them are without the slightest trend. The hornblende showing tints ranging from pale yellow to grass-green, is now more or less rounded-off, now patchy, or scattered as fragments among the colourless minerals. The latter is also true for the brown biotite. The plagioclase (little more acid than oligoclase-andesine) shows rounded-off pieces of various size, lying in a mass of smaller and more angular grains, while all show strong undulose extinction. The absence of twinning makes it difficult to distinguish the mineral from quartz, the more so as pressure has affected the interference-figures; yet quartz appears to be present sporadically. Ore sends out frayed branches between the mineral-grains, which have been crushed by pressure. Rounded-off apatite-grains are present in fairly large quantities. While the rock mineralogically has the composition of a hornblende diorite, its structure is that of a gneiss.

An ortho-gneiss with the mineral-combination of a quartz mica diorite was collected on the Courantyne on the right bank opposite the most Easterly mouth of the New river (Y. 299). The sample falls into more or less lens-shaped pieces, being partly covered with a shining mass of biotite. Some pyrite and red garnet are to be distinguished here and there. It is not improbable that some motion of the parts mutually took place along the biotite-clad fracture-planes of the sample. Microscopically it indeed appears to be intensely pressed. We observe much plagioclase and biotite, less quartz, a fair quantity of ore, some pyrite and apatite. Coarse plagioclases (andesine) which show but an indication of idiomorphism, lie in a fine mass of plagioclase-grains and quartz-grains. Warping and also wedging out of the plagioclase-lamellae is common. Non-disturbed twinning-systems occur in the coarse crystals. The quartzes are, as a rule, undulose and crushed into aggregates, which, surround the coarser quartz-grains as if the latter had been rolled out. Biotite is frayed intensely, particularly where the pressure-phenomena in the other minerals are strongest. Other crystals, however, with an indication of a base are not warped at all; hence it is the question whether the frayed boundary-lines of the biotite are really a result of pressure. Irregular pieces of ore are present in pretty large quantities; they form ramifications among the other mineral-grains. It is not improbable that the abnormal appearance of ore is a result of pressure. Apatite is present in fairly large quantities in the form of oblong-shaped grains and rods and has not been affected. On the whole the rock exhibits considerable pressure-action. It has not, however, come to recrystallization and the formation of new minerals. The original rock seems to have been a quartz mica diorite with very poorly developed sequence of crystallization.

For the preceding types it was supposed that pressure-action was chiefly responsible for the gneiss-structure of the rock. This is even more probable with regard to the rocks which are going to be described now. As the first example let us mention a rock from the Upper Courantyne not far from the mouth of the Lucie river (Y. 287). In the sample it has gneiss-habitus with well-defined parallel texture, and shows a tendency towards parallel cleavage. It is fine-grained, light gray variegated. Microscopically it appears to consist of plagioclase, quartz, microcline and a good percentage of biotite. The plagioclase contributes towards the characteristic texture of the rock, the crystals being oblong. The composition is oligoclase-andesine. The twinning is wanting completely in by far the majority of cases, or is very vaguely present. Intense undulose extinction is frequent, with the result that at first sight we mistake the plagioclase for quartz. The microcline-structure of potash feldspar is vague and more often entirely wanting. This feldspar, too, is of an oblong shape, rounded-off; more strongly refracting perthite-fibres are visible here and there. While the feldspars, therefore, give the trend to the whole, this is equally true of the quartz. This is still more strongly influenced by pressure; oblong, rounded-off crystals, have been divided into numerous undulose fields. Strings of quartz-grit, mixed with some feldspar, run parallel to the general trend and surround feldspar-crystals. On being strongly magnified an extremely fine mixture of quartz and feldspar is revealed in these strings, the feldspar being potash feldspar. The biotite is striking because of being frayed to a great extent. (Pl. 41 fig. 3 and 4).

As accessories there are only some apatite, insignificant isotropic orthite-pseudomorphs and some zircon. Where orthite-remnants border on biotite, pleochroitic haloes occur, and the same applies to the sparse zircon.

A still more strongly cataclastic gneiss was collected in the Courantyne, 5 km. below the mouth of the Lucie river. The sample (Y. 323) was taken from an extensive exposure showing parallel texture trending NW.—SE., and dipping almost vertically. In the sample strings of biotite run practically parallel. These strings are but a few mm. in breath. Between them lie feldspar and quartz, all smaller than 1 mm. These lighter-coloured parts in places broaden out to lenses of 15 × 5 mm. maximum-size. They are very conspicuous owing to their aplitic composition and lend to the sample a "flaserig" appearance. Some larger crystals appear here and there; they have a maximum-length of 7 mm. and are rounded-off, like the eyes of eye-gneisses. Their maximum-length does not interfere with the rest, and quantitatively they are not important. Microscopically the rock shows very considerable mechanical disintegration without any re-crystallization. Locally the structure is mylonitic. It is composed of potash feldspar, plagioclase, quartz, with little hornblende, and primary epidote, and contains titanite, apatite, ore, orthite, and zircon as accessories. Hence the mineral-combination is granitic. The very well-defined trend of the sample also finds expression in the thin-section by the coloured minerals being arranged to a great extent in the form of undulating strings; the colourless minerals between them, in so far as they have not been completely crushed, show the same trend. The greenish-brown biotite is rolled out, while larger crystals have been bent. The biotite is quite fresh. Traces of green hornblende are found by the side of the biotite. The epidote, in spite of pressure-action, shows the characteristics of primary epidote (page 188): a well-developed prism-zone and corrosionforms. A few pieces enclose orthite-remnants. Other pieces have been more or less torn into fragments. Titanite is present in large quantities as rounded-off pieces showing pressure-twinning. The apatite, too, lacks idiomorphism and occurs in rounded-off pieces, while a few pieces arranged in a row give us the impression that they have arisen from a larger crystal by crushing. Ore is present in the form of irregular and rolled-out pieces. The colourless minerals have the same characteristics as in the former rock. The plagioclase and potash feldspar are pretty well devoid of lamellae, there are but vague traces of them locally, which should, in my opinion, be regarded as relics of lamination and not as a new formation. We observe, however, that very fine groups of lamellae shoot out from the sides in one single plagioclase. These lamellae are possibly of secondary nature. They intersect the fragment only at the edges. This is the only case in which, in my opinion, recrystallisation of plagioclase-lamination has taken place. From the coarser colourless mineral-fragments we find all stages of transitions to powder winding in zones and strings through the thin-section. This grit consists of a very feebly refracting component (potash feldspar) and a stronger one (quartz), in parts possibly of plagioclase too. Such strings will be described more in detail in one of the following rocks as mylonitic zones.

The Nickerie-region has furnished us with various cataclastic gneisses, and here again we recognize what the original material was. This applies to a couple of rocks of quartz hypersthene dioritic mineral-combination (V. 1994, 1998, 2089) already described by Beekman as ortho-gneisses. In the rock V. 2089 the primary structure and texture have got as good as lost. The sample is banded. Microscopically it appears to contain diallage and very little hypersthene, which together are present in much smaller quantity than the plagioclase and the copious quartz. The plagioclase contrasts with the quartz on account of its greater refraction. Some magnetite, apatite and zircon are to be found. The abundant quartz and partly also the feldspars are rolled out to strings consisting of various polarizing-fragments. These strings wind through less crushed, lens-shaped rock-masses, which still in parts reveal, the original structure (Pl. 41 fig. 5 and 6). Intense pressure-action finds expression even in the latter. The plagioclase is here abnormally undulose and the twinning has been warped and wedges out. The pyroxene and the ore have scarcely been affected. In the strings numerous coarse feldspars occur, oblong-shaped and rounded-off. They all show signs of intense pressure and begin to break down. At first sight the pyroxene and particularly the diallage seems to be more resistant. The cleavage, however, points to intense warping, while on closer observation the rounded-off forms are also to be ascribed to crushing, judging from the strings of very fine pyroxene-grit lying in the vicinity. The ore is, to a large extent, rolled out to powder. The apatite and zircon only, have not been affected by pressure. It is obvious that the banded, gneissose habitus is entirely due to cataclasm.

Other rocks, as a result of cataclasm, have assumed eye-gneiss-structure. Eye-gneisses were foud by our expedition on the Courantyne in a fall above the King Frederick William IV fall which is marked on the English map as the Were-kitto fall. At the foot of one of the rapids gneisses occur indistinctly trending N. 55° W. and dipping perpendicularly. In the rock (Y. 297) the white, rounded-off feldspars stand out in great numbers against the black groundmass, which is rich in biotite. The largest feldspars are 2 cm., smaller ones, of a few mm. in size being by far the commonest, however. In the groundmass, besides white plagioclase and biotite, coarse orthite-crystals, more or less rounded-off, and with the colour of pitch, are present locally in large numbers. They belong to the coarsest orthite met with in the Surinam rocks, having a maximum length of 5 mm. Microscopically the feldspar-eyes appear to be solely plagioclase (oligoclase to oligoclase-andesine), while potash feldspar only occurs here and there as antiperthite (with microcline-structure) in the plagioclase. The plagioclase betrays intense pressure-action: the twinning, in so far as it is present, is usually bent or wedged out, while undulose extinction is common. The rest of the minerals: quartz, biotite, muscovite, ore, apatite, zircon, titanite and epidote and very sparse calcite invariably wind themselves between and around the rounded-off feldspars. That pressure has played an important part in the formation of this rock, may be seen from the warping and drawing-out which some of these minerals namely biotite, muscovite and epidote have undergone.

The epidote partly surrounds the coarse orthite as a rim. Apatite asserts itself in the form of rounded-off grains. The ore is partly octahedral in shape, but in the pressed portions it is present both as powder and grit. The sample as a whole gives the impression that the texture of the rock has been considerably disturbed by pressure-action in which the larger rounded-off feldspars possibly have been involved in a rotary movement. Yet there are still characteristic relics of the original structure. The octahedrons of magnetite, the apatite (in part), besides some zircon, have not been affected. The coarse orthite does not seem to have been affected by pressure either. The mineralogical composition is quartz-mica-dioritic.

A second eye-gneiss was collected on the Wilhelmina river, source-river of the Gonini (V. 745). The eyes are only visible microscopically. The sample shows nothing new. A third takes part in the upbuilding of the rocky weir which causes the first large fall in the Courantyne below the mouth of the Lucie river (Y. 324, 325; Pl. 19 fig. 1). In the latter rock mylonitic parts occur, which will be discussed farther down.

C. *Mylonites.*

When the rocks undergo very intense pressure, mylonites appear. The Surinam mylonites appear always to be derived from igneous rocks, as is shown by the undisturbed remnants of the original rock, occurring here and there. The process of mylonitization may be followed step by step in the material, and corresponds with the descriptions given elsewhere, e.g. with those of the Aiguille-Rouges massif by Reinhard and Preiswerk. [1]) Our mylonites are derived both from normal igneous rocks and from ortho-gneisses.

In the first place mylonite-formation may be developed locally in the sample; in this case we observe crushing along micro-faults. The latter sometimes betray themselves macroscopically as they are usually provided with masses of secondary epidote, as e.g. in a quartz mica diorite from the Grutterink mountains (V. 837). Microscopically we observe the same in V. 839, collected near the preceding rock. These rocks form the first step towards perfect mylonites. We shall describe some of the latter.

A rock collected on the Pikien-rio between Adjoko and Santi creek may serve as an example of a mylonite (Y. 76; do V. 1831). The normal rock there is biotite granite, normal-grained, sometimes bearing hornblende or diopside and characterized by microcline-phenocrysts up to 2 cm. in size. A zone, 8 m. broad, of gneissose rock intersects the granite, with a distinct trend (N.—S.), the schistosity dipping 60° W. Numerous flesh-coloured microcline-crystals show parallel trend; they do not show a single crystal-face. They lie in a variegated groundmass, which bears little specks of feldspar, and much green material as if it were chloritized. Microscopically we see the groundmass developed as a very fine mass, in which mineral-fragments are still recognizable (Pl. 42 fig. 2). The fragments are nothing but pieces of acid plagioclase and microcline. The former still shows intensely warped twinning; in the latter the relics of an undulose lamella-system are recognizable. Some feldspar-fragments lie together in such a way that it is clear that they once belonged to each other; now they are separated by the groundmass. The groundmass itself consists of a very fine aggregate, which bears much potash feldspar and quartz. Strings of what once were the coloured minerals wind through the groundmass. These strings consist partly of chlorite, partly of innumerous hornblende-needles (actinolite), partly also of dust which allows of no definition. Together with chlorite, masses of epidote assert themselves. Ore also occurs, and judging from its octahedral shape, it is of secondary nature just as the actinolite, epidote, and chlorite. Possibly this mylonite has originated by motion along diaclases, which intersect the zones. In any case it is a local pressure-zone showing intense cataclasm.

The samples collected by others show that mylonites derived from granitodiorites are not rare in Surinam, but data are wanting to judge of the extent of the phenomenon in each case.

Two suchlike samples are to be found among the rocks collected by the Tumuchumac-expedition of which one (V. 1266) is a mylonitized quartz mica diorite; while the other (V. 1267) is described by Grutterink [2]) as piemontite-bearing porphyrite; in my opinion it should be regarded as a mylonite formed from a quartz mica diorite. Both rocks were collected at ½ km. from each other at the trail "Paloemeu-Sipaliwini river" of the said expedition, at some

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1) M. Reinhard and H. Preiswerk. Über Granitmylonite im Aiguilles-Rouges Massif (westliches Wallis). Verhandl. Naturforsch. Gesellsch. Basel. XXXVIII. 1927. p. 188.
2) J. A. Grutterink. **73.**

km. distance from the spot where the trail passes the watershed for the first time. V. 1266 consists of quartz and very acid, twinned plagioclase (albite). The latter clearly shows traces of idiomorphism towards the former but has also been very much affected by pressure. The lamellae are intensely warped, while numerous oblique cross-fractures are present, along which the twinning system has shifted. The quartz is crushed accordingly. Nothing is left of the original coloured minerals. At the time of crushing or afterwards abundant secondary epidote was formed, in the form of grains, pieces, and aggregates, which lie scattered amongst the mineral-fragments and which are also arranged in strings. Epidote and some sericite also occur in the plagioclase. Intense pleochroitic epidote (a piemontite-like type) also occurs. The distribution of both epidotes undoubtedly points to secondary origin, the latter being described by Grutterink in detail. Ore occurs as black dust, partly surrounded by titanite.

The next rock (V. 1267) may easily be recognized as a more advanced stage of the same process. Macroscopically it is a dense, rose-coloured rock, with feldspar-phenocrysts up to some mm. in size. Microscopically it appears once more to consist of the same mineral-components as the preceding rock and it also appears to be pseudoporphyritic, for the "phenocrysts" are nothing but coarse pieces of feldspar which have been spared in the middle of a completely crushed mass. The acid plagioclases (approximately albite) are considerably warped and the lamellae have shifted along cracks. Secondary epidote intrudes along the cracks and crosses the rock in all directions. The groundmass shows many quartz-fragments by the side of preponderant plagioclase. The secondary epidote in the form of grains and aggregates is present in still larger quantities than in the previous rock. It occurs particularly lying scattered in the groundmass. Here, too, intensely pleochroitic manganese-epidote occurs.

We observe about the same in a rock that originally must have had the composition of a biotite hornblende granite, from the Lucie river, not far from the spot where the latter approaches the Upper Courantyne nearest (Y. 279 B), and in a rock from the Sipaliwini, source-river of the Courantyne (V. 3492).

A mylonite from the Doméké island above the Awara fall, Lawa river is more interesting (V. 1059). It consists entirely of splinter-shaped or rounded-off fragments of microcline, acid plagioclase and quartz which alltogether must once have formed a granite rich in microcline. Indeed pieces of biotite still occur here and there, perfectly intact. The insignificant signs of pressure, which the fragments of the colourless minerals exhibit one by one are, however, striking. Only here and there, when closely examined, they show undulose extinction or some slight warping, and the changes are therefore of just as little importance as if we were concerned with a sedimentary breccia (Pl. 42 fig. 3). We have other granite-mylonites from the Tapanahony (V. 1226), and from the Lower Marowyne V. 2440: the latter locally still shows distinct relics of ortho-gneiss structure in granitic mineral-combination; it is apparently a highly crushed representative of the same gneisses as those which occur in the neighbourhood there. The rock is traversed by an irregular network of epidote-grains and coarser aggregates.

Of special interest are those mylonites of which it is clear that their formation was accompanied by considerable shearing. Such mylonites are to be found locally in some cataclastic gneisses. The finest example, however, is furnished by the mylonites derived from the cataclastic gneisses of the first fall below the mouth of the Lucie river, in the Courantyne, which have been mentioned on p. 337. These mylonites are of special interest, as they may be regarded as the initial stages of the pseudo-tachylytes which cut them. Here then we see cataclastic gneisses locally crushed to such an extent that only here and there feldspar-eyes have been left, lying in a mass of the finest mineral-grit, in which strings occur that originated from one single, entirely rolled-out crystal. These strings are chiefly composed of quartz. In ordinary light they look homogeneous, and show branching (Pl. 19 fig. 2). Between crossed nicols, however, they resolve into innumerable fields. It is remarkable to see how these fields run about parallel to the main trend of the strings. These strings, by stronger refraction clearly distinguish themselves from a surrounding mass, composed of the finest rock-grit (as is distinctly to be seen on the photo, too). This grit on being strongly magnified always resolves into a mixture of quartz and potash feldspar fragments, of which the latter mineral predominates, hence this groundmass refracts distinctly more feebly than the balsam. The quartz-fragments in the mass are directly connected with the larger strings of quartz which have arisen directly from them by crushing. That the potash feldspar powder was also formed in the same way, is proved by the coarse fragments of feldspar that can still be recognized and the crumbling-off of grains at the sides. The changes that the coloured minerals have undergone in these rocks are remarkable. Fragments of biotite, epidote, orthite, zircon, titanite and apatite seem to have lasted longest. On the whole the coloured minerals have been replaced by a coloured powder. It is possible, too, that the coloured minerals have again supplied the material for the extremely fine reddish-brown pigment, abundantly present in the finest parts.

Very typical is also a mylonite from the Blanche Marie fall, Nickerie river (V. 2018, 2019). The sample shows fluidal texture: dark streaks, slightly bent, running parallel in a pink, dense groundmass. These streaks are a mm. or less broad, and are separated by light-coloured zones of several mm. in breadth. With a pocket lens it is to be seen that the dark streaks divide and unite repeatedly. Also streaks which appear to be composed of quartz are present. Here and there feldspar-eyes, oblong, rounded-off and up to 2 mm. occur; the streaks wind around

Plate 19.

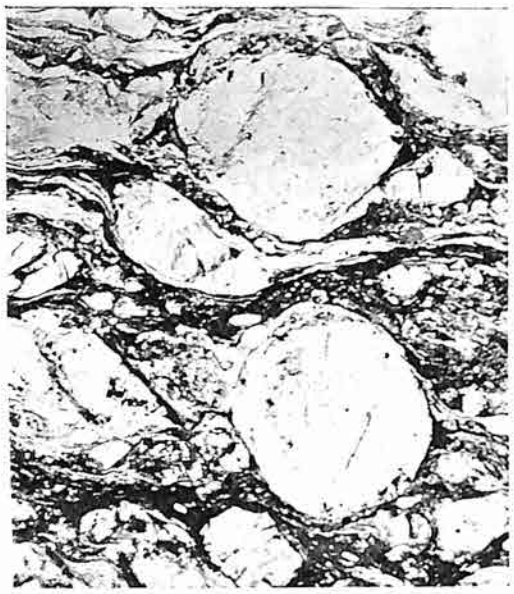

Fig. 1. Cataclastic eye-gneiss. Feldspar eyes in groundmass with fluidal texture. × 8. (Y. 324).

Fig. 2. Detail of mylonitic part of eye-gneiss showing rolled out quartz streaks. Crossed Nicols. × 40. (Y. 324).

Fig. 3. Pseudotachylyte (black) intruding into biotite granite-gneiss. Coppename river. (V. 2339).

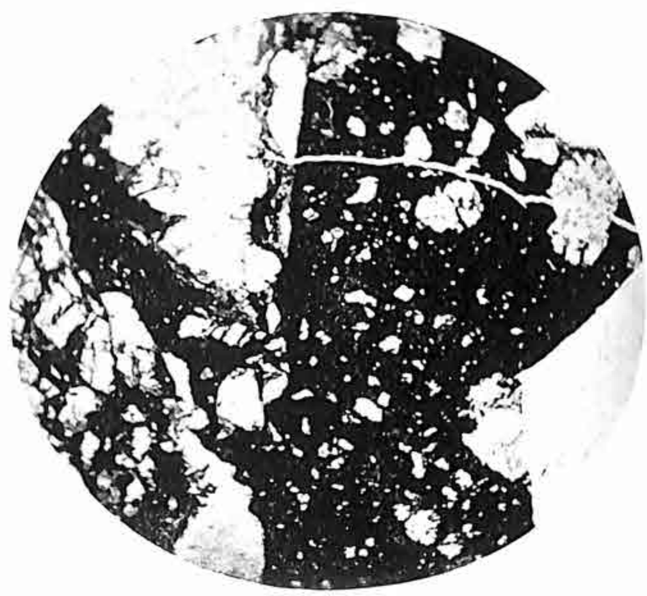

Fig. 4. Pseudotachylyte vein with apophyses in crushed granite gneiss. × 9. (Y. 324 B).

them. Microscopically the pink groundmass appears to consist of a very delicate grit of quartz and potash feldspar, of the type described above. Streaks alternate with it; those of quartz form a mosaic. These streaks come to the fore owing to stronger refraction. The dark streaks are composed of a strongly refractive and undeterminable pigment, together with dust derived from ore. All the streaks are nothing but rolled out quartzes and dark minerals. In the potash feldspar-eyes, here and there microperthite is to be seen. These eyes are strongly undulose and broken up. The rock furnishes a fine example of mylonite-structure: it is no felsophyre, as it has been called by Beekman. [1])

It will probably have been noticed that many of the rocks just discussed show an important percentage of secondary epidote. As typical examples may be mentioned moreover two mylonites of quartz mica dioritic mineral-combination from the Njam creek (V. 30) and from the Tosso creek (V. 1139). Irregular masses of epidote and grains nestle themselves among the mineral-fragments, and besides this, assert themselves particularly in the plagioclases. The feldspars have a more acid composition (approximately albite) than we might generally suppose to occur in the original rocks and it is therefore clear that the epidote has wholy or partly consumed the anorthite-percentage of the primary plagioclase.

D. *Pseudo-tachylytes (Ultramylonites).*

When the Surinam material present in the Geological Laboratory at Delft was placed at my disposal Dr. P. Kruizinga, curator, was so kind as to draw my attention to the occurrence of pseudo-tachylytes among the material from the Coppename.

In two places in the Colony it was observed that highly cataclastic rocks are traversed by dykes and veins of almost dense, black rocks, which at first sight might be mistaken for basaltic rocks. On closer inspection, however, it appeared that they are equivalent to the remarkable rocks occurring in South-Africa described as "pseudo-tachylytes" by Molengraaff and Hall and to the "flinty-crush-rocks" in the Outer Hebrides described by Jehu and Craig, and to rocks from elsewhere described by other petrographers. [2]) Pseudo-tachylytes have been found by our expedition in the first large fall in the Courantyne 15 km. below the mouth of the Lucie river. The rocks of the large fall are partly cataclastic eye-gneisses, locally even real mylonites (p. 338; Pl. 19 fig. 2). Where the rock is crushed most, it is penetrated by basalt-like veins and strings. The coarsest veins are 1 dm. thick. Now they have a constant trend, and run parallel to the texture of the rocks, now they run in all directions, getting alternately broader and narrower. The line of demarcation between the dark

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1) E. H. M. Beekman. **63.** p. 108.

2) A bibliography concerning pseudo-tachylytes and allied rocks is given here:

C. T. Clough. The Geology of the Cheviot Hills. Mem. Geol. Surv. Gr. Britain. 1868. p. 22.

Sir Thomas Holland. The Charnockite Series, a Group of Archaean Hypersthenic Rocks in Peninsular India. Mem. Geol. Surv. India. XXVIII. 1900. 2. p. 191.

B. N. Peach and J. Horne. The Geological Structure of the Highlands of Scotland. Mem. Geol. Surv. Gr. Britain. 1907.

C. T. Clough, H. B. Maufe, E. B. Bailey. The Cauldron Subsidence of Glen Goe land and the Associated Igneous Phenomena. Quart. Journ. Geol. Soc. LXV. 1909. p. 611.

P. Termier et J. Boussac. Sur les mylonites de la région de Savona, Comptes Rendus. LII. 1911. p. 1552.

P. Quensel. Zur Kenntnis der Mylonitbildung, erläutert an Material aus dem Kebnekaise-gebiet. Bull. Geol. Inst. Upsala. XV. 1916. p. 91.

S. J. Shand. The Pseudo-tachylyte of Parijs (Orange Free State) and its Relations to "Trap-Shotten Gneiss" and "Flinty Crush-Rock". Quart. Journ. Geol. Soc. LXXII. 1917. p. 198.

T. J. Jehu and R. M. Craig. Geology of the Outer Hebrides. Trans. Royal Soc. Edinburgh. LIII. 1925. pp. 419 and 615; LIV. 1926. p. 467; LV. 1927. p. 457.

A. L. Hall and G. A. F. Molengraaff. The Vredefort Mountain land in the Southern Transvaal and the Northern Orange Free State. Verhandelingen der Koninklijke Acad. Wetensch. Amsterdam (2e Sectie). XXIV. 1925. No. 3.

material and the adjoining rock is sharply defined, but veins may locally penetrate into the gneiss as a delicate network. The veins show numerous inclusions from the adjoining rock, up to 1 cm. in size, contrasting by their light colour with the black tint of the veins.

As is evident from the descriptions of Essed [1]) and the material presented by him to the Geological Laboratory at Delft, that the geological appearance of the pseudo-tachylytes on the Coppename river must be the same; Essed, however, does not call them pseudo-tachylytes:

"After having carefully examined the rocks in their mutual relations, I arrived at the conclusion, that a powerful mass or laccolith of gabbro rose below the granitite, which was pushed up and ruptured in three principal directions, the rents being filled with gabbromagma, that in some parts consolidated under diminished pressure into diabase, into gabbro where the consolidation took place under the weight of a considerable mass of overlying rocks.

But besides that, it looks as if the granitite, in being pushed up by the intruding gabbro, had been at the same time profoundly shattered, so that the gabbromagma found little difficulty in making its way amongst the fractured and sundered masses, forming what is called an injection plexus. Moreover, it inserted itself along the planes of foliation and even between the crystals of felspar and quartz, apparently absorbing parts of the invaded rock, altering the felspar into a turbid granular mass, sometimes of a reddish colour, then again greenish or snowwhite, itself having turned at last into an amorphous, dark green glass, which through devitrification assumed a somewhat finely granular aspect, very much like aphanite, at last giving rise to a new rock, that may be considered, partly as a mixing, partly as an intermingling of the granitite and the gabbro." (l.c. p.p. 336, 337).

Some samples of granite-gneiss from the Coppename show dense, basalt-like veins (Pl. 19 fig. 3). One sample (V. 2342) has quite the same habitus as the granites traversed by pseudo-tachylytes from Vredefort area collected by Molengraaff and Hall, and present now at Delft. Another Surinam sample (V. 2341) exhibits pseudo-tachylyte masses, enclosing quite a number of fragments of the adjoining granite gneiss.

Microscopically the rocks reveal numerous interesting phenomena. Let us begin with those from the Courantyne.

At first sight we recognize more or less numerous fragments of the adjacent rock in an almost opaque groundmass. The fragments are now rounded-off, now angular (Pl. 19 fig. 4; Pl. 42 fig. 4—6). They show all the pressure-phenomena of the eye-gneisses from the same place: pronouncedly undulose plagioclase-remnants, whose lamellae are warped or more often entirely absent, a few remnants of potash feldspar, rounded-off, or intensely rolled-out quartz, fragments, bearing both rolled-out strings of quartz and a very fine groundmass rich in potash feldspar, and a few pieces of titanite, apatite and green hornblende. We often observe how these fragments disintegrate and are subdivided by the opaque groundmass which penetrates along cracks. Some cavities give the impression of being corrosion-cavities, although this is not

[1]) E. Essed. **105.**

certain. The opaque groundmass in thin-sections appears to be more or less transparent and also crystalline. The components are: first black ore-dust, which causes the poor transparency of the sections, and further numerous colourless microlites. They are lath-shaped, maximally 70 μ long, their thickness amounting to 1/16 of this. Others are broader and shorter. On being strongly magnified they show coloured material, being in the centre arranged parallel to the lenght of the crystal, on account of which, it appears that the lath is wholly or partly split lengthways (fig. 52 b and c) or only the extremities are split: a. Here and there appear rectangular almost square sections with a centre coloured by pigment of the same form: d. The latter are somewhat coarser than the laths, but it is not impossible that they are cross-sections of the short and thick laths, while the dark centre would in that case correspond to the pigment-stripe of the longitudinal section. The laths lie scattered about; locally, however, they are arranged in the form of stars. The composition of these microlites is unknown, but probably they are plagioclases (see p. 342). The material between the laths, in so far as it is not opaque, is not quite colourless, sometimes brownish and cryptocrystalline. Locally brown masses assert themselves, which show no laths, but these, too, appear to be non-amorphic; sometimes they show spherolithic extinction (Y. 324 B. II). At the edge of the same thin-section a less dark lot appears; it is free of laths, but contains octahedral ore-dust coarser than the ore-dust in the darker parts.

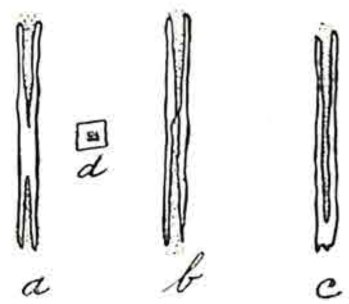

Fig. 52.

Microscopical examination of the samples from the Coppename reveals the following: The granite-gneiss which is cut by the pseudo-tachylyte is, in places, intensely pressed; the quartz has disintegrated and changed into a finely polarizing aggregate; while locally the whole rock is crushed (Pl. 42 fig. 1). Next to this, however, lots occur which have been less affected. On the whole then the crushing does not go on so far as in the rock of the Courantyne. Microscopically the pseudo-tachylyte-veins appear to wedge out in the crushed lots of the gneiss and form a fine network in the fragments. In the veins numerous angular- or rounded-off fragments of the adjacent rock are met with. They are pieces of different minerals or rock-fragments. Besides the colourless minerals of the granite-gneiss, rounded-off chloritized remnants of the coloured minerals and also pieces of unmodified ore occur. The groundmass has a composition differing from that described for the Courantyne rocks. The colour is greenish. With the aid of strong magnification we discover numerous greenish grains, rounded-off and oblong. They certainly constitute the greater portion of the material (V. 2342). We might mistake them for hornblende, the polarization-colours corresponding to those of this mineral. It is, however, far from certain that they are primary minerals in the pseudo-tachylyte groundmass, as chlorite-formation, etc., in the adjacent rock also suggest a modification in the material of the veins. Other components are of but little importance; but the whole mass is crystalline.

The microscopical resemblance between the pseudo-tachylytes of Surinam and those of South-Africa and the Outer Hebrides is great. Prof. Molengraaff has kindly placed the S. African material at my disposal for comparison. At first sight we are struck by the similar appearance of enclosed fragments of the adjoining rock, which invariably show the same characteristics of intense crushing. For a comparison with the groundmass only the tachylytes from the Courantyne can be taken into consideration, those from the Coppename having undergone changes. The groundmass of the pseudo-tachylytes from the Courantyne shows some resemblance to pseudo-tachylyte which cuts gabbro at Kaffer-kop (not far from Parijs in the Vredefort-region) viz. as to the large quantity of ore-dust. On their being strongly magnified we fail, however, to discover the lath-shaped microlites in the latter rocks.

It is striking that the same type of microlites as occurs in the groundmass of the Courantyne rock is also found in the flinty crush-rocks of the Barra Islands of the Outer Hebrides. According to Jehu and Craig the ortho-gneisses are intersected by the flinty crush rocks there. In their description they state (l.c. LIII. 1925. p. 434), "occasionally slides prepared from the more acid types display a felt of feldspar microlites arranged in radial groups". These microlites are regarded as belonging to the groundmass: "A further stage of the incipient recrystallization of fused material is beautifully shown in a slide cut from a pseudo-conglomerate pebble from the beach at Baghnam black, North West Barra. Radiate groups of feldspar microlites are well-developed in a part of the slide" (l.c. p. 436). These microlites are pictured and if we examine the photo closely, the resemblance to the Surinam microlites is unmistakable: here too, we are concerned with clear lathshaped crystals which seem to have split up lengthways, while extremely fine, coloured material fills the central channel. The tendency towards radial arrangement, is, as has been stated, also shown by the Surinam microlites. Jehu and Craig do not describe the microlites any further, and do not mention their structure. Judging from the illustration the ony difference is that the Scottish microlites are coarser, the coarsest attaining to almost 0.2 mm. These feldspars resemble those which not unfrequently occur in basalts or diabases.

The connection in Surinam between the veins and the crushed adjacent rocks is just as conspicuous as in South-Africa. The intense shearing in the adjacent rock on the Courantyne, closely resembles that near Twin-kopjes on Rietpoort near Parijs (l.c. Pl. XIX, fig. 2). The signs of pressure in the adjacent rock on the Coppename correspond to those usually occurring at Vredefort. The enclosed fragments of adjacent rock have the same habitus in both countries; we should mention, however, that fragments of ore and relics of coloured materials may occur, while these are extremely rare in the African rocks (l.c. p. 104). The gradual transition between the most finely crushed lots and the pseudo-tachylyte material, recorded by Molengraaff-Hall, cannot be observed in the Surinam thin-sections; even the lots most finely crushed, which are enclosed in the tachylytes from the Courantyne, show no transitions; this is not surprising, as the tachylyte-material seems to have re-crystallized. A chemical comparison between the tachylyte-material of the Courantyne and the adjacent rock must be omitted as the former is crowded with inclusions even to the minutest particles.

For a theoretical consideration of the origin of the pseudo-tachylytes, we cannot do better than refer to the opinion of Molengraaff and Hall, in connection with their study of the rocks in South-Africa.

Distribution of pressure phenomena in the Colony.

It appears that rocks absolutely devoid of pressure-traces are rare, and these rocks invariably are found in the neighbourhood of others which have been more or less affected; hence it is not possible to point out a single region of considerable size quite free from cataclasm. We may truthfully say that the granites of the Gran-rio massif on the Tapanahony are, relatively speaking, the least pressed, but we are well acquainted with every stage of the crushing-process there. The distribution of cataclasm in the other regions locally varies very much; rocks showing undulose or crushed quartzes, often accompanied by warped feldspars, are by far the most common; those showing intense cataclasm are scarcer; mylonites, pseudo-tachylytes and also gneisses whose features are a consequence of cataclasm are still less common. Intensely pressed rocks are abundantly present in the material from the Nickerie region.

Let us conclude with the supposition that pseudo-tachylytes will certainly be found in many other places in Surinam, taking into consideration the frequency of intense pressure, shown by the rocks of the basal complex. In connection with this we may mention that some samples from the Upper Kabalebo river, and also from the King Frederick William IV fall in the Courantyne suggest that pseudo-tachylytes are present there, but owing to the poor state of the material at our disposal, our supposition needs further confirmation.

XI. FURTHER DISCUSSION OF THE ORTHO-GNEISSES AND THE GENESIS OF THE ORTHO-GNEISSES.

INTRODUCTION.

In this chapter a summary of our data about the ortho-gneisses is given, besides which the important question as to whether the gneiss-characteristics are of primary or of secondary nature is discussed. In order to answer the latter question, we must first treat the gneiss-characteristics of the Surinam rocks at greater length. If anyone should afterwards occupy himself with the Surinam ortho-gneisses and come to other genetic conclusions than are given in the following pages, he will do well to bear in mind that only the theoretical side of the case is disputable, the morphology having been fastened down as much as possible in illustrations.

Among the Surinam ortho-gneisses we can distinguish three groups of different genesis:

I. Ortho-gneisses whose gneiss-characteristics are primary.

II. Ortho-gneisses whose gneiss-characteristics were caused by cataclasm.

III. Ortho-gneisses which are the recrystallized equivalents of basic igneous rocks, gabbros, diabases etc.

The following remarks have reference especially to group I and II.

We will discuss group III with the recrystallized ortho-schists.

A. REMARKS ON THE ORTHO-NATURE AND THE GEOLOGICAL RELATION OF THE GNEISSES.

Proofs of the ortho-nature of the rocks mentioned as ortho-gneisses.

We may put the question whether the rocks, mentioned as ortho-gneisses in the previous descriptions, do indeed possess ortho-nature, and whether confusion with para-rocks is excluded. The arguments in favour of the former supposition are of three kinds, viz. the mineral combination, the texture of the rocks, and the structure. Mineralogically we may compare the gneisses direct with the granitodiorites which we have discussed. This comparison holds good even in detail. The granite-gneisses which we classified as facies with the Gran-rio granites, are mineralogically quite their equivalent. The same applies to the acid or basic diorite-gneisses which form part of the "diorite-facies", and also to the gneisses and gneissic rocks which we met as the equivalents of the rocks of the Nickerie-region, while a single gneiss of the De Goeje mountains is nothing but a gneissic facies in an igneous rock of the same composition. Of the gneisses we discussed under the "Remaining granitodiorites" we sometimes can not indicate direct equivalents among the igneous rocks, owing to their more variable composition and to the lack of data, but mostly the contrary is true.

There occur in many of these gneisses minerals, which are very characteristic of the normal igneous rocks, viz. primary epidote and orthite. Both may serve as "guide minerals" to distinguish the ortho-gneisses from para-rocks.

This applies of course only to the area under discussion. In connection with this it may be observed here, that also in the Schwarzwald the mineral orthite has been made use of as guide mineral to distinguish the "Schapbach gneise" (ortho-gneisses) from the "Rench-gneise" (para-gneisses).

A second argument for the ortho-nature of these rocks, which equally applies to all of them, is the absence of minerals that are characteristic of metamorphic sediments.

Needless to say that the chemical composition of the gneisses also proves their nature. As has been discussed the tables on page 234 and 288 show analyses of gneisses which are the chemical equivalent of igneous rocks with normal structure.

In the same manner the texture, the stereometrical relation of the minerals may serve as an argument in favour of their ortho-nature. Apart from the presence or absence of parallel texture, the minerals are regularly distributed in the rock. In para-gneisses on the contrary we generally find irregular distribution: local amassments of one or more kinds of minerals, lenticular or zonary and banded arrangement. These irregularities in the stereometrical relation may serve as clues to distinguish para-gneisses.

Geological relation between ortho-gneisses and granitodiorites of similar composition.

Of prime importance is the question whether the ortho-gneisses throughout the Colony are related to the granitodiorites, or whether there is a difference in age between the two, in this sense that either the granitodiorites break through older gneisses, or the gneisses are of a more recent date. The answer has been given repeatedly in the preceding pages, and a summary brings out clearly that most ortho-gneisses are nothing but a structural facies of the granitodiorites, of which they form the mineralogical equivalent, so that there can be no question of a separation owing to difference in age; at any rate this is very plausible for most of the ortho-gneisses. We have stated this for the granite-gneisses which are the mineralogical equivalent of the Gran-rio granites, for many gneisses of the diorite-facies of these granites, for several of the gneisses discussed under the "remaining granitodiorites", and for several pyroxene gneisses of the Nickerie region (see p. 276).

The cataclastic ortho-gneisses show the same geological connection.

In the chapter on allo-metamorphism we have set forth, that these gneisses show relics of original structures, which justify the view that rocks with a normal crystallization sequence, and also ortho-gneisses of group I, have been the origin material. Intense cataclasm has destroyed the structures and the textures of the original material, and has brought about or intensified parallel texture. The cataclastic rocks are united by intermediate types with the original material, and the process can be traced step by step. We have seen that recrystallization is of no significance. Indeed, secondary minerals such as epidote, chlorite etc. can be formed from the dark minerals, but recrystallization of the colourless main components does not take place, so the process is above all cataclasm.

B. REMARKS ON THE MORPHOLOGY OF THE ORTHO-GNEISSES.

Gneiss-habitus in the sample and in the field.

It is not always easy to decide from the habitus of the sample, whether we may entitle the rock as a gneiss, or not. Many granitodiorites show some parallel texture in the sample, but microscopically appear to be no gneisses. In that case the dark minerals, especially biotite, are somewhat equally directed. It is a habitus that is often attributed to primary fluidal texture.

On the other hand we also have rocks that show no parallel texture at all in the sample and yet microscopically decidedly prove to be gneisses. This is illustrated by the granite-gneisses of the Lower Marowyne (e.g. Vtz. 395, 465, 478; V. 31, 415), in the area of the Suriname river (V. 1373, 1484, 1489, 1490) locally near the Marowyne creek (V. 1676), on the Coppename (V. 1475, 1476, 2334, 2336, 2345, 2346, 2347), locally between Lawa and Tapanahony (V. 86, 115, 117, 118, 391, 761, 821), locally near the Paloemeu river (V. 1196), and likewise by some acid diorite-gneisses near the Suriname river (Y. 15, 33, 36, 37). They prove that gneiss-characteristics need by no means be attended with parallel texture as is rightly emphasized in some handbooks.

Other gneisses again show only indistinct to slight parallel texture in the sample (Pl. 34 fig. 2). From the habitus in the sample one is not inclined to call the rock a gneiss, though it is so indeed. Others again show distinct parallel texture and may at once be recognized as gneisses (Pl. 20 fig. 1).

As all the types mentioned here may occur together with normal igneous rocks which may show some parallel texture, it is as good as impossible to distinguish sharply between the Surinam ortho-gneisses of group I and the granitodiorites in the field. This brings out the necessity of microscopic examination before using the name of gneiss.

A macroscopic comparison of the Surinam ortho-gneisses of group I with those from other parts of the world, shows that the Surinam rocks generally display remarkably regular distribution of the minerals.

Microscopic structural and textural types of the ortho-gneisses.

By the term structure is meant the form and size of the crystals; by texture is meant the manner in which the components are added together, i.e. the stereometric relation. The two ideas are here kept apart as much as possible. The structure of the gneisses (group I), in opposition to that of the normal igneous rocks, is characterized by the absence of a sequence of crystallization. The minerals mutually impede each other as if they crystallized contemporaneously, contending for space, without one of the principal components succeeding in bringing about idiomorphism. This fundamental difference between the two groups of rock appears very clearly in the Surinam ortho-gneisses. The structure of our ortho-gneisses is in many respects closely related to that of the crystalline schists which Becke, Berwerth and Grubenmann [1]) entitle as "crystalloblastic".

[1]) F. Becke, F. Berwerth, U. Grubenmann. Petrogr. Untersuchungen der kristallinen Ge-

Plate 20.

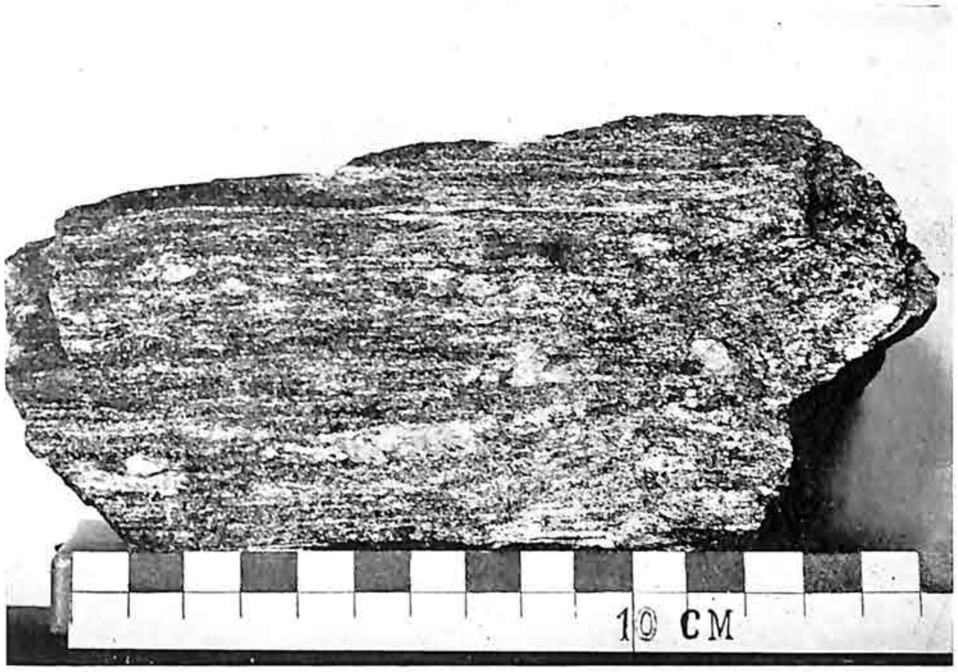

Fig. 1. Biotite granite-gneiss showing distinct parallel texture.
King Frederick William IV fall, Courantyne. (Y. 270).

Fig. 2.

Fig. 3.

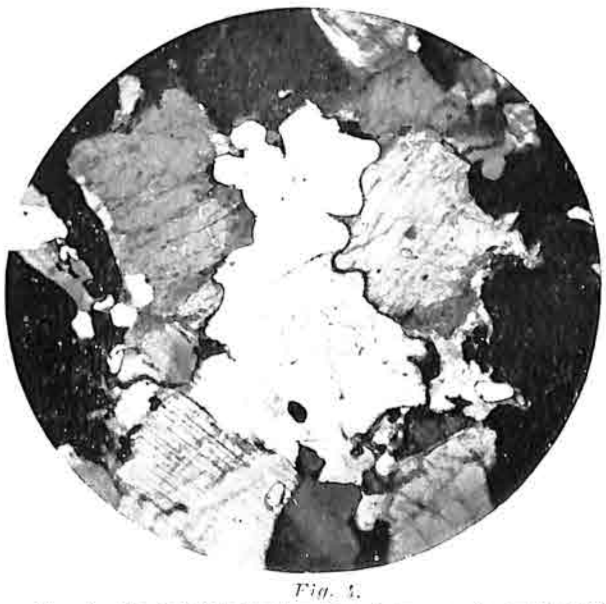

Fig. 4.

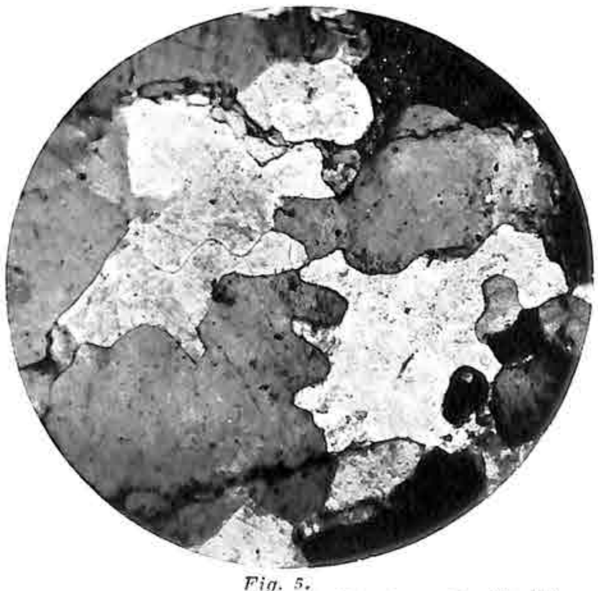

Fig. 5.

Fig. 2. Undulating border lines between plagioclase and quartz in diorite-gneiss. Suriname river. Crossed Nicols × 31. (Y. 30).
Fig. 3. do. × 13. (Y. 33). *Fig. 4.* do. Marowyne creek. × 32. (V. 1658).
Fig. 5. do. between potash feldspar and quartz. Coppename river. × 32. (V. 2347).

As the name indicates, Becke c.s. think of secondary structure, the recrystallization of minerals, growing from old nuclei. This name cannot be applied here, because the structure of our ortho-gneisses is to be looked upon not as secondary but as primary. In our case there are not only points of agreement but also points of essential difference in relation to the crystalloblastic structure. For the sake of comparison we subjoin the characteristics of the ortho-gneisses of group I by the side of the eight principal points by which the crystalloblastic structure is characterized in the publication quoted (l.c. p. 35—36).

Structural characteristics of the Surinam ortho-gneisses.

1a. The colourless principal components mutually impede each other, possess no crystalline shapes and seem to have crystallized contemporaneously.

1b. However, they do not enclose each other, as yet.

2. Where something is visible of crystal-faces, no bearing on the cleavage can be observed, though in case of the feldspars there is of course the greatest chance of the faces running parallel to (001) or (010).

3. Skeletons are not wholly absent; granophyric intergrowth may be very locally developed.

4. The absent sequence of crystallization of the colourless principal components absolutely holds good for the ortho-gneisses in the most typical form; if locally imperfect sequence of crystallization is to be seen, it occurs only with plagioclase.

5. Parallel texture may be developed by equal direction of the dark

Characteristics of the "crystalloblastic structure".

1) Die wesentlichen Gemengteile des krystallinen Schiefers sind gleichwertig, keines ist vor dem anderen krystallisiert, wie die Einschlüsse beweisen, jeder Gemengteil findet sich gelegentlich als Einschlusz in allen anderen vor.

2) Ausbildung von Krystallformen ist verhältnismäszig selten. Die vorhandenen Krystallformen sind stets sehr einfach und oft parallel der Spaltbarkeit. Häufig treten Individuen auf, welche nur eine Krystallfläche zeigen, die einer Spaltfläche parallel geht, oder nur eine Zone von solchen Krystallflächen, sonst aber der Krystallflächen entbehren.

3) Es fehlen durchwegs durch Voraneilen des Kanten- oder Eckenwachstums entstehende Skelettbildungen.

4) Nach der Ausbildung der Krystallform lassen sich die Gemengteile in eine Reihe mit abnehmende Krystallisationskraft bringen, so dasz jedes in der Reihe voranstehende Mineral in Berührung mit einem nachfolgenden seine Krystallform zur Ausbildung bringt.

5) Parallelstruktur kommt zustande nicht allein durch Parallelstellung

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steinen der Zentralkette der Ostalpen. I. F. Becke: Über Mineralbestand und Struktur der krystallinischen Schiefer. Denkschr. Kaiserl. Akad. Wissensch. Mathem. Naturw. kl. 1903.

minerals only, or by that of the colourless minerals as well. There is no reason to see a secondary texture in this. Parallel texture may also be entirely absent.

6. Zonal structure is absent from the typical ortho-gneisses, if traces of it are shown by the plagioclases, the nucleus is more basic than the border zone.

7. Inclusions are of very little importance, except liquid inclusions in quartz and occasionally unimportant inclusions in both quartz and feldspars.

8. The structure of the orthogneisses is compact.

fertiger Krystalle mit ihren Längsdimensionen (wie bei der Fluidalstruktur der Erstarrungsgesteine), auch nicht blosz durch mechanische Kataklase, sondern durch die Begünstigung des Wachtens der Gemengteile in der Richtung senkrecht zur stärkeren Pressung. Sie gewinnt den gröszten Teil ihrer Wirkung, wenn Minerale vorhanden sind, die ihrerseits begünstigte molekulare Wachstumsrichtungen haben.

6) Zonenstruktur fehlt den Gemengteilen oder ist, wenn vorhanden, von anderer Ausbildung und folgt anderen Regeln als bei den Erstarrungsgesteinen.

7) Die Einschlüsse der Krystalle folgen zumeist nicht der Zonenstruktur, sondern entsprechen entweder dem Aufbau aus Anwachspyramiden oder sie lassen eine ältere Gesteinstruktur erkennen.

8) Die krystalloblastische Struktur ist schlieszlich durch die möglichste Kompaktheit der mit ihr ausgestatteten Gesteine charakterisiert. Weder blasige noch zellige marioliti-sche Strukturformen sind mit ihr vereinbar.

Regarding these points we may observe:

Point 1. There are very important differences between the two types of structure in so far that with the crystalline schists all principal components behave equivalently; with the Surinam ortho-gneisses, however, it is especially the colourless principal components that come into consideration for this relation. It is a remarkable fact that the gneiss-characteristics of the Surinam ortho-gneisses are based entirely on the structural relations of the *colourless* minerals. The dark minerals show in their shape and other characteristics no deviations at all from the corresponding minerals in normal igneous rocks.

Under "1 b" attention was drawn to another important point of difference with the crystalline schists, viz. the absence of mutual inclusions, which is essential to crystalloblastic structure. To be sure, drops of quartz sometimes occur in the feldspars of our ortho-gneisses, but this phenomenon is always of little importance, and is also known to occur in a slight degree in normal igneous rocks. Points 2 and 3 reveal no marked differences; point 3 owing to the small importance of the skeletons in the ortho-gneisses. Point 4. There can hardly be question of a "krystalloblastische Reihe" for the reason that as a rule there are only two or three colourless principal components present (quartz and plagioclase, either with or without potash feldspar); of these, plagioclase crystallizes "more strongly" than the two others, for this mineral shows a vague inclination towards idiomorphism. If we want to include the dark mineral components and accessoria in the series as well: they show the same crystallization sequence as in the corresponding igneous rocks. Point 5: The argumentation of the thesis that the paralleltexture is not secondary, follows later.

We might still add to this list, that in the ortho-gneisses, leaving the eye-gneisses out of consideration, the granular size of the components generally differs little; in the crystalline schists it may be very variable especially in the same rock.

The essential differences between the two types of structure may be found in points 1 and 4. The absence of mutual inclusions in the components (of course, only the colourless principal components are meant) is the cause that with our ortho-gneisses, structures that are entitled as kelyphitic, poikiloblastic, and sieve-structures do not occur.

As, however, mutual inclusions may also be little developed in the crystalline schists sometimes, the latter may also show structures that hardly differ from that of our ortho-gneisses, especially if the mineral combination does not essentially differ and the distribution of the minerals is equable with an even size of the minerals. For metamorphic rocks the term "granoblastic structure" is used in that case. Especially metamorphic biotite gneisses may show the same structure as part of our ortho-gneisses.

Our ortho-gneisses, all lacking in sequence of crystallization show various structures, however, distinguished by the shape of the colourless principal components which may be "irregular", "undulating", or "polyhedral". Here follow some details.

a) The "irregular type". In stead of crystal-faces there appear angular or curved borderlines (Pl. 33 fig. 6, Pl. 35 fig. 2 and Pl. 38 fig. 6). The grains are approximately of the same size or differ more or less. If the latter is the case, we may often observe that the smaller grains have a tendency towards polyhedral shape. We may lay down as a general rule that the principal components behave in the same manner, no matter whether similar or dissimilar minerals come into contact with each other.

The tendency towards poikilitic structure is of very slight importance, occasionally an initial stage of it may be observed (Pl. 35 fig. 1). Parallel texture of the colourless and coloured minerals may occur. If the parallel texture has an abnormally strong development, it may somewhat resemble the "lepidoblastic structure" which we know especially in mica-schists (Pl. 39 fig. 2).

b) The "undulating type". The border-lines have a more or less pronounced undulating course here (Pl. 35 fig. 4 and 5; Pl. 20 fig. 2, 3, 4 and 5 show this in detail). If the grains are comparatively large, the course is not so obvious at first sight; it appears as a notching at the edges of the crystals (e.g. Pl. 35 fig. 4). Parallel texture may be present or absent.

c.) The polyhedral type. This is characterized by equal shape of the grains. This type differs from the first in that the polygons are more equilateral. This structure is at its best if the grains are isodiametrical. Then we have the equivalent of the "Pflasterstruktur", which we know in hornfels, amphibolites etc. This may also be attended with parallel texture. We have come across both types in the discussion of the hornblende gneisses of the "Diorite-facies" (Pl. 36 fig. 2).

The first two structures may also occur side by side. The same mineral-individual may also show them simultaneously. Consequently the differences are hardly essential; they must be considered as variations of the same structure, and must probably be attributed to the same causes genetically.

None of these three structural types are specific for the ortho-gneisses of Surinam, but they occur just as well in gneisses of numerous other localities; images of entirely the same nature may be found in the descriptions of gneisses, for instance those of Bohemia and the "Schwarzwald".

Structure and texture in gneissic granites and diorites.

We have numerous rocks showing structures keeping midway between those of normal igneous rocks and of gneisses. We came across them especially when discussing the "Diorite-facies". But they also occur in the other groups of rocks. In that case a small part of the colourless crystals show an idiomorphic face or angle, and by far the majority show irregular shape; besides other crystals on account of their general shape often remind us of the idiomorphic type, without having pronounced crystal-faces though. It is especially in the larger crystals that this structure occurs. Attention should be paid to the fact that here again the plagioclases especially show partial idiomorphism. This holds good for the gneissic granites as well as for gneissic diorites. The adjoining illustrations give some idea of such partially idiomorphic plagioclases.

The crystals which are irregular in shape locally show, crystal-faces (a), which may sometimes be recognized as such, because they run parallel to cleavage or twinning. They may form idiomorphic angles (*b* fig. 2 and 6). In other places the irregular border-lines may show the same undulating course as with the "undulating type" (point c. in fig. 1, 3, 4, 6). Upon the whole the general form of the comparatively large crystals suggests crystalline shape.

Rocks rich in such types are here entitled as *gneissic granites, gneissic diorites,* etc.

Becke c.s. [1]) have introduced the name blasto-granitic, blasto-dioritic, etc. for gneissic rocks and gneisses whose structure reminds us of normal igneous rocks by local crystal-shapes. In doing so they thought of relic-structures and consequently considered the gneissic characteristics as secondary; so these terms do not apply here.

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[1]) l.c. p. 48.

If indications of idiomorphism are present in a comparatively large quantity,

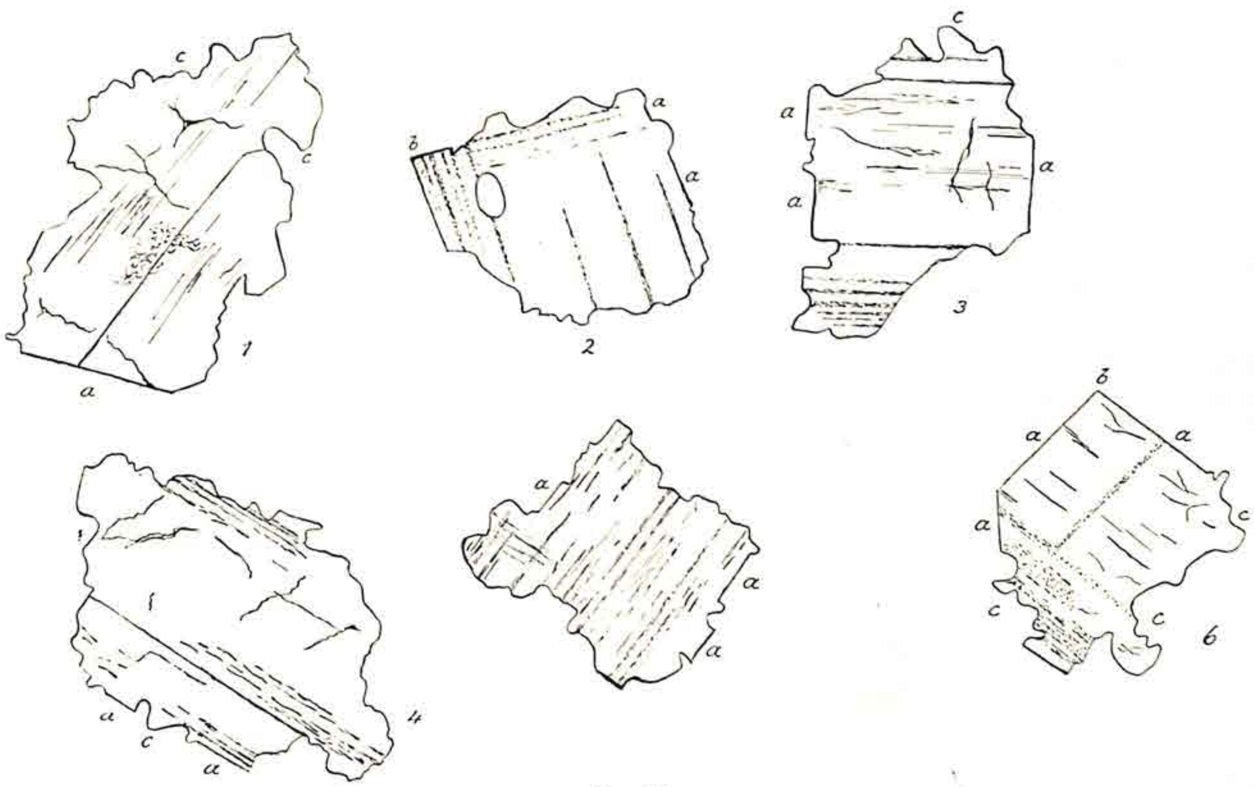

Fig. 53.

the question arises as to whether we had not better group the rock with the igneous rocks showing indistinct sequence of crystallization (such as we see them for instance in section B. of the scheme on p. 226). If, on the other hand, they are very scarce, the question arises whether it would not be better to classify them with the gneisses. Here, too, there again occur types with or without parallel texture; likewise, the dark minerals do not essentially contribute to the gneiss characteristics. It should be mentioned that gneissic granites and gneissic diorites from other areas, are often entitled as "gneisses" merely. This is indeed rational, with reference to an uninterrupted gneiss-area, where the intermediate forms are of secondary importance. So it is possible that part of the rocks which are here called "gneissic" would be considered by others as perfect gneisses.

C. ON THE QUESTION WHETHER THE STRUCTURE OF THE SURINAME ORTHO-GNEISSES IS PRIMARY OR SECONDARY.

Objections against secondary nature: primary nature is probable.

Of prime importance is the question whether the gneissic characteristics of the ortho-gneisses of group I must be considered as being of secondary or of primary nature. As had been said, *primary genesis* is probable. To start with, we shall discuss three arguments which, in my opinion, exclude secondary genesis.

1) We have seen that the ortho-gneisses are now regionally dispersed, now again occur very locally. The "Upper-Courantyne-area in a wide sense" may serve as an instance of the former; the second case however, is more general in the rest of the Colony. Very remarkable is the occurrence of rocks of the same mineralogical composition, partly with crystallization-sequence and partly with gneiss-structures, within the limits of small areas. Indeed, both forms are found locally within some tens of yards and even less. In the preceding chapters we have repeatedly come across examples of this. In view of these facts it is clear that we cannot allege in explanation any process of metamorphism that influenced large areas more or less equally. The distribution of the phenomenon, which may even vary in one and the same sample, seems to me an unsurmountable obstacle for any theory of secondary genesis.

2) Important is the fact that the structural characteristics of the Surinam ortho-gneisses do not appear to be entirely limited to typical gneisses, as they occur locally just as well in igneous rocks with normal structure. A few examples may illustrate this. Fig. 54 represents idiomorphic plagioclases, with the local deviating structure. Near *a*. we see plagioclases bordering on quartz; the line of demarcation between the two minerals is undulating. This local structure is entirely of the same nature as we see it throughout the sections of gneisses with the undulating structure type. When once our attention has been arrested, we find the same structures in other rocks. Fig. 55 shows a

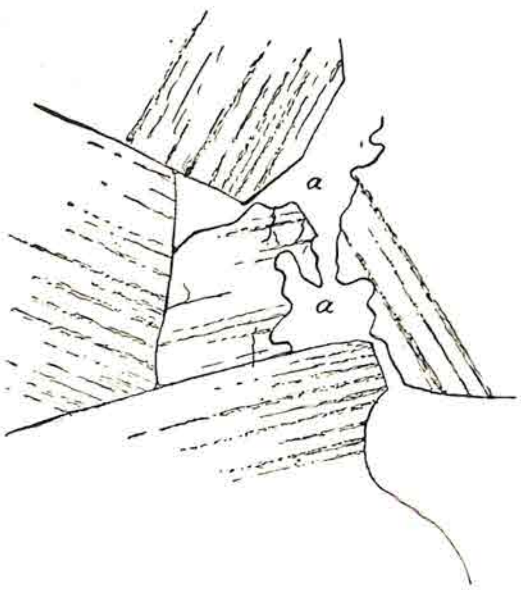

Fig. 54.

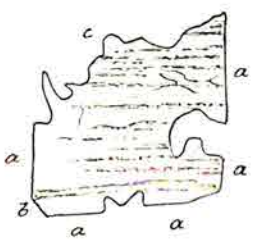

Fig. 55.

plagioclase (from a quartz mica diorite of the Tapanahony river, V. 122). It shows crystalfaces (a) and even idiomorphic angles (b) but at the same time undulating border lines (c). Such a crystal is comparable to those from gneissic rocks, represented in fig. 53. On the other hand this quartz mica diorite shows excellent idiomorphism of the acid plagioclases (approximately oligoclase). The same phenomenon is to be seen in other rocks with predominating clear sequence of crystallisation, if we examine them closely.

This fact pleads against a secondary genesis of the gneiss-structure. If we assume a secondary genesis for the very local gneissic characteristics of the examples given, we come into conflict with the fact that idiomorphism has been preserved chiefly in its most beautiful form. If we want to consider these local gneissic characteristics as the first beginning of metamorphism, we are faced with the problem, why such excessive forms appear as the deep cavities in the plagioclase represented in fig. 54.

3. It is remarkable that the structures of the dark minerals in the ortho-gneisses and corresponding igneous rocks are the same: presence or absence of crystalline shape, phenomena of corrosion, etc. With regard to biotite it must be stated that irregular shape may indeed be present, but this shape can by no means be equated with the fringy shape which, for instance we often meet with in para-gneisses. Hornblende in the acid diorite-gneisses has the same irregular shape, with a tendency towards idiomorphism of the prism-zone just as in the corresponding acid diorites. Our primary epidote shows again the fine cavities and channels which are attributed to corrosion and the same tendency to idiomorphism. With titanite, all characteristics summed up for this mineral may be found again in the gneisses. If recrystallization of the colourless minerals had taken place, the abovementioned dark minerals ought to have recrystallized too. Such radical changes as those which the colourless minerals should have undergone, in order to pass from a rock with sequence of crystallization into a gneiss with the structure of the "undulating type", would inevitably have caused irregularities, no matter of what nature, in the structure of the dark minerals. [1])

These three arguments, especially the last two, plead strongly against the secondary nature of the structure of our ortho-gneisses. It seems probable that the same arguments also hold good for many ortho-gneisses in other countries. The problem why these gneisses show deviating primary crystallization with regard to normal granitodiorites has not yet been solved, however.

On page 287 we have drawn attention to two gneisses the chemical composition of which does not agree with that of typical ortho-gneisses. The abnormal composition is caused by the

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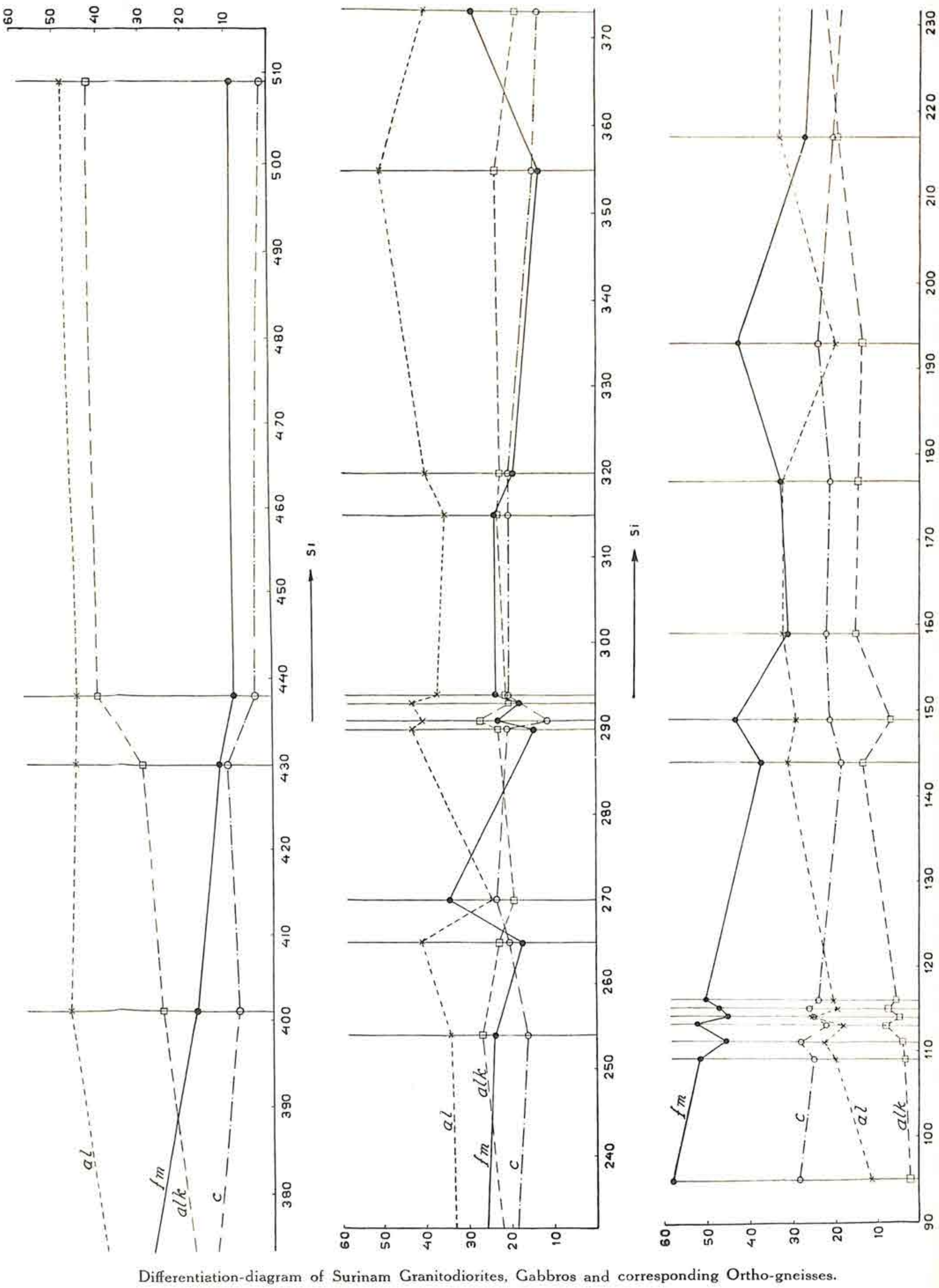
[1]) In connection with this, we might draw attention to the myrmekite of quartz and plagioclase, which is of rather frequent occurrence in our ortho-gneisses. For this, primary nature is nowadays generally assumed. For a long time, however, opinions differed a good deal. Some authors have changed their minds in course of time. Sederholm, who introduced the name myrmekite, considered it as a secondary product (Bull. Comm. géol. de Finl. Nr. 6. 1899. Über eine archaische Sedimentformation im Südwestlichen Finland); afterwards he recanted this opinion and advocated primary genesis. F. Becke, on the other hand, who has greatly enhanced our knowledge of myrmekite, first assumed primary nature (Tscherm. Miner. u. Petrogr. Mitt. IV. 1883. Die Gneiss formation des Niederösterreichischen Waltviertels p. 211), later on, however, (Becke c.s. l.c. p. 139) he mentions myrmekite for igneous rocks as well as for crystalline schists. Grubenmann seems to consider undisturbed myrmekite quite possible in metamorphic rocks: „Die Zweiglimmergneise.... sind weit verbreitet und sowohl nach Textur als nach Struktur in allen den Variationen zu finden, welche vorn beschrieben worden sind. Die etwas kataklastischen, Mikroklin und Mikroperthit führenden Gneise mit reichlichen Myrmekit gehören in den Regel hierher" (O. Grubenmann. Die Kristallinen Schiefer, 2nd edition 1910, p. 153).

In my opinion primary myrmekite, no more than any other subtle primary structure, can remain unaltered under metamorphism, and starting from the primary nature of this formation, we might allege the myrmekite-structure also as an argument against the secondary genesis of the ortho-gneiss characteristics.

very large percentage of biotite. We have pointed to the possibility that these rocks are para-gneisses. The even texture, however, renders it probable that we have to do with ortho-nature, and we suppose a disturbance during magmatic crystallization to have caused the abnormal concentration of the biotite. It does not seem unlikely to us that these gneisses originated under the influence of piezo-crystallization.

We suppose that the biotite crystallized before the colourless main components. Possibly a tectonical disturbance influenced the rock before its crystallization had come to an end, with the consequence that the still liquid parts of the magma flowed away under the influence of stress; the biotite which had already crystallized would, according to this theory, have remained behind and have concentrated in this way. That this "explanation" is highly speculative need hardly be said.

Plate 21.



Differentiation-diagram of Surinam Granitodiorites, Gabbros and corresponding Ortho-gneisses.

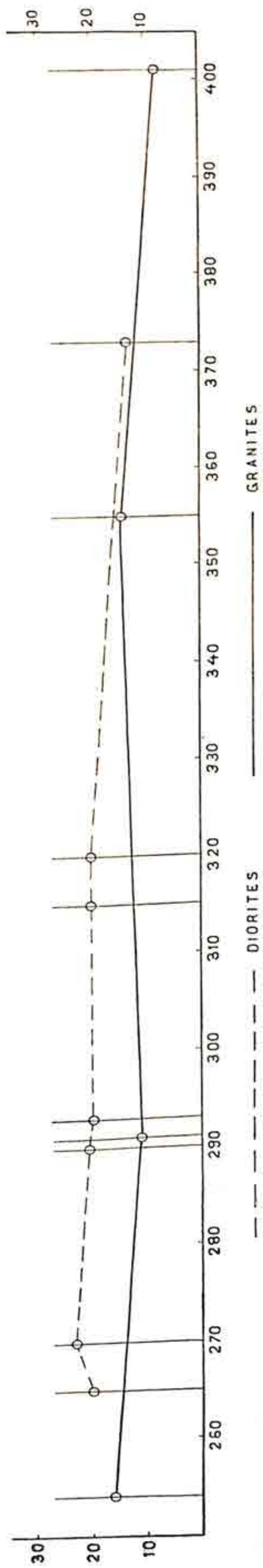


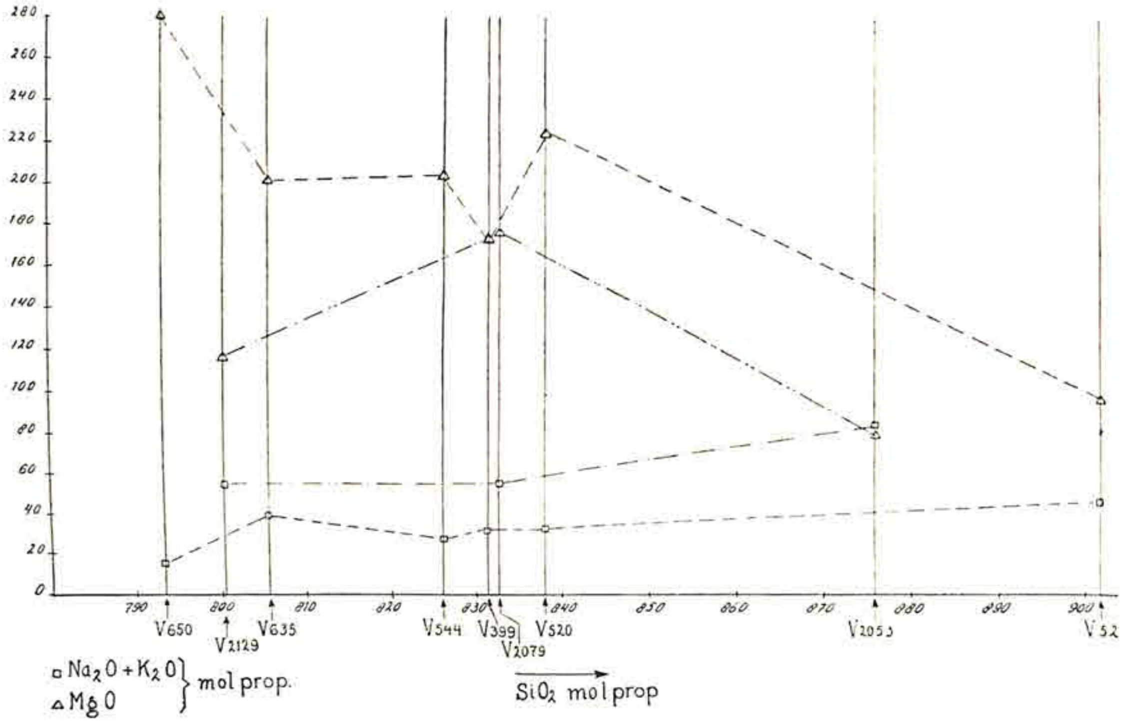
Fig 56.

XII. GENERAL SPECULATIONS ON THE IGNEOUS ROCKS OF THE BASAL COMPLEX.

At the completion of our discussion of the granitodiorites a few remarks will be superadded on their correlation and genesis. It goes without saying that these speculations are far from complete and refer to a great variety of facts.

The granitodiorites belong to a co-magmatic province for the following reasons. 1° Among the acid granitodiorites local differences of facies invariably bring on the same combinations of rock-types. In this respect our ortho-gneisses behave like the granitodiorites with normal structures. 2° In many rocks we encounter a cerium-bearing epidote (orthite) and sometimes also monazite, which implies that the magmas of these rocks are characterized by constant accessory components. 3° The rocks show constant features of secondary importance, such as the frequency of primary epidote, the occurrence of microcline, etc.

All the Surinam granitodiorites belong to the calc-alkali series. For the sake of completeness we subjoin a diagram of the variability of the values fm, c, al, and alk in connection with si (Plate 21). For the construction of the diagram all the available analyses have been laid under contribution, except a few that seem unreliable or examplify very local types. The diagram shows a decrease of fm, and c, and an increase of al and alk with ascending si-value, as usual. The acid rocks are characterized by great variability of the fm- and al-values; any direct connection between these values and si cannot be demonstrated. The c-values of the acid diorites are greater than those of the granites with a corresponding si, which is the normal condition (fig. 56). The basic rocks, however, reveal local features. As we have seen a far-going differentiation locally occurs in the basal complex; viz. in the De Goeje mountains, and in the Nickerie region. There we find gabbros, norites, and troktolites. They are the most basic members of a rock-series, which are looked upon as differentiations of the Gran-rio massif in the De Goeje mountains. Fig. 57 gives the amount of MgO and $Na_2O + K_2O$ of the gabbros and the allied rocks in molecular proportions. In case of an equal SiO_2 percentage the rocks from the De Goeje mountains have a greater magnesium content than those from the Nickerie region. But the rocks from the latter region contain a larger percentage of alkalis than those from the De Goeje mountains. On comparing our gabbros with those used by Niggli in computing the normal gabbroid and noritic magma [1]) the alkali-content appears to be surprisingly low in the De Goeje mountains, but in the Nickerie-region it agrees with the average found elsewhere. The percentages of the other oxides show in both regions no striking differences, for which reason they have been omitted in the diagram.



– – – – – – – Rocks of the De Goeje mountains.
–··–··–··–·· Rocks of the Nickerie-region.

Fig. 57.

The difference in chemical composition is reflected in the mineral assemblages. The relatively high magnesium amount coincides in the De Goeje mountains with the frequency of bronzite and enstatite, ergo magnesium-rich members of the hypersthene-enstatite series. The basic rocks of the Nickerie region, however, contain chiefly hypersthene, which has a larger amount of iron. Olivine often occurs in the basic rocks of the De Goeje mountains (olivine gabbros, troktolites); we do not know any olivine-containing types in the Nickerie region.

It should be observed that on the Coppename river probably a differentiation occurs analagous to the one found in the De Goeje mountains, although our data are too scanty to warrant this supposition (Hebiweri mountain).

The fact that only few syenites are present renders it probable that typical alkali rocks are wanting in the Colony. An albitite, described on p. 161, is possibly an alkali rock; a sample for analysis is not at our disposal; probably we have to do here with an aplitic dyke-rock, or vein, so that the rock is quantitatively of little significance.

We suppose all the granitodiorites to be of pre-Paleozoic age, as the basal

[1]) P. Niggli. Gesteins- und Mineralprovinzen. I. Berlin. 1923. p. 128.

complex continues into the Amazon basin (State of Para) and is there overlain unconformably by Paleozoic sediments, which begin with the Upper Silurian. As we shall see later on the granitodiorites from North Brazil do not differ essentially from the Surinam rocks and we are safe in assuming that we have to do with the same crystalline basement complex.

We have seen that the granitodiorites from the centre and the South-East of the Colony may be conceived as belonging to the same massif: the Gran-rio massif. Elsewhere in the Colony several of such massifs seem to exist, e.g. the granite-area on the Courantyne. We do not know whether these tracts are connected, and whether they are of the same age but we think it probable. In the field we can not help inferring that all the acid granitodiorites must belong to one uninterrupted granitodiorite mass extending beyond the boundaries of Surinam. We repeatedly see the same rock-types and the same differences of facies; moreover in the field we have never discovered facts pointing to age-differences. A few diorites known locally (Coppename) and the frequent pegmatites and aplitic dyke-rocks can not be considered as arguments for age-differences between large masses. It should be pointed out, however, that even in the best exposed riverbeds only a small percentage of the bedrock is visible.

The basic rocks in the De Goeje mountains are petrographically united by intermediate types with the granitodiorites of the Gran-rio massif, but their geology can only be surmised. In the Nickerie region, however, it has been established that gabbros and allied diorites of medium acid and acid composition traverse the granitodiorites partly as dykes, and are to be considered contemporaneous with the latter.

When discussing the crystalline schists we shall see that para-schists are next to exclusively confined to the eastern part of the Colony; the centre and the western part are occupied in so far as in known, by granitodiorites. Some of the schists are certainly older than the granitodiorites, and this is probably true for all the schists. The distribution of the rocks in the field renders it probable that the intrusive granitodiorites are also present below the schist-complexes; the latter seem to be only remnants of much more extensive complexes for the greater part carried away by erosion. The granitodiorites disappear eastward and northward below the schist region, and owing to erosion they become visible again in a number of places. That the granitodiorites extend below the schists results from the enormous dimensions of the igneous areas, and from their local appearance inside the schist region. They are typical bottomless intrusions, leaving no space for schists ar their base.

Regarding the Gran-rio massif we remark that it is a granitodiorite mass vying in size with the biggest batholits known elsewhere. This holds even if we confine ourselves to the core of the massif, which comprises the basin of the Upper Suriname river, the Gran-rio, the Pikien-rio, the Upper Tapanahony, and the Paloemeu river. For this region we may safely assume that it is occupied by a connected granitodiorite region. This core takes up, roughly estimating, an area of 20000 square km., or 8000 square miles.

Considering the unsettled demarcation of the Gran-rio massif we have not named it the Gran-rio 'batholith", but we have looked for a term less indicative of geological ideas. For want of a better one we have adopted the French word "massif" which is employed here for a vast, connected igneous mass whose boundary line has not been established on the surface.

I have stated above that the acid granitodiorites range mostly between acid granites and quartz-rich diorites. Some regions exhibit a constant composition, mostly porphyritic granites; others, however, show a local change occuring between the two extremes. In structure the rocks vary from normal igneous rocks to ortho-gneisses. Broadly speaking we can say that local variation in structure and texture is strongest where also the mineral combination of the rocks is subject to an intense local change. This little constant habitus is the more startling when we consider the large dimensions of the igneous areas. In such large masses we might expect on the contrary a regular change of facies consequent on very slow crystallization. We cannot account for the change of facies in the Surinam rocks so long as the theories about the causes of magma-differentiations are so intensely different, even for the best explored areas elsewhere. A few more remarks will be added here:

It is not probable that the local change of facies results from resorption of material from the country-rock. When discussing the Gran-rio massif we noted that acid diorites that form part of the massif are especially frequent in a zone at the North-East side of the massif, in the region of the "Diorite-facies". This region borders on and partly coincides with the distribution of the para-schists (vide fig. 43, p. 236 and map I). As we shall see the schists are mostly acid types, the majority calcium-poor; limestones are not known. It is, therefore, very improbable that the granite magma has produced diorites through resorption of schists.

Neither can resorption be the cause in other parts of the Colony. I have not been able to establish any significant phenomenon of injection, neither in the field nor under the microscope. Masses looking like inclusions and "Schlieren" are frequent in some areas, but they may as well be of endogenous origin.

It is remarkable that the Surinam mountains chiefly are composed of granites. The acid diorites, which together with the granites are so frequent in the exposures along the rivers, we do not know in the mountains. Many prominent tops, such as the Voltz-mountain, Kassikassima, Teboe, "Magneet" rock, etc. are composed of porphyritic biotite granite. So far as we know, the Emma chain and the Van Asch van Wijck mountains are formed by biotite granites. In the Wilhelmina mountains most ridges and tops consist of acid, for the major part even of aplitic granite. These facts might point to gravitation-differentiation, especially for the very acid rocks in the Wilhelmina mountains. In this connection it may be observed that corrosion phenomena of the dark minerals are very frequent in the Surinam granitodiorites; just think of the corrosion phenomena with biotite, hornblende and primary epidote, discussed by us. It is not quite impossible that these crystals have sunk in the magma and have undergone corrosion in zones of a higher temperature (as Bowen imagines). Similar corrosion phenomena, however, may as well be the effect of other causes. It is known, moreover, that the granites in the basal complex are quantitatively more frequent than the acid diorites, so the chances are in favour of the mountains being composed of granite. As a third possible interpretation we suggest selective erosion, which seems the most plausible. Some granite-types may be more resistent than the granitodiorites in their environs through a slight difference in composition.

The areas with great local mineralogical and structural variabilities might be imagined to represent parts of the igneous complex which have been crystallized in the neighbourhood of crystalline schists. It is a well-known fact that a similar variability often occurs near the contacts, whereas the central parts of the igneous masses show in general a homogeneous habitus. On this basis a frequency of remnants of the schist formation might be looked forward to in the environment of the Surinam areas with great variabilities. As yet we have no observations to support this view.

We have seen that the gneiss-features of most of the Surinam ortho-gneisses are considered to be primary. We do not know why the crystallization sequence of the main components of these rocks is wanting. We have pointed out that our gneisses show in part a parallel texture, whereas others are entirely massive. In most regions the degree of development of parallel texture is widely different; in others, however, the parallel texture of these gneisses is most often wanting. So there is no direct genetic relation between the absence of the crystallization sequence and the occurrence of parallel texture. It might be imagined that the parallel texture is a consequence of piezocrystallisation. According to Weinschenk the parallel texture in the marginal zone of the Alpine granites results from crystallisation under stress (piezocrystallisation). We do not know whether there is also in Surinam a similar correlation, contacts between the ortho-gneisses and the schists having never been examined.

INTRODUCTION TO THE CRYSTALLINE SCHISTS.

Next to the granitodiorites the crystalline schists are the most important rocks in Surinam. They also form part of the basal complex. According to our present knowledge, they occur especially in the Eastern part of the Colony [1]).

The crystalline schists belong to numerous groups of sedimentary or igneous origin. It appears that quantitatively the sedimentary schists surpass the ortho-schists by far, contrary to the opinion expressed formerly.

The same characteristics used elsewhere to distinguish para- from ortho-rocks, namely, the species of minerals found, their structure and texture and the presence or absence of relics are also here brought forward. They have been verified in typical representatives of some groups by chemical analyses; the last method could be applied, however, on a small scale only.

The following scheme has proved to be fit for the discussion of the schists.

Sedimentary or Para-schists	I.	The Sillimanite- and Cordierite gneisses.
	II.	The Garnet- and Staurolite-bearing Mica schists and corresponding gneisses.
	III.	The Mica gneisses and Hornblende gneisses of sedimentary origin.
	IV.	The Graywacke formation.
	V.	The Quartz Calcite Chlorite Albite schists and allied rocks.
	VI.	The Quartz Sericite Calcite schists and allied rocks.
	VII.	The Quartz Chlorite and Quartz Chlorite Sericite schists.
	VIII.	The Chloritoid schists and Chloritoid phyllites.
	IX.	The Phyllites and Clay slates.
	X.	The Quartzites.
	XI.	The Schalsteine.
	XII.	Some Contact rocks.
Ortho-schists	XIII.	The Amphibolites, Hornblende gneisses and related rocks.
	XIV.	The Quartz Hornblende schists.
	XV.	The Hornblendites, Hornblende schists, and Gedrites.

The term formation has been only used for one group (IV). Indeed it is

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[1]) For clearness' sake let it be mentioned that most Surinam ortho-gneisses have been discussed already. This also refers to the ortho-schists, which are included among the quartz porphyries and porphyroids, just as the schistose epidiorites, which are connected with the intrusive diabases and gabbros.

the most important group, as it occupies extensive regions. It has been a true clastic formation.

We know that the groups V, VI, VII, VIII, IX and X form an other extensive schist complex at the Suriname river: besides they occur in many other places in the same association. Some indications lend support to the assumption that the six groups mentioned and the graywackes are different facies of the same formation and if so, by far most of the schists might be looked upon as one large formation, of about the same age.

The groups I—III, of highly metamorphic schists are but locally known; petrographically, however, they could be the equivalent of the other schist-groups just as well.

The ortho-schists, quantitatively less important, all appear to be metamorphosed basic igneous rocks. Part of them occur in massifs of considerable extent, as results from field-observations.

As we will see by far the greater part of all these schists is older than the granitodiorites.

We shall discuss the geological data at each group of para-schists separately; the groups V—X, however, are geologically so closely connected in the field that we may discuss the geology of all these groups together (after the petrographical descriptions). In conclusion we will give a summary of what is known about the distribution, the tectonics, the relation to other formations and the age of the para-schists.

The ortho-schists are discussed in groups together with their geology.

THE SILLIMANITE- AND CORDIERITE GNEISSES.

These highly metamorphic gneisses are present from various parts of the Colony and according to their mineral combination may be classed into the following groups:

a. Sillimanite gneisses
b. Sillimanite cordierite gneisses
c. Sillimanite garnet gneisses
d. Hypersthene-bearing sillimanite gneisses
e. Cordierite garnet gneisses
f. Sillimanite schists.

Though the last group does not belong to the gneisses sensu stricto, it is so closely related to the former, that it may be discussed in connection with them.

THE MINERAL COMPONENTS.

Sillimanite. Sillimanite has a very varied habitus. Prismatic, comparatively large crystals are common, which may attain to a size of 0.7 by 4.5 mm.; most of them, however, are smaller. The prism (110) yields the well-known pseudo-quadratic cross-sections, intersected diagonally by the (100) cleavage. The rods manifest quite a number of cross-fractures. The coarsest crystals show very characteristic pleochroism. We observe cloudy distribution of tints of red according to n γ to light brownish according to n β and almost colourless according to n α (see V. 1909, 1955, 2064, 2066; Vtz. 604). These colours occur especially in the central parts of the crystal. Very striking are the black or brown, apparently isotropic inclusions: innumerous needles and rods. These are found in the coarse specimens particularly, and run parallel with the c-axis (Pl. 43 fig. 2). (V. 2064, 2066; Vtz. 604.) Short prisms often show the well-known brush-shape at the ends (Pl. 43 fig. 4 and 5); a special type of the sillimanite shows spongy structure, when strongly magnified (e.g. B. 8). The sillimanite forms irregular masses. Also fibrolite occurs.

The relation between sillimanite, biotite, and ore in a few rocks is remarkable. Sillimanite nestles itself in this case preferably in biotite, so that the latter is intersected by numerous needles and prisms; this goes on to such an extent that only narrow rims of the biotite may remain. Sillimanite may grow in various ways around ore (magnetite). It may form equally polarizing rims or fine needles arranged more or less radially (Pl. 44 fig. 1). The porous spongy type may also surround ore. These relations between sillimanite, biotite and ore have already been described and illustrated by Bergt. [1]) In one respect I cannot agree with him: namely the myrmekitic intergrowth of sillimanite and biotite (l.c. p. 121); see biotite.

[1]) W. Bergt. **45.** p. 118 and following pages.

Cordierite. Microscopically the cordierite now appears to be idiomorphic, now not at all. In cordierite garnet gneiss from the De Goeje mountains (V. 568), we observe oblong, almost prism-shaped crystals, which attain to a length of 7 mm. By the side of these, irregular patchy, sometimes even perforated pieces appear. All of them together contain ore-granules, biotite, and occasionally also droplets of quartz; the biotite shows a well-defined base. These inclusions together may supersede the crystal to a great extent. The change of the cordierite in this rock is restricted to the formation of aggregates of fine sericite-like mica-scales hemming in the edges of the crystals and appearing along the (100) cleavage or along cracks. The diminution of double-refraction to an isotropic modification occurs but here and there.

The cordierite in sillimanite cordierite gneiss from the watershed of the Gran-rio-Lucie rivers (Y. 163) is more difficult of recognition. Here the crystals lie close together; the limpid fields are very similar to quartz. The yellowish pleochroitic haloes around extremely fine zircon (?) granules provide a means of distinguishing it from quartz. Twins are rare. In other thin sections of the same rock we notice isolated cordierites in prisms with a distinct tendency towards idiomorphism. The change into sericite-like mica mentioned above, and still more into yellowish, isotropic pinite is frequently met with. The occurrence of isotropic zones around comparatively coarse zircon-grains is conspicuous here; the breadth of these zones is about ¼ of that of the zircons. The lines of demarcation between isotropic material, zircon and cordierite are sharp. In that case we again observe in the cordierite a very weak, yellowish pleochroism around the isotopic zone. We might think, that the isotropic zones are a result of the radio-activity of zircon, as we frequently find mentioned in the literature on the subject, but in contradistinction to this, the isotropic zone seems to be composed of the same material as the above-mentioned pinite, which need not at all be caused by zircon. Ore, biotite and sillimanite occur as inclusions. The cordierite most difficult of recognition is that in sillimanite cordierite gneiss from the Gran-rio (Y. 95), where cordierite appears in a quartz- feldspar mosaic, agreeing with it entirely in size and shape. The limpid cordierite may be recognized here in as far as pleochroitic haloes occur. Here again an isotropic zone may appear around the coarses zircon-granules; in its turn surrounded by a vague, yellowish halo in the adjacent cordierite; as in this case the cordierite has changed around zircon only, we have in contradistinction to the supposition made above, to attribute the isotropic zone to an action originating in the zircon grain.

Cordierite in a sillimanite cordierite gneiss from the Fallawatra creek (a tributary-creek of the Nickerie river) below Stone-dansi (V. 1905), may very easily be mistaken for acid plagioclase. Cordierite is found in abundance here, so that some fields are, for the greater part, composed of it, with enclosed ore, biotite, sillimanite, apatite, and zircon. This limpid cordierite does not show the slightest trace of change. Between crossed nicols we see twinning structures: quite a number of irregular lamellae (Pl. 43 fig. 3). They rarely intersect a cordierite field in its full breadth, but emerge from the sides and end wedge- of spear-shaped, or they appear in groups anywhere in the otherwise equally polarizing crystal; in addition to this, they sometimes split up at the ends. In other cordierites again we observe a division into two differently polarizing lots, which work into each other; in this case the structure may remind us of "Schachbrett-albite". Sometimes three systems of lamellae occur, intersecting each other. The resemblance to albite is strengthened by the index of refraction, which is about the same or a little feebler than that of the balsam. It is once more the yellowish haloes here, which point to cordierite.

Garnet. In a few rocks garnet is even macroscopically recognizable as pale-red or practically colourless granules. In a single gneiss from the Courantyne (Y. 298) they attain to 6 mm. Enclosed biotite occurs here; its crystal shape is nowhere well-developed. It is the common iron-aluminium garnet. In the gneisses from the Nickerie region (V. 1955 and 2064) the garnets are pretty wel colourless in the thin-section. The enclosed ore is remarkable here; it is present in abundance, arranged in numerous dendrite-like forms and still more as dust. Enclosed sillimanite needles occur. Some garnet grains have a porous structure. In a cordierite garnet gneiss from the De Goeje mountains (V. 568) the granules are rounded off, or are approximately crystalshaped, apparently the rhombendodekahedron.

Biotite. Patchy biotite, mostly of a brown, sometimes also greenish-brown colour, calls for little notice.

In a few sillimanite gneisses from the region, Bergt describes myrmekite-like intergrowth of biotite with sillimanite, which latter is enclosed in biotite. [1]) I cannot share this view. In this case the sillimanite shows the above-mentioned porous structure. The biotite, however, is likewise pierced by numbers of channels; these are curved, vermiform and extremely fine. We might get the impression, that the sillimanite, where it borders on biotite, is intergrown with the latter, in the sense that sillimanite sends out vermiform bodies into the biotite and that we are therefore concerned with a myrmekite-like intergrowth, as Bergt supposes. [1]) When these rocks are strongly magnified, it appears that there is no connection between the structure of biotite and sillimanite.The biotite shows the vermiform perforation in itself, without silliminate being present in the channels in the biotite.

Simple pleochroitic haloes around zircon are common, in one single case also around sillimanite.

Hypersthene. Hypersthene is found in a few rocks from the South-East of the Nickerie region. It appears in oblong pieces, developed according to the c-axis, or shows irregular forms, invariably devoid of idiomorphism. The pleochroism is strikingly intense; a beautiful green (according to n γ), to reddish-brown (n α) and yellowish-brown (n β). The interference figure is clearly positive. The strong double-refraction and strong pleochroism point to hypersthene rich in iron.The characteristic leaflets of titanomagnetite (?) are enclosed in abundance.

Potash feldspar. Potash feldspar occurs as crystals whose shapes vary considerably and which are never idiomorphic. Larger pieces of potash feldspar often surround rounded-off droplets of plagioclase and other minerals. In one single rock, potash feldspar contributes to the formation of a polyhedric mosaic (in sillimanite cordierite gneiss from the Gran-rio, Y. 95).

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[1]) W. Bergt. **45.** p. 121; see also E. H. M. Beekman. **63.** p. 156—157.

The potash feldspar in the gneisses collected from the basin of the Nickerie, along the river itself and the tributary Fallawatra, and on the watershed with the Coppename, is characteristic. The potash feldspar is developed there as orthoclase, and invariably contains an important percentage of micro-perthite. The latter is usually present in oblong spool-shaped fibres, which trend parallel to the c-axis of the potash feldspar. In their most typical form these fibres are present in abundance. About half of the potash feldspar may be replaced by fibres (see V. 2112). The fibres are usually not so abundant, and further their shapes may vary; we never observe patch-like perthite, however. The comparatively strong refraction is very characteristic; we are not concerned here with albite, which generally forms microperthite, but with a plagioclase having approximately the composition of oligoclase (see V. 1909, 2064, 2065, 2066; Vtz. 592, 597; B. 8, 10 for the different forms of micro-perthite). Vague microcline-structure among the perthite-fibres is to be seen in but one of these rocks (B. 10).

In the gneisses from the Pikien-rio (V. 1835, 1838) the potash feldspar shows microcline structure; fine microperthite fibres are not wanting here either. The same also applies to gneisses from the Gran-rio (Y. 95), from the watershed between this river and the Lucie river (Y. 163), and from the Upper Courantyne (Y. 298).

Plagioclase. The plagioclase of these gneisses is always acid, whether oligoclase, or oligoclase-andesine. Idiomorphism is only visible when small plagioclases appear enclosed in potash feldspar. The twinning structure is not very much developed; it is vague or wanting in a great number of the specimens. This is a primary phenomenon, although we often observe secondarily bent lamellae wedging out into an undulous field. This is the case for instance in the gneisses from the Nickerie region which may have undergone intense pressure. Anti-perthite may be present, particularly in the plagioclases from the Nickerie-region. The fields are now approximately isodiametric, now oblong-shaped (see the anti-perthite in V. 1973, 1974, 2064, 2065, 2066; B. 8; Vtz. 597). We find a different and striking type of anti-perthite in a sillimanite gneiss from the watershed between the Nickerie river and the Coppename (V. 2110). So much perthite material is present that the plagioclase is restricted to a netshaped skeleton, comprising approximately half of the crystal. We see the plagioclase filled with oblong-shaped fibres of potash feldspar; all of them trending alike. They often anastomose sideways with each other. As we observe the fibres in practically all sections, they seem to be united into an anastomosing network, intergrown with a plagioclase skeleton. The plagioclase and the anti-perthite together are often bent secondarily. The plagioclase again has the composition of oligoclase, which is easy to ascertain where rounded quartz droplets are enclosed. Twinning is not to be recognized in the plagioclase skeleton.

In a number of rocks plagioclase together with quartz form myrmekite where plagioclase borders on potash feldspar. The myrmekite is of the same type which we meet in igneous rocks, penetrating into the potash feldspar. The vermiform quartz, however, is often present in small quantities (see Vtz. 592, 597; V. 1909, 1973, 1974; B. 10; Y. 163, 303 B.). Of the enclosed microlites, hexagonal leaflets of titanomagnetite (?) and needles must be mentioned (V. 2064, 2065).

Quartz. The quartz shows nothing in particular. Dust, sometimes arranged in strings, microlites, among which leaflets of titanomagnetite (?) and needles, may be enclosed (V. 1835, 1838, 2064, 2065, 2066, 2110).

Ore. The ore invariably appears to be magnetite or titanomagnetite. Instead of an idiomorphic octahedral shape as we should expect in magnetite, the ore forms either grains, irregular pieces, or dust. The greatly varying relation to the rest of the minerals we can better discuss when treating the rocks separately.

Spinel. Bluish-green spinel (pleonast) as a rule accompanies the ore. The spinel is exclusively found as quantitatively insignificant pieces, having no crystal-shape, and being enclosed in ore (see V. 33, 1909, 1955; Vtz. 597; B. 9, 10). There is one single case in which spinel, enclosed in sillimanite, is not surrounded by ore.

Apatite. Rounded off or indistinctly prismatic grains are common.

Zircon. Zircon shows rounded off, more or less oblong-shaped grains, sometimes indistinctly prismatic. By the side of these there are extremely fine granules, which, in cordierite, cause most of the haloes, and which also probably belong to zircon.

Rutile. Rounded off, yellowish rutile-grains appear in a few rocks.

PETROGRAPHICAL DESCRIPTION.

The Sillimanite Gneisses.

The sillimanite gneisses from the Nickerie region are usually normal-grained occasionally also fine-grained. Parallel texture is more or less well-developed, but the rocks are not schistose. In the sample we might easily take them for granite-gneisses. The feldspar and quartz are gray or brownish against which the dark minerals stand out sharply. The latter are biotite and sillimanite while locally sillimanite-needles are recognizable in the gray parts of the sample. The coloured minerals may be united into bands or lenses, in which case they contribute materially to the parallel texture.

From the Pikien-rio we possess three, very weathered samples, coloured by limonite. They vary from coarse to fine-grained. In the coarsest one we can recognize potash feldspar exceeding 1 cm. in size. On the planes of fracture the sillimanite may cause a silky lustre (see V. 1835).

A single rock from the De Goeje mountains has the habitus of a fine-grained granite-gneiss, in which curved strings and nests of sillimanite are visible (V. 42).

Microscopically, the gneisses from the Nickerie region appear to be closely related. Quartz, plagioclase and potash feldspar occur. Some of them are strikingly rich in potash feldspar (V. 1909; B. 10) or plagioclase appears in varying quantities next to quartz and potash feldspar. All of these minerals are characterized by irregular border-lines and no trace of crystal-faces is recognizable. If the potash feldspar is strikingly coarse, poikiliticly enclosed pieces of quartz, plagioclase, and ore appear. The plagioclase is conspicuous by an indistinctly developed lamination; a tendency towards myrmekite formation occurs repeatedly. Biotite together with copious sillimanite appears accumulated into masses and strings, which have tendency towards parallel texture. The sillimanite of the prismatic, but partly also of the porous type, is found for the greater part in the brown biotite; for he rest it is of the types described above (see p. 362). It is in some of these rocks that sillimanite forms rims around ore, but by its side we may observe in the same rocks, how ore is wholly confined to the space left by the well-defined sillimanite prisms; sillimanite may even be enclosed in ore. Rounded off, oblong-shaped zircon grains occur (e.g. B. 10; V. 1909; Vtz. 604); occasionally accessory garnet too (B. 8); or accessory, little modified cordierite (B. 10).

All these rocks from the Nickerie region have experienced intense pressure-action judging from the undulose quartz and feldspar, while the lamination of the plagioclase may be slightly warped and frequently wedges out. Sillimanite may be affected too (V. 2110); the mineral is warped and cracked.

The weathered gneisses from the Pikien-rio are of little interest. Here the size of the grain varies considerably. Potash feldspar with a well-defined microcline structure and some fine perthite is present in abundance. Plagioclase seems to be entirely wanting. The sillimanite is prismatic and needle-shaped, in densely accumulated bundles. Some zircon and rutile belong to the accessories. The intense weathering which the rocks have undergone has caused the appearance of holes in the thin section, which once possibly contained cordierite.

A rock from the De Goeje mountains consists of quartz, plagioclase, biotite, muscovite, with curved strings of innumerous sillimanite needles.

The rocks from the Nickerie region are from the main-river near the Stone-dansi fall (B. 10) and from the large tributary creek, the Fallawatra, where they were collected at the first rapid (B. 8; V. 1909, 2029); from the latter place, too, there are very likely a large number of beautiful samples of Voltz's marked "below Draai-bakka", three numbers of which have been microscopically examined (Vtz. 592, 597, 604). One single rock is from the trail of the Nickerie Expedition to the watershed Nickerie-Coppename (V. 2066). We have three rocks from the Pikien-rio (V. 1835, 1837, 1838).

The Sillimanite Cordierite Gneisses.

Of the gneisses, which, besides sillimanite also contain a considerable quantitiy of cordierite, we possess three, of different habitus.

One rock from the Stone-dansi fall, Nickerie river (V. 1905) in its exterior shape agrees entirely with the sillimanite gneisses; it is normalgrained, with a parallel texture, but not schistose. Dark spots stand out against gray quartz and the grayish and brownish feldspar; the dark spots consist of biotite and also of bluish-black, sparkling cordierite. Microscopically the colourless minerals appear to be quartz and plagioclase; there is no potash feldspar. There is a very considerable quantity of cordierite present. The plagioclase is indistinctly twinned; the clear cordierite likewise shows lamination of the deceptive type described on page 363. The latter mineral is met with in such large quantities that large parts of the thin section, apart from enclosed biotite, sillimanite, ore and apatite consist of cordierite. The cordierite-crystals are separated in the same way as the plagioclase and quartz by irregularly and sometimes also undulating border-lines. Almost homogeneous polarizing spots of sillimanite are conspicuous, which are intersected by an irregular network of cracks or possibly a poorly-developed cleavage system; idiomorphic cross-sections of prisms with distinct cleavage appear locally in these spots. It is probable that we are concerned here with an accumulation of parallelly oriented crystals impeding each other. Moreover sillimanite may be enclosed in biotite again, or free as bundles and clusters, intersecting the colourless minerals. Aggregates of the finest sillimanite needles are conspicuous and lie all mixed up together along the edges of the colourless components and grow out into them. The copious ore (magnetite) conforms to sillimanite. Apatite is present in considerable quantities as grains or rounded-off prisms. Some zircon-grains are also found. Pressure-action is developed.

A rock from the watershed between the Upper Lucie river and the Gran-rio shows a new structure (Y. 163). In some thin sections no idiomorphism is shown by the quartz, microcline and plagioclase (oligoclase) nor gneiss-structure; in others, on the contrary, striking idiomorphism both of plagioclase and microcline, in respect to quartz which fills the interstices. Some muscovite is found by the side of biotite. Among the accessories we ought to mention a dark brown strongly refracting and doubly-refracting mineral, optically bi-axial negative, with very strong dispersion reminding us of brookite. It is usually found together with pieces of ore and has not been further identified.

A rock from the Gran-rio (Y. 95) has a habitus differing from all the rest of the sillimanite- or cordierite-bearing gneisses. It is bluish-gray in colour and shows innumerous very minute needles of sillimanite in an almost dense quartzite-like groundmass. The needles generally have a parallel trend, so that the rock shows some parallel texture, but is not schistose. Unlike that of the former rocks the microscopical figure is very even (Pl. 44 fig. 2). We observe a polyhedric mosaic of almost isodiametric grains of quartz, acid plagioclase and microcline, all of them mostly smaller than 0.035 mm. Potash feldspar is recognizable from its lamination and moreover contains microperthite fibres; plagioclase, however, is now scarcely twinned and difficult to distinguish, now the reverse. In this mosaic we see limpid cordierite, conforming entirely to the other components. Numbers of yellowish haloes appear around extremely fine inclusions. The percentage of cordierite is considerable. The quantity of ore grains (magnetite) is also significant; the ore tends towards an octahedral shape. A very significant percentage of sillimanite is found throughout the rock. The mineral is prismatic to needleshaped, frayed at the ends, with typical cross-fractures. In general the crystals have a parallel trend. The rock exhibits no signs of pressure.

The Sillimanite Garnet Gneisses.

We have four typical representatives of these gneisses from the Nickerie river, viz: from the Blanche Marie fall (V. 1955, 1973, 1974) and the Wilhelmina fall (V. 2012). They are normal-grained, with a distinctly parallel-texture and indistinctly schistose. The coloured minerals are in places accumulated into strings. Besides biotite, we distinguish needles of sillimanite and pale-red garnet grains. The latter are particularly numerous in some of the samples (V. 1973, 1974).

Microscopically quartz, acid plagioclase and potash feldspar containing micro-perthite are the colourless components showing a typical gneiss-structure. Sillimanite, biotite and irregular pieces of ore are for the greater part accumulated into strings and groups. The sillimanite, partly distinctly prismatic, partly also with a sponge-like structure and in that case not crystal-shaped, shows a tendency to nestle in biotite as has been described for other Nickerie-rocks. The garnets have a pale-red tint in the thin-section and enclose the dendritic ore mentioned on p. 364. Some spinel appears in the patchy ore. It is remarkable that we find both ore and spinel enclosed in a comparatively coarse sillimanite needle. Both rocks show signs of intense pressure; bundles of sillimanite will sometimes show compound fracture and warping of the prism zone; ore dust is partly derived from rolled out pieces of ore.

Less typical are the following rocks. First a gneiss with little garnet and sillimanite, likewise from the Nickerie region, from a trail running from the. Fallawatra creek in a Southerly direction (V. 2063). This rock has been described by Beekman (l.c.p. 166) as leptynite. It is practically massive in the sample and manifests pale red garnet granules. Microscopically, plagioclase and quartz appear to be the essential components, with some biotite, garnet and a few sillimanite prisms. The plagioclase has entirely developed as antiperthite of the type described on page 365. Typical gneiss structure is present without parallel texture, however. Another sillimanite garnet gneiss is from the Upper Courantyne (Y. 298). The normal-grained sample shows a distinct parallel texture, the biotite being accumulated in bent masses. Red garnet grains, by way of exception 6 mm. in size, occur irregularly dispersed. Numbers of sillimanite needles appearing together with the biotite may be discovered by means of a magnifying-glass. Microscopically the irregular structure and texture are conspicuous. The feldspars (potash feldspar showing poor microcline-structure and acid plagioclase) and quartz vary much in shape and size, and are also irregularly distributed. Among coarser pieces of the three minerals, aggregates of much finer grain occur, which now consist chiefly of plagioclase, now chiefly of microcline. In the larger potash feldspars quartz and biotite are poikiliticy enclosed. The distribution of the components is the same as that which is typical of metamorphic sediments. The thin section has touched a few sillimanite prisms. Among other things, some pinitized cordierite occurs accessorily.

The Hypersthene-bearing Sillimanite Gneisses.

Closely related to the sillimanite and sillimanite garnet gneisses of the Nickerie region are three rocks which also come from this region and are characterized by a quantity of hypersthene. All of them were collected on the trail of the Nickerie Expedition running from this river to the watershed with the Coppename river.

The hypersthene occurs as oblong or irregularly shaped pieces without crystal form and has intense pleochroism (see p. 364). In two rocks the pieces are partly accumulated together with biotite and sillimanite, and then trend parallel, to the last components. The pieces may appear also among the colourless minerals. The hypersthene is present in such large quantities here that it comes next to sillimanite and garnet quantitatively. In one of the rocks (V. 2065), however, we see only a few sillimanite prisms and weathered hypersthene grains. What is striking here is that the latter may be enclosed in the former. Garnet is present in considerable quantities in one of the rocks (V. 2064). It encloses dendrite-like ore. All the components are warped or undulose. To this group belong the numbers (V. 2064, 2065, 2112).

The Cordierite Garnet Gneisses.

One single gneiss from the De Goeje mountains is characterized by this mineral combination (V. 568). The sample shows quartz, feldspar and copious biotite; the biotite is irregularly distributed and causes a parallel texture.

Microscopically it appears that quartz, plagioclase and copious cordierite are present as colourless minerals. The features of the latter mineral, which sometimes encloses abundant biotite, ore, and quartz droplets, are referred to on p. 363. The biotite is of a reddish brown, rich in pleochroitic, single haloes around zircon-grains and besides this, contains strongly reflecting leaflets of titanomagnetite. The biotite may be perforated by numerous quartz-grains. The almost colourless garnet-grains seem to have a tendency towards the rhombendodekahedron.

Sillimanite Schists.

These rocks are closely related to the preceding ones but contain only quartz and sillimanite as colourless main components. Feldspar is entirely wanting. This fact, together with the schistose texture makes the name "schist" desirable; considering the mineral combination only, they might be called sillimanite quartzites. We possess samples from the Pikien-rio (V. 1836) and from the De Goeje mountains (V. 33). They are fine grained rocks, having the habitus of pale-coloured quartzite schists. On the splitting-planes we observe sparkling needles of sillimanite.

The microscope shows a mosaic of quartz-grains, having more or less the shape of flattened polygons. The latter lie parallel. Running parallel to and intersecting the mosaic are innumerous sillimanite needles. They are distinctly prismatic and may attain to a length of some millimetres, and show the typical cross-fractures (V. 1836), or they are extremely fine (V. 33). Signs of pressure are wanting.

THE GEOLOGICAL BEHAVIOUR OF THE SILLIMANITE. CORDIERITE AND GARNET BEARING GNEISSES. THE ORIGINAL MATERIAL AND THE NATURE OF THE METAMORPHISM.

On the Nickerie river we have sillimanite-, cordierite-, garnet- and hypersthene bearing gneisses from the Blanche Marie fall, from the Wilhelmina fall and from the Stone-dansi fall near the mouth of the Fallawatra creek; and also along the trail from this river, in an SE. direction to the water-shed of the Coppename.

The following passage may be quoted from Van Cappelle [1]), who made researches in these regions. "Le caractère schisteux est peu distinct dans les roches entre Stone Dansi et la Fallawatra. Par endroits des bandes de magnétite grenue et de biotite pailletée décèlent une tendance à la structure parallèle. A la surface des roches, elle s'étendent parallèlement aux barages qui traversent généralement la rivière en une direction N-S; à l'intérieur des schistes dirigé du N. au Sud., je remarquai ça et là des indices de "contorted foliation" (l.c. p. 27).

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[1]) H. van Cappelle. 62.

Along the trail mentioned, the gneisses are found continuously covering a distance of several km. (l.c. p. 28) and about the trend the following statement is made:

"Il nous faut observer une fois de plus, que non seulement les schistes, mais des roches d'origine intrusives aussi, traversent la fôret en rangées de blocs à tendance généralement N.O.—S.E. c. à d. parallèle à la direction invariable des crêtes" (l.c. p. 29).

From these quotations it follows that the gneisses belong to important systems, which retain the same trend along considerable distances, and apparently trend N. tot NE. in the district. Very important are the relations between the gneisses and the granitodiorites and gabbros, along the river at Blanche Marie fall: "Le grand développement des diorites et des gabbros, alternant par endroits avec le granite, joint aux observations faites plus septentrionalement ne m'auraient pas fait présumer dans cette zone la présence du système archéen; il y forme des bandes étroites et indistinctes, séparées par des roches intrusives, et, il est curieux de l'observer, ces dernières n'ont exercé aucune influence métamorphique sur la roche encaissante" (l.c. p. 27).

The same relation is also emphasized further on (l.c. 27, 28). Though the eruptive rocks do not seem to have influenced the adjoing gneisses, the relation between the two rock-groups can only be interpreted in this way, that the former are intrusions in the latter.

The sillimanite cordierite gneiss of the watershed between the Gran-rio-Lucie rivers (Y.163) projects as a rock of several metres in diameter through the laterite cover of the hilly country there. Although the contact is not visible, the exposures of biotite granite in the neighbourhood point to the probability that the gneiss is a large inclusion in the latter.

This most certainly applies to a mass of gneiss of a few metres in diameter at the foot of a low hill on the left bank of the Gran-rio, below Tetakosidam. At very low water a completely weathered sillimanite gneiss is visible, in contact with normal-grained biotite granite. The granite is dappled with biotite. The massive gneiss has not been described, on account of its bad condition.

The sillimanite cordierite gneiss of the Upper Courantyne (Y. 298) is exposed as a rounded-off rock face on the bank. It shows steeply dipping parallel texture. In the same rock-face we may observe locally, considerable folding of the texture, so that ribs, rich in coloured minerals protrude by weathering.

Concerning the behaviour of the rest of these rocks nothing is known for certain.

From what we said above it is evident that the gneisses form a part of the basal complex and that they may be intruded by-, or enclosed in the granitodiorites, *consequently they are older than the latter.*

In as far as parallel texture is present, it dips steeply in the field. The gneisses may have undergone intense pressure and this tallies with the fact that the granitodiorites, which are younger, show the same signs of pressure.

These gneisses are undoubtedly metamorphosed, completely re-crystallized rocks. Their structure indicates it; instead of showing a well-defined sequence of crystallization, the components may enclose each other, mutually, as the following list shows. We have observed:

Quartz enclosed in potash feldspar and plagioclase;
Plagioclase and potash feldspar in quartz.
Quartz and feldspar in biotite.
Biotite in quartz, feldspar, and cordierite.
Cordierite in quartz and feldspars (sometimes idiomorphic).
Quartz, biotite, sillimanite and ore in cordierite.
Sillimanite in quartz, plagioclase, potash feldspar, biotite, cordierite and ore.
Ore and spinel in sillimanite.
Hypersthene in quartz and feldspar.
Quartz in hypersthene.
Quartz, biotite and ore in garnet.
Garnet in quartz and feldspar.

So the structure is true crystalloblastic, typical of metamorphic rocks. A crystalloblastic series, in which some components still show a greater tendency towards idiomorphism than others, and have simple, open crystal shapes, is truly difficult to compile. Sillimanite shows the greatest tendency towards idiomorphism and the fewest inclusions of the other components.

The original material must, for the greater part, have been of a sedimentary nature. The accompanying analysis gives the composition of a cordierite sillimanite gneiss (Y. 95) described on p. 367.

SiO_2	55.42
Al_2O_3	24.92
Fe_2O_3	10.35
FeO	1.25
MnO	0.03
MgO	0.84
CaO	0.43
Na_2O	2.10
K_2O	2.10
H_2O+	0.53
H_2O-	0.04
CO_2	—.—
TiO_2	1.52
P_2O_5	0.37
	99.90
Anal. Dr. S. Parker, Zürich.	

TABLE 30.

Such a large percentage of Al_2O_3 and iron, together with so little CaO, we do not know in igneous rocks. The large percentage of Al_2O_3 here causes the appearance of sillimanite and cordierite.

As we have seen, the distribution of the mineral components is irregular in the gneisses; sillimanite and cordierite, often together with coloured minerals may be accumulated while the relation between the colourless minerals, especially plagioclase and potash feldspar, varies considerably. This heterogeneous texture may also speak for the sedimentary origin, parts rich in aluminium and iron having been irregularly distributed among material rich in SiO_2 and alkalies.

The sillimanite schists form a special type, characterized by a very large percentage of SiO_2 and a considerable percentage of aluminium, while other components are negligible. Suchlike feldspar-free schists are but rarely mentioned in the literature.

A sedimentary origin, however, may not be assumed for a sillimanite cordierite gneiss discussed on p. 367 (Y. 163). Crystalloblastic cordierite points to sedimentary origin, but quartz and feldspar may show a distinct sequence of crystallization, and it is clear, that quartz crystallized later than feldspar. This figure points to the igneous origin of parts of the rock. The rock is probably neither of truly sedimentary, nor of truly igneous, but of mixed origin, and might just as well be looked upon as a contact-rock.

Of special interest is the mineral paragenesis of the rocks of the Nickerie region. Besides quartz, feldspar (orthoclase and plagioclase), biotite and ore, and the quantitatively unimportant spinel, which may occur in all the rocks, the following combinations have been met with:

a. Sillimanite
c. Sillimanite and garnet
b. Sillimanite and cordierite
d. Sillimanite and hypersthene
e. Sillimanite, hypersthene and garnet.

a—c are combinations commonly observed elsewhere. Of special interest, however, are d and e. Hypersthene occurs in our rocks together with sillimanite and garnet, but not together with cordierite. This suggests that cordierite may have been superseded in part of the rocks by quartz, sillimanite and hypersthene as follows:

$$\underset{\text{cordierite}}{(Mg.Fe)_2\,Al_4\,Si_5\,O_{18}} \Longrightarrow \underset{\text{quartz}}{Si\,O_2} + \underset{\text{sillimanite}}{2\,Al_2\,Si\,O_5} + \underset{\text{hypersthene}}{(Mg.Fe)_2\,Si_2\,O_6}$$

It may be remarked, that the last paragenesis is new. Magnesium metasilicate (enstatite) has been found repeatedly in metamorphic rocks, together with cordierite, or forsterite, but not together with sillimanite. The latter fact seems to have induced Niggli [1]) to the supposition that the combination quartz, sillimanite and enstatite is not stable, as it is not in melts, and must pass into cordierite together with a varying combination of quartz, sillimanite and enstatite; so this supposition must be abandoned.

The minerals separately, point to the fact that metamorphism must have been completed under high temperature. The very frequent appearance of micro-

[1]) U. Grubenmann — P. Niggli. Die Gesteinsmetamorphose. I. Berlin. 1924. p. 114.

perthite in potash feldspar, of anti-perthite in plagioclase, and in one single case of myrmekite-like intergrowth of quartz and plagioclase, points to conditions approaching those of igneous origin.

Dittler and Köhler have shown that perthite-bearing potash feldspar when heated may be altered into an isomorphous mixture, by diffusion of solids; [1]) so there is every probability that perthite may also be formed by demixture in a solid phase. The experiment of Dittler and Köhler was taken at a temperature of 1000° and at normal pressure. These inverstigators conclude on theoretical grounds that increase of pressure will promote the demixture. If we take the high pressure under which the formation of our gneisses took place into account, it seems probable that the perthite originated at a temperature higher than 1000°. It must have been, below 1425°, however; for it is known that in melts, of the system MgO, Al_2O_3 and SiO_2 quartz, sillimanite and iron-free cordierite are formed below this temperature. These speculations seem to point to the fact that our perthite-bearing sillimanite cordierite gneisses were formed at a temperature between 1000 and 1425°.

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1) E. Dittler and A. Köhler. Zur Frage der Entmischbarkeit der Kali-Natron-feldspäte und über das Verhalten des Mikroklins bei hohen Temperaturen. Tscherm. Min. Petrogr. Mitt. XXXVIII. 1925. p. 229.

THE GARNET- AND STAUROLITE-BEARING MICA-SCHISTS, AND CORRESPONDING GNEISSES.

Only in some localities of the Colony mica schists were found, containing more or less garnet or staurolite or both together. Locally feldspar occurs, so that the term gneiss can be used there. All these types occur promiscuously, and are so closely related petrographically, that they may be discussed together.

Besides the chief components quartz and biotite, which are always present, there may be a considerable amount of plagioclase, muscovite, chlorite, garnet and staurolite, while kyanite, ore, apatite, zircon and tourmaline, are among the accessories. We shall start with the discussion of the mineral components, next the rock-types will be discussed and finally, what is known about their geology.

THE MINERAL COMPONENTS.

Quartz: In all rocks quartz forms a mosaic of irregular fields. Pressure has mostly caused undulose extinction in various degrees. Sometimes pressure has crushed the quartzes. For the rest little is to be said about the mineral. Some dust, occasionally arranged in indistinct strings may be enclosed, sometimes also granules of ore, zircon and tourmaline. In the rocks of the Lower Marowyne river a rather large amount of fine ore-graines occur in the quartz.

Plagioclase: Acid plagioclase is the only feldspar identified. It is not idiomorphic. The size of the fields varies with that of quartz. Twinning is often wanting or appears only vaguely. The mineral is distinguished from quartz by cleavage, lamellae and general habitus; the feldspar percentage might, however, easily be overlooked. The composition always approaches that of oligoclase-andesine. The lamellae may be bent and may wedge out. The plagioclase is as a rule clear.

Potash feldspar: Only one rock (V. 2068) contains potash feldspar, with microcline structure and some perthite.

Biotite: In all these rocks biotite is distinguishable macroscopically, sometimes coarse, now again in leaflets of a few millimetres. Microscopically biotite varies very little; it has a pleochoism of a greenish brown and brown to bright-yellow. The crystals are developed according to the base, the latter being of irregular shape. Simple haloes, around undeterminable grains are very common. In the rocks from the Lower Marowyne ore-dust appears enclosed in biotite.

Muscovite: Besides biotite sometimes less important muscovite occurs. Its size is the same as that of biotite, and it is distinctly developed according to the base. Another type is met with in a rock rich in muscovite from the Sara creek

(V. 1614). Here the muscovite is thickly tabular. We may also detect faintly pleochroitic haloes, there.

Chlorite: Besides biotite a slight amount of chlorite may occur. It is pale green, distinctly flattened according to the base. Its optic behaviour is remarkable. Besides anomalous polarization colours very faint double-refraction often occurs which causes very indistinct interference figures, so that the optic character cannot be determined. Striking is the polysynthetic twinning which is seen in a rock from the Armina falls (V. 3556). Sections vertical to the base show a rather considerable oblique extinction (to 8°). The twinning is according to 001. In contradistinction to our case this twinning seems mostly to occur in chlorite with a stronger double-refraction.

Garnet: A number of rocks shows a rather large amount of garnet distinguishable in the sample. Some rocks from the Lower Marowyne contain crystals to the size of ¾ cm. but as a rule they are smaller. The crystals show rhombendodekahedron combined with ikositetrahedron (Lower Marowyne; also Tafra island, Suriname river), or are rounded. The colour is pink, pale red or brown, in the latter case infiltrated with limonite along cracks. Microscopically the garnet may be perforated, enclosing grains of quartz. Dust of ore occurs in the garnets of the Lower Marowyne.

Staurolite: The staurolite in the samples is invariably brownish black and shows crystal faces very distinctly. Most often we notice the orthorhombic prism, and (010) being much less developed than (110); the terminal planes are indistinct. The planes are of a dull lustre The length of the prisms varies greatly, their usual length being from 1 to 2 cm. in the rocks from the Marowyne. They may even attain to a length of 4 cm., sometimes as much as 6 cm., while the breadth increases proportionately. Vertical crossings intergrown according to (032) seldom occur; crossings at an oblique angle occur all the more, probably intergrown according to 232. Under the microscope it appears, that not in all cases the staurolite is idiomorphic. Evenly polarizing crystals may be markedly perforated and enclose quartz, up to such an extent that only skeletons remain, strongly perforated inside, with inclusions of quartz (see Pl. 44 fig. 3 and 4). Other inclusions of less significance are pieces of ore and tourmaline prisms (G. 1902, 160). Ore-dust occasionally occurs together with quartz-grains, but in that case the dust is located in the quartz and not in the Staurolite itself. The cleavage is insignificant. Pleochroism passes from pale yellow ($n\alpha = n\beta$) to brown-yellow ($n\gamma$). Stronger pleochroism round inclusions is not to be detected.

Kyanite: Kyanite has been found only in quartzites occurring locally in the schists from the Marowyne. It occurs with colourless garnet. The two minerals have no boundary of their own and penetrate into each other irregularly. Apart from the weak birefringence and some cleavage in the kyanite, the minerals have a strong likeness. The refraction of the kyanite is hardly weaker and the surface-relief is the same as that of the garnet. Inclusions of some importance do not occur. The remaining accessoria, ore-grains, tourmaline-prisms, apatite, an occasional grain of zircon need not to be discussed.

PETROGRAPHICAL DESCRIPTION.

The rock-types will now be discussed in connection with their localities.

The rocks from the Lower Marowyne are distinctly schistose or show only some parallel texture.

They are fine, normal and sometimes even coarse grained. Parallel mica leaflets are invariably to be seen in a grey, mostly bluish-grey groundmass.

The coarse types are rich in oblong mica-leaflets, as much as 4 mm. This mica has a bronze tint. These rocks split planparallelly (see e.g. V. 3555, 3557, 3562, 3565, 3573), or they are slightly foliated (e.g. V. 2449, 2450, 2451, 3558, 3564, 3576, 3585). The fine grained types are schistose, of a clear bluishgrey tint, and apparently with a larger amount of quartz (V. 3556, 3559). Now the rocks are pure biotite schists (V. 2436, 3584) now they are garnet-bearing (e.g. V. 3555, 3557, 3561, 3563), or staurolite-bearing (e.g. V. 3558, 3564, 3576, 3585), or the two minerals occur simultaneously (V. 2448, 2450, 2451, 3562, 3565, 3573). The garnets are distributed evenly, for staurolite the same holds good, or parts very rich in staurolite occur locally, especially in light foliated types, with comparatively coarse biotite (see V. 2447, 3564).

As has been said, staurolite crystals may attain to a length of 6 cm., and the rocks in which they appear also contain very coarse biotite so that here one has to do with very coarse schists.

Microscopically the parallel texture is conspicuous by the parallel orientation of the biotite leaflets situated in a mosaic of smaller quartz-fields. The latter are about isodiametrical, or oblong. Besides quartz also some indistinctly twinned plagioclase (oligoclase-andesine) may occur in the mosaic. Muscovite and chlorite are always of minor importance. Chlorite is predominant only in one of the rocks (V. 3556). The accessoria ore and apatite are of little importance; in most cases, there is, however, a fair amount of ore, distributed evenly over the quartz, which may also account for the bluish-grey tint of the samples.

Quartzite layers and lenses occur in the schists. The samples induce us to think that they have a thickness of half a decimetre, they consist of coarse grained quartz which shows under the microscope cords of dust-inclusions. Besides these a fair amount of colourless garnet may be recognized together with kyanite, which, as was said before, penetrate into each other without showing crystal-forms.

After this description of the rocks of the Marowyne we may discuss the others in brief.

The rocks from the isle of Tafra (Lower Suriname river) are less variable, but are allied to those of the Marowyne. They are distinct schistose mica-schists, splitting with parallel planes. They present a more or less silvery lustre owing to the reflection of the mica, which, however, appears to be no muscovite, but merely biotite. Many samples are garnet-free, others contain this mineral and consequently are garnet mica schists, while macroscopically staurolites are perceptible in some of them. The staurolite mica schists sometimes contain coarse staurolite (vide collection Voltz). Some samples, which do not present any staurolite macroscopically, appear to contain this mineral together with garnet, when viewed under the microscope (e.g. Vtz. 538; V. 1374, 2470, 2471). Microscopical examination points out in addition that a good amount of acid, hardly twinned plagioclase (oligoclase-andesine) occurs. (See the thin sections from Vtz. 146; V. 538, 1374, 2470). The feldspar may here be distributed unevenly in feldspar-bearing and feldspar-free, microscopically thin zones (V. 1374). So these rocks have partly developed as gneiss. Here also quarzite lenses appear (V. 1375, 2071).

A sample from the L. and F. De Jong placer, near the Colonial railway (G. 1902, 160) resembles outwardly the normally granular garnet mica schists from Tafra. The microscope however shows a fair amount of highly perforated staurolite, and moreover of acid plagioclase (oligoclase-andesine), so that it is a garnet staurolite biotite gneiss. Accessorily tourmaline occurs.

A sample from the Upper Tempati creek (V. 61; a more definite locality cannot be given) macroscopically shows numerous small red garnets, while microscopically a fair amount of strongly perforated staurolite, and also very acid plagioclase, is perceived. Besides biotite, muscovite and chlorite are present as micas.

A garnet mica schists from the De Goeje mountains (V. 25) is in every sense comparable with those from Tafra island in the Suriname river.

A garnet biotite gneiss from the Nickerie district collected on the trail of the Nickerie-expedition going from the Fallawatra creek in a southerly-direction, shows in the sample distinct parallel texture and numerous dark garnets. Microscopically we observe besides quartz, plagioclase (oligoclase-andesine), reddish brown biotite and a great many rounded garnet grains, together with the accessoria ore, pyrite, and rutile. It is not clear whether the latter is idiomorphic. The vaguely twinned plagioclase is bent out of shape. Here and there some potash feldspar is to be observed, sometimes with microcline structure and microperthite

Of quite a different composition is a garnet-bearing schist from Victoria placer in the basin of the Sara creek (V. 1614). The sample is distinctly schistose, evenly fine-grained and glistening, owing to an abundance of muscovite. Microscopically we observe an excessive amount of muscovite, together with quartz, the latter seems even to be scarcer than the former. The muscovite individuals are tabular according to the base. The only important accessory mineral is colourless garnet, markedly perforated by enclosed quartz-grains.

Another independent type is a garnet-bearing muscovite gneiss from the Gonini (V. 1153). The normal to fine grained sample displays a distinct parallel texture by muscovite leaflets present on the cleavage-planes. On the transverse cracks the amount of muscovite appears to be much smaller, only grey feldspar and quartz is to be observed. Microscopically we observe quartz and plagioclase (oligoclase-andesine) together with muscovite and numerous garnet-grains. The shape and the size of the plagioclase and quartz grains are variable. The muscovite is united into cords of slightly bent leaflets with a sinuous course. The light-red garnet grains are rounded.

It should be noticed that the rocks from the Marowyne, Suriname river, Tempati creek, Sara creek and Gonini all display some signs of pressure: undulose extinction and crushing of quartz.

THE GEOLOGICAL OCCURRENCE.

Voltz already (1853) reports garnet mica schists from the Suriname river and the Marowyne. He collected numerous beautiful samples, among which also the coarse staurolite mica schists. It is surprising that the latter have never been described. The schists from the Marowyne appear near the island of Guidala, 55 km. above the mouth. On the Dutch bank the Aschendagana creek constitutes more or less the boundary of the ortho-gneisses (see page 289). First completely weathered mica schists occur (V. 3541—47). Garnet and staurolite schists are exposed a little way above the mouth of the Agora creek on the Dutch bank. Grutterink's collection (Delft) originates from this locality. Voltz's material comes from the same locallity. Taking all in all we have to do here with a complex extending over a distance of a few kilometres. The schists dip steeply; the strike near Agora creek is N 50° W.

The quartzite lenses intercalated in the schists are of sedimentary origin, considering the amount of garnet and kyanite. Upstream the first rocks are exposed near the Sipariwini creek where clay slates occur at any rate according to Voltz. The relation between the two formations is not known; the metamorphism they have undergone is widely different.

The schists in the Lower Suriname river from the isle of Tafra, belong to a local exposure from which nothing at all can be concluded regarding the connection with other rocks. According to Martin [1]) they dip 27—30° to the NW., and they strike N 37° E. Thin layers of quartzite are intercalated.

Nothing is known about the geological occurrence of the rocks from the upper course of the Commewijne river (V. 61) and from the Sara creek.

The staurolite garnet gneiss from L. and F. de Jong placer originates from a district where phyllites, clay slates, quartzites, and conglomerates are largely distributed.

Of more importance is a schist collected by Voltz at the Armina falls (Marowyne), which appears to contain garnet and staurolite, with some acid feldspar (Vtz. 378). This rock must occur among the graywacke formation, considering the extensive material we possess from these falls: feldspar-bearing crystalline graywackes, and mica quartzites. If there is no confusion in the material, the occurrence of this rock sample renders probable that garnet and staurolite schists may be a facies of the graywacke formation.

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[1]) K. Martin. **26.** p. 149.

THE MICA GNEISSES AND HORNBLENDE GNEISSES OF SEDIMENTARY ORIGIN.

Para-gneisses of this composition seem to be of little importance in Surinam. Mica gneisses occur especially on the Upper Courantyne. Of the hornblende gneisses we possess only a few samples.

Biotite and biotite muscovite gneisses.

These gneisses are normal to fine-grained. Some parallel texture is present, or the rocks are distinctly schistose. Besides biotite muscovite may be present in varying quantity. The other minerals are quartz, feldspar (plagioclase with or without potash feldspar), together with the accessoria ore, apatite, zircon, sillimanite, cordierite and garnet, in varying combination.

Biotite gneisses with acid plagioclase we have from several localities. In the De Goeje mountains we have fine-grained rocks with manifest parallel texture (V. 553, 684). The first rock is of interest on account of the irregular distribution of the colourless components, as appears from the thin section. Besides brown biotite one sees a crystalloblastic mosaic for the greater part of quartz and few, vaguely twinned plagioclases (oligoclase). Locally quartz is pretty well the only colourless mineral. The quartz is distinctly undulose.

A biotite gneiss from the Lucie river (Y. 275) again contains plagioclase (oligoclase), but is notable for the very fine scales of brown biotite. The minerals are evenly distributed. The mineral combination is comparable with that of a quartz mica diorite. The habitus of the biotite, however, possibly intimates para-gneiss, but the rock is of doubtful origin.

Typical biotite muscovite gneisses of sedimentary origin we have from various places. From the Coppename North of Weri creek we have two mica gneisses with distinct parallel texture. In the sample the considerable muscovite percentage can already be recognized. The muscovite crystals are in part larger than biotite and reach a length of 1 cm. (V. 2372, 2373). The microscope shows both acid plagioclase and microcline, and the accessoria ore, apatite, zircon and sillimanite. The latter has lodged itself mostly in muscovite. The structure is irregularly crystalloblastic.

Some biotite muscovite gneisses from the Upper Courantyne again show muscovite in some coarser crystals (V. 3494, 3495, 3500). There is an equal quantity of muscovite and biotite; the micas are contrasted against the quartz and feldspar and bend round quartz nodes. The plagioclase is oligoclase. The accessoria are again the same. Bundles of sillimanite needlets penetrate the feldspars and quartzes. Microcline appears here and there among the quartz masses and shows indistinct lamellation.

Other bi-mica gneisses from the same area bear a large amount of microcline (V. 3493, 3499, 3503). Their parallel texture is distinct and their amount of mica is very large, so that they could be considered as mica schists. The microcline may contain some microperthite. The structure is distinctly crystalloblastic. In one of the rocks (V. 3493) sillimanite occurs. The distribution of the minerals is very uneven. Thin layers and lenses, which are very rich in mica, alternate with layers chiefly composed of microcline and quartz. These gneisses might suggest injection and igneous origin of the lenticles and laminae composed of quartz and microcline.

Banded biotite gneisses.

Banded biotite gneisses, which are in part para-rocks we have from the watershed between the extreme upper course of the Gran-rio and the Lucie river.

At the trail of our expedition some very large boulders were found, showing parallel bands in a groundmass of light colour and less distinct parallel texture. The dark bands are slightly bent, their breadth ranging from a few cm. to a few dm. The light coloured bands between them vary between the same dimensions. The light bands have the habitus of a biotite gneiss poor in biotite with indistinct parallel texture. On closer inspection we discern in the latter eye-gneiss structure (Y. 162, 162 C). The eyes are composed of microcline. Microscopically this gneiss appears to consist of quartz, microcline with faint lamellation, and sometimes microperthite-fibres, greenish biotite, some muscovite, and the accessoria ore and zircon. The structure is irregularly crystalloblastic, above all in the parts bounding on the dark bands (see the thin section of Y. 162 C). Some thin sections are rich in microcline (Y. 162 B), in others this mineral is lacking pretty well entirely (Y. 162 C). Quartz presents locally flattened crystals and occurs also in the feldspars as droplets.

The dark bands are very rich in biotite. Now the mica is the main component, again quartz and plagioclase are arranged as laminae and lenticles among the parallel biotite. A thin section of these lenses which are relatively rich in colourless minerals, shows quartz and vaguely twinned plagioclase. The size of the grains is less variable than in the eye-gneiss bands. Biotite is brown here instead of green, and strikingly rich in haloes. Fluorite is remarkable; it appears as irregular crystals, to a considerable amount. Sericite is present in the plagioclase. This is also the case in the eye-gneiss bands. The dark bands are para-gneisses. This is not quite sure for the light bands; anyhow where the latter prevail cryst-alloblastic structure is little distinct. It is not improbable that these light bands should be of igneous origin.

Hornblende gneisses.

We have hornblende gneisses from the neighbourhood of the De Goeje mountains (V. 44, 45), and from the Upper Courantyne (V. 289).

One of the rocks from the De Goeje mountains has in the sample the habitus of a very fine-grained amphibolite, and shows some parallel texture by dark and lighter bands (V. 45). The microscope shows that the dark parts are garnet-bearing hornblende gneiss. The oblong hornblende crystals lie in a mosaic of plagioclase (oligoclase-andesine) and quartz grains. Although the hornblende is no longer fresh and passes locally into chlorite, we recognize a colourless hornblende variety with numerous polysynthetic twins according to (100). The other constituents are coarse garnet grains, traces of biotite and granular ore. Owing to a decrease of the amount of hornblende these parts pass gradually into the lighter zones, which consist for the major part of a finely granoblastic mosaic of quartz and plagioclase. Besides sparse hornblende crystals we also discern there brownish biotite and locally again coarser garnet grains, so that we have here a biotite hornblende gneiss which contains garnet and is poor in dark minerals. The hornblende in these groups is the often twinned variety again, but it is oblong according to c and lies parallelly. The flat biotite leaflets contribute to the parallel texture. Locally a few coarse plagioclases occur which behave like porphyroblasts, judging from the innumerable enclosed drops of quartz. The garnets may enclose pieces of quartz and biotite at the rims and have no crystal-forms. The highly promiscuous texture proves the para-character of the rock.

The second hornblende gneiss from the De Goeje mountains shows in the fine-grained sample, grey feldspar, quartz and hornblende and unequal texture. One sees namely faintly bounded zones, running parallel, now rich in hornblende, again hornblende-poor, and gradually merging into one another. Parallel texture is manifest above all in the weathered parts of the sample. Under the microscope green hornblende is discernible, together with plagioclase (oligoclase-andesine), quartz, and the accessoria biotite, ore, titanite and zircon. Plagioclase and quartz constitute a mosaic, the components of which now have the same seize, now are unequal. The plagioclase is indistinctly or not twinned at all. Under the microscope the zonary texture observable in the sample corresponds with a change of the size of the grain of the mosaic. Some of the zones contain many hornblende fragments, in part also biotite; others are almost entirely composed of quartz and plagioclase in variable percentages. Some lenticular groups are composed only of coarse quartz crystals. Titanite fragments, relatively coarse, have originated from ore, judging from the ore remnants that may be present in them. The very uneven texture of this gneiss forms a sharp contrast with the even texture of the ortho hornblende gneisses to be discussed later on.

Furthermore we have a rock from the Upper Courantyne, collected at the King Frederick William IV falls, near the Dutch bank (Y. 289). On the outside this rock looks like a hornblende gneiss or amphibolite. It is composed chiefly of fine-grained hornblende among which light-coloured material can be detected. This material is amassed locally to cords that run parallel to this indistinct parallel texture. Groups of a coarser material also occur, consisting chiefly of quartz-grains to the size of a few mm.

Microscopically the rock appears to be closely allied to hornblende gneisses, but it does not contain any feldspar. Its main constituent is hornblende; it contains also quartz, epidote, apatite, ore and muscovite. The hornblende is of the ordinary green colour with a local indication of a brownish tint in the centre. The crystals are crystalloblastic and show a number of perforations and enclose quartz, epidote, muscovite and much ore and apatite.

The interstices among the hornblende are filled up chiefly by epidote and quartz. The epidote is spongy, highly porous, enclosing a number of rounded quartz granules. However, where the amount of hornblende is smaller, quartz prevails more and more; it shows undulose fields. The epidote and the muscovite may be of later date than the hornblende, and may have replaced feldspar entirely.

The apatite is very remarkable. There is an abundance of this mineral, always in rounded and oblong grains, of the same type as in sediments. The size is abnormally variable, from very small to $\frac{1}{2}$ mm., a few even of the size 1×0.7 mm. (Pl. 45 fig. 1). Ore is partly intergrown with pyrite. Traces of calcite and titanite are present, and also a single rounded zircon grain.

A few notes on the geology of the Mica- and Hornblende gneisses.

There is no doubt that all these gneisses are constituents of the basal complex. The biotite- and bi-mica gneisses from the Upper Courantyne appear among ortho-gneisses and gneissic granitodiorites. They show a very variable trend in the field, and so far as they are schistose, they dip steeply. Their tectonics agree with that of the ortho-gneisses in the field, and since they do not differ distinctly from the basic ortho-gneisses macroscopically, it is difficult to separate the two groups in the field. A number of the observations of dip and strike given on page 301, have most probably been made on para-gneisses. Sometimes the para-gneisses are distinguishable in the field by the coarse muscovite scales or by the occurrence of coarse quartz nodes. Although no direct contacts between the para- and ortho-gneisses have been detected, a few insignificant granite-pegmatite dykes in the para-gneisses favour the probability that the latter are older.

The gneisses with indistinct schistosity form rounded rock masses in the river. Distinctly schistose texture is found here and there above Point right about.

Little is known concerning the geology of the gneisses from other areas. The mica gneiss from the Lucie river (Y. 275) shows in the field distinct parallel texture and steep dip.

The banded biotite gneiss from the watershed Gran-rio—Lucie river shows rounded boulders of large dimensions, which can hardly have been removed. As we are here in a region of prevailing granitodiorites, the light-coloured bands are probably correlated with the latter and we have to do here with an injection phenomenon.

The hornblende gneisses in the neighbourhood of the De Goeje mountains occur in a region of complicate composition, where para- as well as ortho-schists are of common occurrence.

The hornblende gneiss from the Courantyne, King Frederick William IV fall, (Y. 289) appears among granitodiorites and ortho-gneisses in a way that it is evident that the para-gneiss is surrounded by the ortho-gneisses, even though the contact between both be invisible.

The mica gneisses are petrographically very nearly related to the garnet bearing and the staurolite-bearing gneisses discussed above. The metamorphism that these rocks have undergone must be closely related to that of the schist-groups I and II (see p. 377), in view of the occurrence of microperthite and of microcline structure in the potash feldspar.

THE GRAYWACKE FORMATION.

The mining-engineer Du Bois was the first to call attention to the occurrence of a clastic formation, developed especially in the East of the Colony, on the Marowyne. The rocks belonging to it he calls graywackes and describes them as metamorphic rocks in which original clastic material is still to be recognized. Locally, he even met with conglomerates with rounded-off boulders. Besides the clastic elements proper, he mentions crystalline ones, principally orthoclase, plagioclase, chlorite, sericite, quartz, apatite and ore. The origination of these new minerals is expressed by the term "Kristalline Grauwacken". [1]) On the Marowyne, he met with this graywacke formation over a distance of no fewer than 75 km.

Later on Bergt described a few crystalline graywackes from the Coppename river, which he regarded as contact metamorphic rocks. [2])

The former petrographical descriptions were based on but a few samples. The extensive material now available, however, shows that besides the rocks falling under the crystalline graywackes in a narrow sense, mica quartzites and graywacke-quartzites are present in no small measure, together with a few conglomerate-schists and conglomerates. All the types are comprised here under the term graywacke-formation. The variability of the rocks is principally governed by two factors: on the one hand by the quantity of biotite, chlorite and sericite, on the other, by the presence or absence of primary structures, of clastic quartz and plagioclase. Rounded-off or shard-like grains of quartz and plagioclase are very frequent. The shape of these grains is still the same as at the time of their sedimentation. In a number of rocks they dominate the structure. It must be stated that clastic fragments of rocks, except in the conglomerate-schists and conglomerates, are rare. This fact is of importance, as the name graywacke, given by Du Bois, makes us expect them to be of frequent occurrence. Those rocks which have lost their primary structures, may be classed under the name of *mica quartzites*. Owing to increase of mica some of them might be called *mica schists* as well. For those which still show their primary structures, Du Bois's name of *crystalline graywacke* has been retained. A third group is characterized by a great wealth of recognizable water-worn quartz-grains, dominating the structure, with a quantity of sericite. These rocks are an intermediate from between quartzites and sandstones; for the latter the name of *graywacke-quartzite* has been adopted. We also know a few more *conglomerate-schists* and *conglomerates*, which in an intensely recrystallized groundmass, show large fragments of diverse rocks.

In view of this classification, the types will be discussed in detail, preceded by a description of the mineral components separately.

[1]) G. C. Du Bois. **40.** p. 38—39 and 11.
[2]) W. Bergt. **45.** p. 127—130 and 107.

THE MINERAL COMPONENTS.

Quartz, plagioclase, potash feldspar, biotite, chlorite, sericite, chloritoid, ore, tourmaline, apatite, zircon, rutile, calcite, epidote, garnet, and pyrite are met with.

Quartz. This mineral shows the same features as are generally found in quartzites. It shows numerous fields which are now polyhedral, now irregular in shape, and work into each other at the edges. The finest quartz especially, forms a mosaic. Rounded off quartzes are as a rule oblong-shaped, sometimes also globular (Pl. 22 fig. 1—4). The original worn surface of the grains is often no longer present, but has disappeared on account of re-crystallization and intergrowth with adjacent material. Distinct zones of growth, separated from the original grains by fine dust or limonite covering are not present, and we are only concerned with partially preserved primary structures. The coarser crystals with primary structure may be cataclastic. A mosaic may appear internally, and, if the shape of the grains is not pronouncedly rounded-off, the distinction from groundmass-quartz is uncertain. Enclosed dust occurs here and there, as a rule in strings. The characteristic liquid inclusions with bubbles, however, are not present. Strings of dust sometimes run through differently polarizing fields of quartz and indicate in this case that the fields have arisen from originally homogeneous specimens of quartz (e.g. C. 101). Hair-inclusions etc. are rarely found.

Plagioclase. Re-crystallized or newly-formed plagioclase may occur. It is irregular in shape. It is chiefly an acid plagioclase with a composition of oligoclase, oligoclase-andesine, or albite. This plagioclase is more or less clearly twinned. The plagioclase may contain numerous, rounded-off quartz droplets lying scattered poikilitically in it (e. g. Vtz. 356, 365). The rounded-off, more or less oblong-shaped, comparatively coarse plagioclases must be regarded as clastic relics. By their side there also occur splinter-shaped ones. The undulating border-lines show that re-crystallization has most certainly taken place at the borders. The twinning is often well-defined, but various disturbances, wedging out, warping, .etc. may be present. Comparatively coarse albite fields may show irregular, repeatedly interrupted lamination resembling the structure of "Schachbrett Albit" (see V. 500).

Potash feldspar. Unlike the plagioclase, the potash feldspar is extremely rare. Only in a few rocks do we see (e.g. V. 500) water-worn potash feldspar grains, with microcline structure.

Biotite. It is a strong pleochroitic biotite having a very pale yellowish to greenish-brown or brown tint. Its shape varies considerably. In a number of rocks there appear patchy pieces of larger dimensions and much perforated in all directions, while the colourless minerals are visible through the pores (Pl. 45 fig. 2) (e.g. V. 2189; Y. 351, 355; Vtz. 363). Simple haloes are very common, especially in the coarser biotite; they appear around the grains of zircon and once or twice around the adjacent epidote-granules, and often, too, around small mineral-grains that defy closer definition.

Chlorite. Chlorite is just as important as biotite. It appears as scales or leaves in which only the base is developed, while the size varies considerably. The colour is always a decided green. According to its optical properties the chlorite is far from being constant. Most of the chlorite has such a feeble double-refraction that the optical character cannot be ascertained. Another type has stronger double-refraction and fairly often shows a well-developed base. This chlorite is mostly sea-green. The optic character may be positive or negative. It may be twinned according to (001), and slight oblique extinction is present. The character of the last chlorite type agrees most with clinochlore (see V. 420, 2188, 2189; Y. 352; Vtz. 363).

An intergrowth of chlorite with biotite, according to the base, is rare; in this case the former mineral appears as narrow lamellae in the latter (Vtz. 363). Haloes in chlorite are rare.

Sericite. Sericite is also important. Whereas the two preceding minerals usually vary considerably in size in the same thin section, the sericite invariably appears as fine scales. In a few rocks, however, coarser scales also occur, which had better be called muscovite (e.g. V. 438, 2187, 2188.)

Chloritoid. Chloritoid occurs in but a few rocks. It shows crystals flattened according to the base, and generally twinned polysynthetically. Many crystals show crystalloblastic structure owing to the enclosure of numerous quartz grains. The pleochroism on the base varies from greenish to blueish.

Ore. The ore shows chiefly octahedrons, which points to magnetite or titano-magnetite. The grains are as a rule small. In a few rocks, however, (e.g. Y. 350, 358, 359) they are coarser and attain to a diameter of 1 mm. and a well-developed crystal shape. Irregularly shaped ore may, however, also occur (e.g. V. 421, 424, 438; idem Y. 351). Its transition into titanite or leucoxene, which, otherwise so often appears in metamorphic rocks, is completely wanting here.

Tourmaline. Needles of tourmaline are widely distributed in some types of rocks. It shows the typical cross-fractures. The pleochroism exhibits much variation. The needles are usually shorter than 0.4 mm.

Apatite. More or less rounded off grains and also prismatic, short crystals occur. They are apparently in a worn-down state.

Zircon. Oblong and rounded-off grains, devoid of a well-developed prism-zone, and of slight dimensions occur fairly often. Very fine granules causing haloes in biotite are common.

Rutile. Yellow rutile granules are very scanty.

Calcite. Calcite is very insignificant; it sometimes appears in pieces devoid of crystal shape (V. 427).

Epidote. Epidote is rather common as grains of small dimensions. It may be very important in a few rocks. The orthodomatic zone is nowhere strikingly developed.

Garnet. Colourless granules of garnet may occur as unimportant accessoria, showing a tendency towards idiomorphism (V. 442; Y. 352).

Pyrite is rarely met with.

PETROGRAPHICAL DESCRIPTION.

The mica quartzites.

In the sample these rocks are fine-grained to almost dense, of a greenish-gray or brownish-gray colour in the main. The plane of fracture shows a difference in roughness. It may be smooth, splintery (see Y. 352), rough or finely speckled. Sometimes mica scales may be distinguished (Y. 351; Vtz. 351, 356). Most of the rocks show parallel-texture in the sample; a few are clearly schistose (V. 424, 434). Some are massive (Y. 352).

All are very rich in quartz; next to this occurs a varying quantity of biotite, chlorite, and sericite (or muscovite) in a varying combination, while feldspar as acid plagioclase may occur with ore, tourmaline, apatite, zircon and epidote as accessories. The percentage of mica varies so much that the rocks rich in mica approach mica schists. In habitus, however, they differ from these by the mica being macroscopically less easily recognizable. In the rocks poor in mica the quantity is comparable with that of mica quartzites. Distinct quartz-relics are no longer to be recognized. The mica leaves and also chlorite appear on the whole to possess more parallel trend than the sample would lead us to suppose. Variation in the structure is mainly attributable to the relative size of the fields of the quartz mosaic and the mica. The biotite often has a tendency to appear in comparatively large crystals (see V. 420, 424, 434, 435, 1709; Vtz. 371; Y. 351). Such crystals prove their crystalloblastic origin by their patchy and perforated structure. The ore-grains may show a tendency to arrange themselves in strings. Tourmaline on the other hand, usually developed in the form of rods, grows in all directions. Apart from the variation in schistosity the mineral components on the whole are evenly distributed.

One single rock only, shows a deviation in texture. In a fine-grained rock from the Marowyne (V. 506) parallel bands of a few mm. in breadth occur which have a pure quartzitic composition.

In connection with the combination of biotite, sericite and chlorite, different types may be distinguished. Those containing a predominant quantity of biotite, occur at the Marowyne (V. 435, 506), and at the Coppename above the Raleigh falls (C. 12). Forms, which, by the side of biotite also bear a considerable quantity of chlorite, are found near the Armina falls at the Lower Marowyne (V. 420, 422, 2430; Y. 352; Vtz. 371). Others again have biotite, chlorite, as well as sericite: from the Marowyne below Apatoe (V. 2431), from the Armina falls (V. 1709, 2188, 2434, 2435; Vtz. 356, 372), from Feti-tabiki (V. 2190) and not far above it (V. 2428). Or, next to biotite, sericite is present: from the Marowyne, Armina falls (V. 351; Vtz. 360, 365) and higher upstream (V. 424, 2429) and from the middle-course (V. 434); further from the Coppename above the Raleigh falls (C. 10), and below these falls (V. 2385, 2390); from the Tanjimama creek (tributary creek of the Coppename C. 98). Another type shows chlorite together with sericite (V. 360, from a little below the Armina falls). One of the rocks is rich in chlorite and calcite and on this account constitutes a transitional form towards the calcite-bearing quartz chlorite schists (V. 448). Very nearly related to mica schists are: V. 2190, 2431; C. 98.

The crystalline graywackes.

In the sample these are fine-grained to almost dense rocks, again of a gray, greenish-gray or brownish-gray, frequently also bluish-gray colour. The plane of fracture is rough, occasionally, however, it is smooth and the rock has quartzitic habitus (Y. 354). Minute spots of different tints are common. In the coarser-grained rocks we distinctly see specks of biotite (Vtz. 363; Y. 353, 354, 355, 358), in others it is not possible to recognize any single component. In one single rock (Y. 357) we observe conspicuous nests of fine scales of mica, which together form dark spots up to ¾ mm. in size, contrasting with a greenish-gray and almost dense groundmass. Most of the rocks show a parallel texture in the sample; they are, however, rarely schistose (V. 2187); some are massive (V. 1465, 1739; C. 9). A few have a hornfels habitus; in that case they are very fine-grained, with fine sparkling mica-scales in a dark gray groundmass (Y. 353).

Microscopically, by the side of mica, a quartzite structure appears again. Here, however, relics of rounded-off quartzes and plagioclases occur too. The size of the relics and their quantitative relation varies considerably. Of course, those rocks which are rich in water-worn quartz and feldspar are graywackes in a narrow sense, while others, poor in relics can not be strictly separated from the mica quartzites discussed above; hence the idea of crystalline graywackes is taken in a wide sense here (for types with distinct graywacke-features see V. 426, 427, 438, 601, 1465, 1466, 1705, 1706, 1739, 2187, 2193; Y. 354, 358; B. 20; C. 9; G. 273, 1923) (Pl. 22 fig. 1).

As we have already seen, it is almost invariably quartz and feldspar that appear as relics; while fragments of rocks are very uncommon. In the thin sections of a graywacke from the middlecourse of the Marowyne we observe very fine material consisting of extremely fine mica-scales, ore, etc.; these parts of the rock are distinctly schistose and clastic, apparently remnants of a schists. We see the same in a graywacke rich in relics, from the Lower Coppename and already described by Bergt (B. 20). Among the few samples collected by Du Bois there is a rock from Bonidoro (Marowyne) (V. 1706), in the thin section of which a fragment of andesitic composition appears; the latter consists of plagioclase laths with flowstructure arrangement, and a few minute plagioclase phenocrysts.

Accessory minerals are ore, apatite, zircon, epidote, and tourmaline rods; again the latter are not in accordance with the schistosity. In the schistose rocks the relics are frequently oriented parallelly with their maximum length.

In accordance with the combination of biotite, sericite and chlorite we might arrange these rocks in the following order. Rocks rich in biotite come from the Marowyne above the Merian creek (V. 421, 423); from the Lower Coppename (B. 19, 20, 22; V. 2375, 2387, 2389, 2391, 2397; G. 273, 1923); from the Tanjimama creek (tributary-creek of the same river, C. 101) and from the De Goeje mountains (V. 557). Rocks which, by the side of biotite, also bear a considerable quantity of chlorite are known to occur at the Marowyne: at the Armina falls (Vtz. 363) and near the Merian creek (Y. 350, 353, 354, 355; V. 2189), below Langa tabbetje (Y. 357, 359), at the middle-course of this river (V. 436). A few rocks from the Armina falls (Y. 350, 358), and higher upstream on the Marowyne (V. 2425) have biotite, and chlorite as well as sericite. Other rocks, by the side of biotite, only show sericite in considerable quantities: from the Marowyne above the Merian creek (V. 1708), in front of the Nassau mountains (V. 432), from the Lawa (V. 601); from the extreme upper-course of the Commewyne (V. 1739); from the Lower Coppename (B. 20) and above the Raleigh falls (C. 9). Rocks which have chlorite together with sericite are known to occur at the Marowyne above the Armina falls (V. 426, 427, 2187, 2424; Y. 356); at the middle-course of this river (V. 438, 1705, 1706) and at the Lower Coppename (V. 2399). Rocks containing sericite almost exclusively occur at the Marowyne over a long distance (V. 425, 429, 430, 439,

Plate 22.

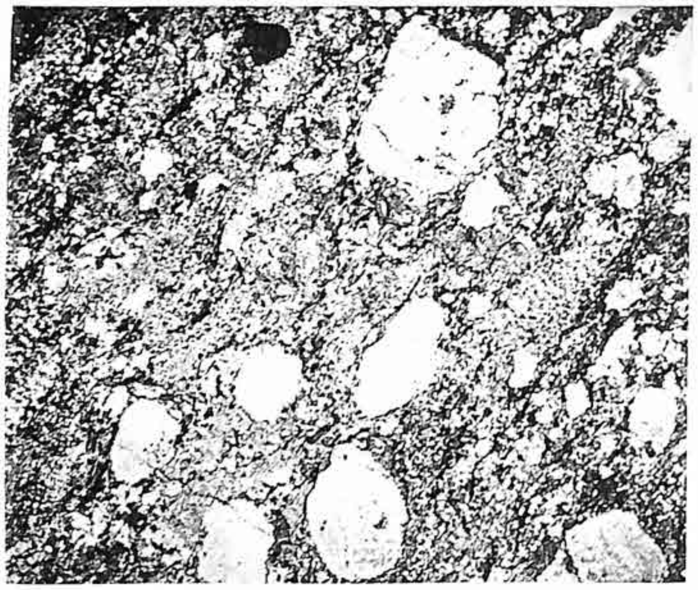

Fig. 1. Crystalline graywacke containing rounded-off, primary quartz grains. Lawa river. × 20. (V. 601).

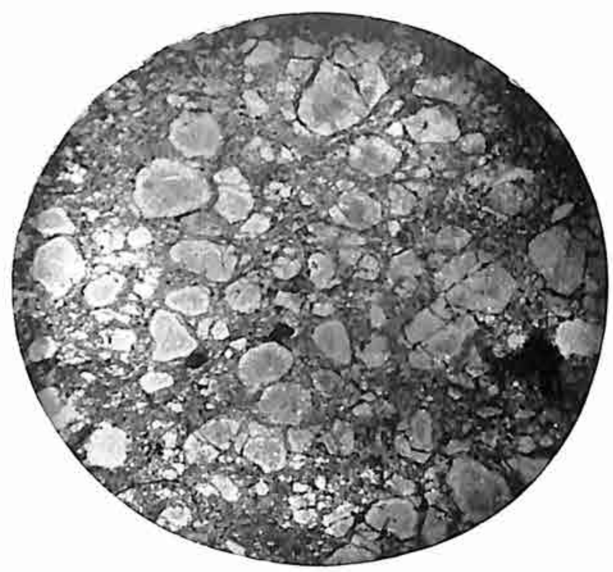

Fig. 2. Graywacke-quartzite containing rounded-off quartzes, in groundmass rich in sericite. Near Dabikwen. Suriname river. × 34. (V. 1535).

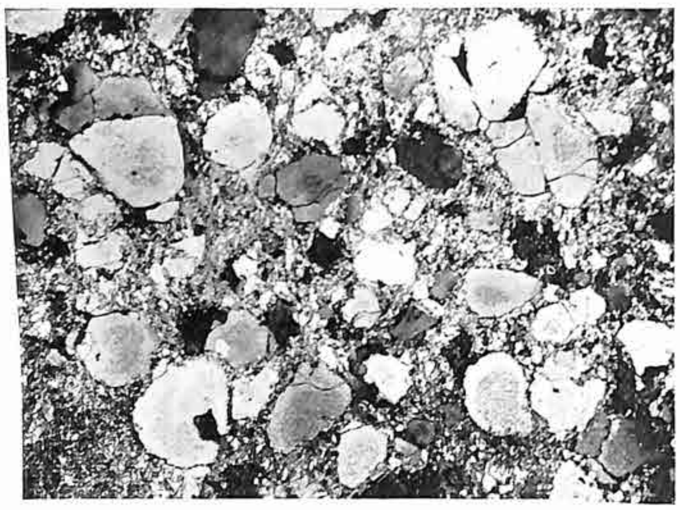

Fig. 3. The same as fig. 2, Crossed Nicols. × 42.

Fig. 4. Graywacke-quartzite showing shard-like and rounded of primary quartzes. Marowyne river. Crossed Nicols. × 12. (V. 441).

Fig. 5. Crystalline graywacke traversed by dyke of porphyritic biotite granite. Upper Gran-rio.

445, 501, 2194). We know rocks rich in epidote from the Marowyne (V. 446) and from the Coppename (V. 2392).

A rock from the Marowyne above the Merian creek (Y. 356) is worthy of special notice. It is a very fine-grained rock, showing distinct schistosity; we might, on account of its dark green tint, take it for a chlorite schist. Microscopically, however, it appears to belong to the crystalline graywacke-group. Chlorite in abundance and next to it sericite-scales in somewhat smaller quantities are present, among which a quartz mosaic is visible. Oblong-shaped, rounded-off quartz grains and also plagioclase of somewhat larger dimensions and distinctly recognizable as water-worn grains appear in the latter. This rock is closely related to those which will be described as quartz chlorite sericite schists on account of their considerable percentage of chlorite etc. (see page 404) and only differs from them because of the quartzrelics.

The graywacke-quartzites.

This third group, closely related to the crystalline graywackes, comprises rocks, which, to a great extent consist of water-worn quartz-grains. The latter lie in a cement of fine quartz-material and a varying percentage of sericite. In the samples they are usually normal-grained, almost or completely massive rocks, which, macroscopically, show numerous quartz grains on the rough planes of fracture. The rounded-off grains as a rule appear not to be sharply separated from the cement which is also rich in quartz. In one single rock this is the case, and the grains are well-rounded-off. One of the rocks, bearing cement rich in colourless mica, is schistose (V. 1696). The colour is very variable in accordance with the nature of the cement, gray in various shades, often finely speckled, rarely green or white. Many samples have assumed a red colour on account of some limonite.

Microscopically the cement appears to be thoroughly recrystallized and the edges of the quartz relics, too, are intergrown with the quartz of the groundmass. The relics, however, are very conspicuous, thus determining the structure (Pl. 22 fig. 1—3). The grains of the quartz mosaic have strikingly small dimensions. The quartz-grains may exhibit a more or less parallel orientation. Besides this also the cement may show parallel orientation, because of the sericite scales running parallel throughout the whole thin section. The water-worn quartzes polarize homogeneously or undulously; the latter phenomenon is quite frequent. In the case of more intense pressure-action the larger grains are cataclastic, the primary structure becomes less distinct and that of true quartzites comes more to the fore. A few water-worn feldspar-grains occur, and here and there some remnants which seem to be schist-fragments (see e.g. the rocks V. 907, 2210). Other components are ore, some pyrite, zircon, and apatite. Tourmaline appears occasionally as short rods and grains. Pieces of epidote are observed in the groundmass more frequently.

We have similar graywacke-quartzites from the Suriname river (V. 1392, 1520, 1524, 1527, 1530), from the Dabikwen trail (V. 1535); from the Marowyne, Armina falls (V. 2186); from this same river higher upstream (V. 500, 803); from the neighbourhood of the Witlage placer, West of the Marowyne (V. 2209, 2210, 2214); from the Lely mountains (V. 907); and from the Guyana Gold-placer (V. 4050, 4051).

Other rocks of quite the same composition strongly incline towards the quartzites, because of the quartz-relics showing more and more recrystallization and intergrowing with the groundmass; besides this, the latter may also be coarser through re-crystallization by which the difference between the groundmass and the relics becomes less distinct. Similar rocks are, in parts, not to be distinguished from sericite-bearing quartzites but at the same time agree with those just described. Samples of this type come from the following localities: from the middle-course of the Marowyne (V. 440, 442, 443, 444); from the Djoeka creek (V. 1696);

from the Mindrineti creek (Pieters-creek, V. 1761, 1768); and from the Lely mountains (V. 1012).

The conglomerate-schists and conglomerates.

We have rocks falling under this term from two localities viz. from Guyana Gold placer, and from the Colonial railway (near km. 123). They consist of pebbles of various sorts, in a completely re-crystallized cement. If the pebbles are rounded off and the cement is devoid of parallel texture, they have the habitus of conglomerates. If distinct parallel texture is present they show the habitus of conglomerate-schists. The conglomerates of Guyana Gold placer (V. 4047, 4048 from "Noutoe mountain" and V. 3598 from "A sa njam monni mountain") are typical. They are coarse and contain numerous pebbles of quartzite or pieces of quartz. In one of the samples, red-coloured on account of limonite also weathered pieces of phyllite occur. The pebbles have a tendency to rest evenly on their flattened sides; they attain to a length of 7.5 cm. The cement is coarse, variegated and shows quite a number of small pebbles and grains. Clusters of fine black sparkling leaflets occur here and there, which, microscopically turn out to be chloritoid (in V. 4047). The conglomerates and even more the conglomerate-schists, contain flattened pieces of very fine-grained green schists, particularly rich in chlorite (V. 2988, 3597, 3606, 3607, 3608, 3609, and G. 274, 1923). Microscopically the pieces of schists appear to consist of very fine quartz-mosaic, chlorite and epidote. The cement of these conglomerate-schists is coarser crystalline than the fragments of schist. Microscopically it appears to have the same composition as the crystalline graywackes; it bears water-worn quartz and plagioclase grains, and has the same variable combination of biotite, chlorite and sericite.

Contact-metamorphic graywackes.

Graywackes which have been recrystallized by contact-metamorphism are known to occur at the Upper Gran-rio. Bergt has described several graywackes from the Coppename river as contact-metamorphic rocks, but in my opinion the nature of the metamorphism is somewhat doubtful.

The rocks from the Coppename (from Makambo island) are remarkable, as they give indications concerning their sedimentary origin (B. 22). Bergt [1]) has already pointed this out. Some show a very fine-grained quartz mosaic richly provided with mica-scales, epidote and ore-grains. The ore is in parts somewhat coarser and in that case shows a well-defined octahedral shape (magnetite). Locally the quartz-mosaic also gets considerably coarser, the coloured components diminish and the thin section gets a quartzitic composition. Suchlike quartzite spots are now irregular in shape, now clearly rounded off; they were rounded-off quartzes. In other thin sections this phenomenon has developed to such an extent that some parts of the slide have a quartzitic composition, poor in coloured components; other parts, however, wholly consist of rounded-off and angular grains of quartz, only partly split

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[1]) W. Bergt. **45.** p. 130.

up into fields by varying polarization, and all of them together lie in a much finer mass of many granules of epidote, mica-scales and extremely fine quartz material, while some chlorite may also occur. These last parts show the same appearance as the graywackes, only they are much richer in epidote. Here, then, we have clear indications of the origin of the material. Other rocks, from above the Jaba creek, and from above the Visch creek, Coppename (B. 19 = V. 1465 and B. 20 = V. 1466) are also regarded by Bergt as contact-metamorphic rocks albeit under the name of crystalline graywacke (l.c. p. 127—130). Indeed they differ little from the preceding rocks at any rate from those parts, which show remnants of primary structure in abundance. To what extent we might speak of contact-metamorphism in these rocks is difficult to decide. It is true they are richer in epidote granules, but for the rest, there are no points of difference with the rocks of the graywacke group; twinned plagioclase occurs among the rounded-off relics.

A few graywackes rich in epidote also fall under the possible contact-metamorphic graywackes (V. 2392 from the mouth of the Kwama creek, and V. 446 from the Marowyne). The same is also true of a type rich in fine, frayed and confusedly intergrown sericite, containing many ore grains and much ore dust (V. 2423 from Bonidoro on the Marowyne). Another rock again shows a relationship with hornfels structure (V. 2403, Coppename between Visch and Parama creek); the quartz-mosaic is polyhedral, copiously sprinkled with ore-granules; of the micas (biotite and sericite) the latter is more coarsely developed than is usual in the graywackes.

A rock from the Marowyne, below the mouth of the Merian creek shows a new type (V. 2427). The very fine-grained, dark, massive sample shows sparkling conchoidal fracture. Microscopically we observe a quartzitic tissue in which aktinolitic hornblende and epidote-grains are found, with accessory apatite, garnet, titanite, biotite, and ore-dust. The distinctly green aktinolite varies from needle-shaped to oblong, with typical cross-fractures. Coarser crystals may be perforated. The hornblende appears in bundles, with a tendency towards parallel orientation. After hornblende the pieces of epidote are the most important ones among the coloured minerals. Garnet forms skeleton-like masses here and there. Masses of titanite have originated from ore, judging from the relics appearing in them. Other components are of no importance.

A local occurrence of graywackes on the extreme upper course of the Gran-rio shows other signs of contact-metamorphism. The last great waterfall upstream in the Gran-rio is formed by a rock-complex of some dozens of metres wide, over which the river descends step by step. Above the fall there follows deep water, below, however, at a short distance, Gran-rio granite of the normal type is exposed. The rock obstruction itself, consists of smooth rounded-off graywacke. The contact with the granite is not visible. A few dykes, however, of pegmatitic granite, rather more than 1 dm. broad appear in the centre of the complex and may be traced over a great distance in it (Pl. 22 fig. 5). Fragments of the adjacent rock are enclosed in these dykes.

Microscopically the rocks are partly typical crystalline graywackes, partly also of another composition.

A sample taken approximately from the middle of the complex (Y. 139 C), may serve as an example of a normal graywacke type. It is a dense gray quartzitic rock. Microscopically we see numerous comparatively coarse, rounded-off, oblong-shaped quartzes in a finer groundmass of biotite, sericite-scales and quartz granules. The quartzes run parallel to their maximum length, and they are typical relics of sedimentary origin. The mica-scales also run parallel. A phenomenon that is not usually seen in the graywackes is to be observed in this sample viz. the appearance of copious epidote-granules in the groundmass; in the same way as has just been described with regard to the rocks from the Coppename.

Other samples of the same complex, likewise collected at a considerable distance from the contact with the granite are again grayish or bluish-gray and massive. Sometimes they even admit of the beautiful primary quartzes being seen through a magnifying-glass, which, microscopically again appear to be quite of the same type. The groundmass, however, has another composition (see Y. 139). It consists of quartz, much potash feldspar, a smaller quantity of twinned plagioclase, lath-shaped biotite-leaves, some pale-green hornblende and epidote, ore-grains, with accessory needles and grains of apatite, pieces of calcite and some brown titanite of irregular shape. The whole exhibits a typical hornfels structure; the colourless components form isodiametrical fields, which, however, vary in size locally. The potash feldspar deserves special attention. This mineral is seldom met with in the graywackes or allied rocks; here, however, we find it in abundance. The fields show microcline structure, the larger ones containing quartz drops and some microperthite fibres. The coarser quartzes exhibit a peculiar phenomenon. On close observation we discover that the rounded-off, coarse crystals at the sides manifest a more or less distinct notched course, especially where the potash feldspar of the groundmass adjoins it. This quartz also exhibits deep indentations here and there, invariably filled with potash feldspar. These phenomena are still more pronounced in a thin section of another sample (Y. 139 H) from the same place. The quartzes remind us of those in the preceding thin sections by their comparatively large size, but their shape is quite different, the rolled-off form has disappeared, the edges are bounded by irregularly curved lines. Here again, we may observe protrusions of the potash feldspar into the quartz. This relation may also account for the rounded-off potash feldspar-spots appearing in the quartz crystals. On the whole the figure reminds us of the corrosion-phenomena as we see them in the quartz phenocrysts of the quartz porphyries, though less pronounced than there. It is possible that we are concerned with a corrosion-phenomenon here. Other samples of the same rocks manifest, besides the copious percentage of potash feldspar, also a considerable variation in coloured minerals, especially in the degree in which epidote appears, but they are of little interest. The enclosed fragments of adjoining rock in the dykes of pegmatitic granite appear to have completely re-crystallized to fine-grained mica hornfelses. The coarse-grained granite is of the Gran-rio type, with a considerable percentage of potash feldspar (microcline). The latter also forms a few phenocrysts of more than 2 cm. in size (see Y. 140 B). The coarse grain gives the rock a pegmatitic habitus.

The appearance of potash feldspar in the graywackes here, points to intense metamorphism accompanied by supply of material from the granite. Here we have a case analogous to that which has been described by Lacroix [1]) as "leptynolites feldspathisés par imbibition" with regard to the Pyrenees (massif of Quérigut). It has not been proved, however, that in the contact-zone of the massif of Quérigut feldspar-imbitition from the granite has actually taken place, and that consequently all feldspar manifesting itself in these contactrocks should have originated owing to supply of material, as is assumed by Lacroix. Erdmannsdörffer [2]) had his doubts about the existence of exclusively feldspar-producing supply of material in contact-zones, such as Lacroix supposes to be the case. For the rest the possibility of new formation of feldspar in contact-zones without supply of material having taken place, exclusively owing to recrystallization therefore, has been proved by V. M. Goldschmidt. The latter has been able to demonstrate with the aid of analyses that in the Christiania-territory feldspar-bearing hornfels has originated from clays and marls without any magmatic supply of material through contact-metamorphism. [3]) Types of feldspar-bearing contact-rocks which Lacroix denotes as "leptynolites feldspathisés par imbibition" may therefore just as well have come into being without supply of material. In our case, however, the series of transitions shows that supply of material has indeed taken place. The original material is already crystalline and is a rock rich in quartz which does not contain components in a sufficient degree to supply the material for the abundant quantity of potash feldspar.

GEOLOGICAL BEHAVIOUR AND DISTRIBUTION OF THE GRAYWACKE FORMATION.

The main distribution of the formation is in the extreme east of the Colony, on the Marowyne. It appears along this river over a distance of 85 km. only being relieved here and there by allied schists. The area where the copious sample-material was found in this territory is marked on the accompanying sketch. In the first rapids on the Marowyne, the Armina falls, the first rocks of this groups are exposed and from there they continue to the fall-complex below the junction of the Lawa and Tapanahony. The gneisses on Du Bois's sketch-map exposed in the first falls above Apatoe-kondre microscopically appear to be mica quartzite and crystalline graywackes. The granites in front of the Djoeka creek, on the same map may also be left out of consideration for we only know rocks of the graywacke-group from here. Other rocks, however, occur locally: amphibolites, sericite schists with calcite porphyroblasts, and, in the south also quartz porphyries, porphyroids and quartzites.

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[1]) A. Lacroix. Le granite des Pyrénées et ses phénomènes de contact (premier mémoire). Les contacts de la Haute-Ariège. Bull. Carte géol. de la France, No. 64, 1898.
[2]) O. H. Erdmansdörffer. Petrographische Untersuchungen an einigen Granit-Schiefer-kontakten der Pyrenäen. Neues Jahrb. f. Mineralogie. Beil. Bd. 37, 1914.
[3]) V. M. Goldschmidt. Die Contactmetamorphose im Kristianiagebiet. Vidensskabsselskapet Skrifter. Kristiania. 1911. Math. Natur. Klasse I. Bind 1912).

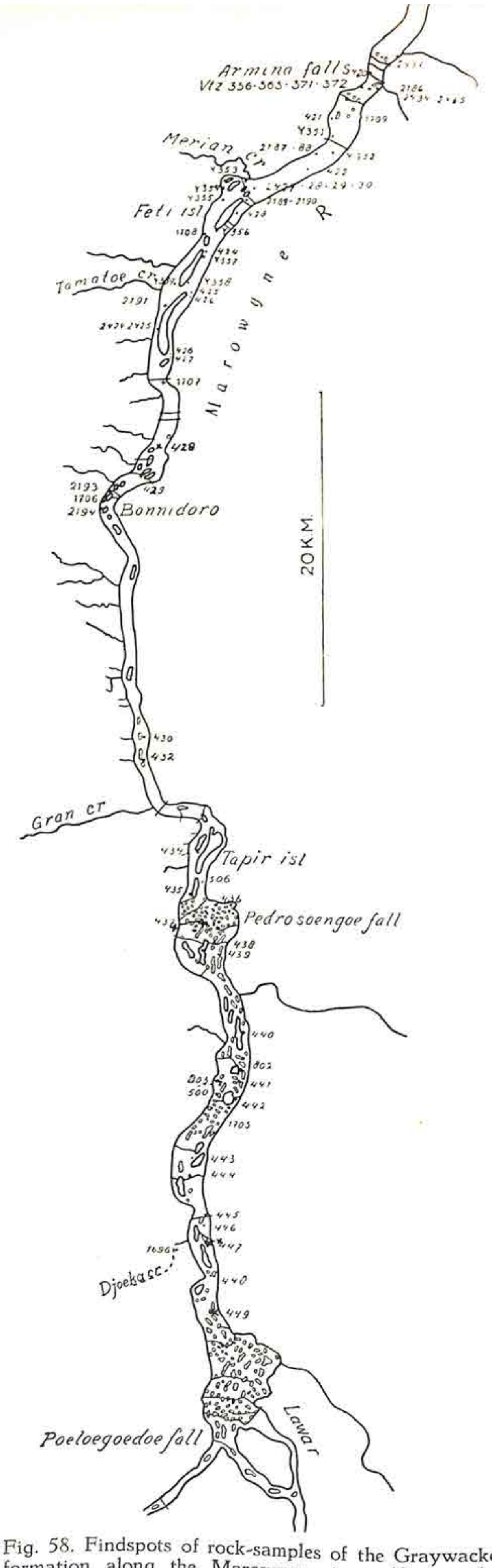

Fig. 58. Findspots of rock-samples of the Graywacke-formation along the Marowyne river. (Some other rocks, chiefly schists, are indicated by crosslets. Numbers without preceding letter refer to the collection of the Polytechnic at Delft).

Hence we may rightly say that the graywacke formation occurs almost exclusively over the distance mentioned. It is obvious that the distribution must also extend beyond the river-bed proper, both on the Dutch and the French banks. About the latter we have no data whatever. On the Dutch side we only have a few data, indicating that by the side of the graywackes, other rocks may appear; graywackes occur in the neighbourhood of the Witlage Placer (West of Bonidoro) in the neighbourhood of the Gran creek and near the Hermina placer between Marowyne and Tempati creek).

Beyond the Marowyne region we know the formation but locally: at the Lely mountains, at the De Goeje mountains, at the Suriname river near Brokopondo, at the Miendrineti creek, at Guyana Gold placer and elsewhere on the Colonial railway, and at the Granrio on its extreme upper course. The distribution on the Coppename below the Raleigh falls is more important, where graywackes over a distance of 20 km. interchange with granitodiorites and contact-metamorphic rocks; we also know some graywackes above the Raleigh falls.

It appears that the three main types, the mica quartzites, the crystalline graywackes, and the graywacke-quartzites do not occur each in a special area; in most of the regions we find them all, and often by the side of each other. However, the conglomerate-schists and conglomerates only occur locally. They form layers among the graywackes, below Bonidoro at the Marowyne. At Bonidoro they alternate with graywacke-quartzites (according to notes of the engineer G. Duyfjes). They also occur on the Colonial railway and at the Guyana Gold placer. In the last mentioned locality they appear together with graywacke-quartzites.

If parallel texture is present, this manifests itself in the river-bed by the appearance of narrow, steep, sometimes plateshaped rocks. The almost massive or massive types, however, form somewhat rounded-off benches and small cupolas. This has already been recorded by Du Bois; I, myself, have seen it on the Lower Marowyne: instances of the first form in front of the Merian creek, and of the second in the Armina falls. Concentric cleavage is know to occur in graywacke-quartzite near the Gonsoeto fall. Where schistose texture is indicated or well-developed, the plane of schistosity appears to be steep. According to observations of the Engineer G. Duyfjes and myself, the trend appears to be strikingly constant (N. 0—45° W., with steep dip), over no less than 35° km. viz. from Armina falls up to Bonidoro. A few observations farther upstream seem to point to the same. Microscopical investigation shows that the parallel texture of the samples, coincides with the original bedding of the sedimentary material. The waterworn quartzes etc. in as far as they are oblong-shaped, run parallel to it.

We have a single contact-metamorphic (?) rock from the basin of the Marowyne, but no conclusive data concerning the relative age with respect to the granitodiorites there.

As has already been stated graywackes have been met with on the Upper Gran-rio, bordering on Gran-rio-granite; they are cut by small granite dykes, and affected by contact-metamorphism (see Pl. 22 fig. 5). Moreover, we know of andalusite-hornfels from this region. Hence it is obvious that in this case the graywackes are older than the granites. As has already been mentioned the graywackes have been materially affected by contact-metamorphism on the Coppename, and the granitodiorites, alternating with them there, are undoubtedly the cause; so the latter are younger.

That the graywackes are also older than the intrusive diabases has been ascertained on the Marowyne, just above the mouth of the Merian creek. In the rapid there we observe a broad dyke of olivine diabase in crystalline graywacke. The dyke follows the trend of the graywackes (approximately N. 20° West).

May a few words suffice to state that the graywacke-formation has nothing to do with the Roraima-formation, especially as Harrison expresses the opinion in his monography [1]) that Du Bois's graywacke-formation is the equivalent of the basal members of the Roraima-formation. The later sandstone-formation, however, is discordant with the basal complex, and the graywacke-formation belongs to the oldest parts of the basal complex. Petrographically the graywacke-quartzites differ from those of the Roraima-formation: the former contain worn down crystals of plagioclase but not of potash feldspar, while microcline is very common in the latter (see p. 81).

Traces of cataclasm which for the greater part probably originated after

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[1]) J. B. Harrison. **68.** p. 83.

re-crystallization of the rock had ceased, are very common, without materially interfering with the structure and texture. In quite a number of rocks, the rounded-off quartzes show distinctly undulose extinction (e.g. V. 421, 423, 438, 1466, 1468; Y. 350, 351, 357, 358, 359). The same phenomenon occurs in types showing a quartzitic structure. The twinning of the plagioclase may also be somewhat disturbed. Tourmaline rods, besides the cross-fractures, sometimes show distinct micro-faulting. Without attaining great intensity, therefore, signs of pressure have a fairly large distribution in this formation.

THE ORIGINAL MATERIAL AND THE NATURE OF THE METAMORPHISM.

There is no doubt that the graywacke-formation, on the whole, is of sedimentary origin. The whole series of rocks must have originated from sediments rich in quartz, probably plagioclase-bearing quartz sands, having clayey and ferruginous components.

The minerals may be divided into secondary and primary components. The secondary ones are biotite, chlorite, sericite, chloritoid, ore, tourmaline, rutile, calcite, epidote and garnet. The coarse pieces of patchy biotite, occurring in some rocks, which are much perforated and which enclose colourless grains, have clearly a crystalloblastic nature. The same is true of coarse chloritoid crystals. Ore is chiefly octahedral. Tourmaline occurs as needles growing into the rest of the components. Epidote and garnet, occurring as grains, show but little tendency towards idiomorphism. Apatite and zircon are rounded-off, and especially the first mentioned mineral presents the habitus it has in sediments, so that no essential re-crystallization has taken place. Quartz and feldspar are present, partly as relics, partly as new-formations. The secondary nature of part of the plagioclase is not doubtful, considering the mutual relation with the secondary components of the groundmass, among otherthings the poikilitically enclosed quartz-drops.

It is striking that potash feldspar is practically entirely wanting as a relic. There is no reason to believe that original, clastic potash feldspar, should have been converted into sericite and quartz during metamorphism; for in quite a number of rocks that contain plagioclase and quartz as relics sericite is completely wanting. Consequently it is probable either that the rocks which provided the sediments of the graywacke-formation bore no potash feldspar, or that potash feldspar was destroyed during the sedimentation. If we accept the former supposition granitic rocks cannot have provided the original material, and this assumption would harmonize with the comparatively later age of the granitodiorites of the basal complex with respect to the graywacke-formation. The second explanation is improbable; it is indeed known that plagioclase is destroyed more readily by weathering than potash feldspar.

In connection with the greater age of the granitodiorites the difference of the graywackes with respect the Roraima formation is striking; the latter is younger than the granitodiorites and often bears a large percentage of microcline in the quartzitic sandstones and it is possible to trace their material back from the granitodiorites of the basal complex.

The occurrence of a rock-fragment of andesitic structure in one of the graywackes points to igneous rocks older than any igneous rock we know of in the basal complex.

The parallel texture of the newly-formed components, together with the tectonic disturbance and the regional distribution of the graywackes, points to stress being the cause of re-crystallization. That the recrystallization of the graywackes has been entirely caused by contact-metamorphism as was formerly supposed by Bergt (l.c.), is incorrect. In the contact-metamorphic types we observe, that the parallel-texture tends to be destroyed; and moreover a formation having a regional distribution, as on the Marowyne, cannot be wholly contact-metamorphic, considering that igneous rocks are nowhere met with.

It is an open question whether the tectonic disturbances which have caused re-crystallization to crystalline graywackes, have any relation whatever to the intrusion of the granitodiorites, or whether they represent the result of older tectonic movements.

THE QUARTZ (CALCITE) CHLORITE ALBITE SCHISTS AND ALLIED ROCKS.

All the rocks falling under this head are supposed to be of sedimentary origin. The original material was probably a mixture of basic tuffs together with clastic quartz and detritic matter. The various components must have contributed in highly varying degrees. Consequently the metamorphic rocks are also very different, but form a transitional series. Quartz and chlorite occur in all the rocks, with or without calcite, sericite and feldspar, and all together in different quantitative ratios. According to the mineral assemblage the rocks have been classified as

A. calcite-bearing forms

B. calcite-free forms.

We propose first to discuss the minerals separately and subsequently to give a description of the rocks.

The mineral components.

Calcite. Calcite can be recognized macroscopically in a number of rocks; many rocks show rhombohedra. Suchlike rocks give with hydrochloric acid a brisk effervescence. Under the microscope calcite shows an intense variation in form and size. Sometimes we see among a fine quartz-mosaic, mixed with chlorite small, irregular calcite particles. Mostly, however, calcite is larger than the other components. In that case we may have to do with true porphyroblasts.

Polysynthetic twinning according to (0112) is very common in coarse pieces, often cut by the (10$\bar{1}$1) cleavage. Well defined crystals will occasionally exhibit a porous structure; others again will show inclusions of dust in the centre, which fill up a field that has the same shape as the crystal. (fig. 59). The dust may also be arranged zonally, as if one had to do with zones of accretion. The tendency to form groups of calcite pieces, that hinder each other mutually, is also very typical. Such calcite-nests may be encircled by a narrow zone of chlorite leaflets, and this may again be surrounded by a narrow zone of quartz mosaic. Of common occurrence are oblong calcite masses. In rocks

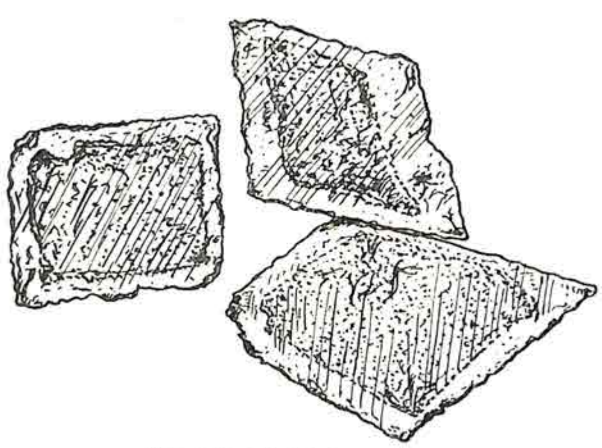

Fig. 59. × 65 (Vtz. 15)

with distinct parallel texture lenses and sometimes even bands of calcite may occur. The replacement of calcite by limonite is very common. This phenomenon starts from the edges as well as from the planes of fissure. The end of the process is entire replacement of the calcite, which now results in irregular spots (see V. 1391) now in rhombohedral pseudomorphs (see for the latter type V. 76 and V. 1691). The limonite no doubt points to a content of iron in the calcite. The typical rhombohedral pseudomorphs have been repeatedly recorded in the Surinam literature as pseudomorphs to pyrite.

Chlorite. Although it is always one of the main components, this mineral gives rise to only few remarks. It occurs in irregular scales from the smallest dimensions up to large masses. In schistose rocks it can form lenses, or sometimes even bands. The anomalous polarization colours may be distinctly developed (see V. 1621). It is an optically positive chlorite.

Sericite: as fine scales and laminae, colourless or of a greenish tint, requires no discussion.

Quartz, likewise a main component, is always present. Quartz shows isodiametric grains, and forms, sometimes in combination with albite, a colourless mosaic. Large quartz fragments are rare, they might be considered as remains of clastic sedimentary material. Where we have to do with clastic fragments, they must have accrued secondarily, as appears distinctly. When looking sharply we see how the extremities of small, oblong albite crystals are enclosed in the outer zone of the quartzes. In that case is it clear that the quartz has secondarily grown (see V. 1391). Moreover apatite needlets may be enclosed.

Albite. Albite is in some cases abundant, in other cases it is rarely seen or is completely lacking. It is not always easy to decide whether the albite is of primary clastic origin, or whether it is a novel formation in consequence of total recrystallization of the rock. In far most cases the latter interpretation is the right one. However, in a few rocks there are fragments of albite, vaguely defined, whose shapes are splinter-like. They may be bent and intersected by micro-faults. The groundmass may penetrate along the cracks. If these feldspars are somewhat larger than the others, the picture strongly reminds us of the porphyroids (see Vtz. 54 to 60 and V. 1379). Sometimes in the same rocks albite of indubitably secondary origin occurs. Surely secondary are relatively coarse crystals, occurring either independently or accumulated in masses. In the first case the shape is more or less distinctly idiomorphic either lath-shaped, tabular, or isodiametrical. If they occur in groups the crystals hinder each other. Twinning lamellae in such coarse crystals are not always distinct. Particles of quartz and chlorite are often enclosed. Nobody will doubt the secondary character of suchlike albite groups. Nests, and occasional vein-like masses (of microscopical dimensions) are to be found.

Finer albite is observed in the "groundmass". The crystals are mostly oblong, more or less lathshaped. The twinning structure is interrupted by enclosed chlorite scales (See V. 1521, 1549, 1638). The smallest albite laths may show a bundled or fanlike arrangement (See V. 1549). Suchlike albite is hard to recognize, and is easily overlooked.

The behaviour of albite is different, when the mineral forms a finely granoblastic mosaic together with quartz. In that case it will be very hard to estimate the albite percentage, though the index of refraction furnishes some help (V. 1638).

Other mineral components are of little importance: *Ore* may occur as a novel formation, probably ilmenite (see the beautifully defined ore particles in V. 1720, 1721, and 1722). Often ore is replaced by leucoxene dust, sometimes also by titanite. *Titanite* occurs only here and there. Remains of ore suggest that it has been formed from it. *Pyrite* is of rare occurrence; sometimes it appears in coarse cubes. *Apatite* occurs only sporadically, in granules or as needlets enclosed by quartz (V. 1391). *Tourmaline* we see only in one rock (V. 1638). *Epidote*. Secondary epidote grains are an exception.

PETROGRAPHIC DESCRIPTION.

A. *Calcite-bearing forms.*

These rocks possess the mineral-combination quartz, chlorite, calcite. Plagioclase may be present. Sometimes there is an amount of sericite.

Of the plagioclase-bearing types we have beautiful specimens collected long ago by Voltz, on the bank of the Lower Suriname river, near Berg en Dal.

In the sample they are fine-grained to compact, greyish or brownish grizzly rocks. They are almost massive, or show indistinct parallel texture, or are schistose. In some types we cannot detect any separate mineral component macroscopically. Others are filled up more or less densely with brownish calcite, in part as rhombohedra, up to a few millimeters (See of the outwardly very varying series Vtz. 15, 16, 38, 39, 44, 48, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66 and 69; part of this series is marked on map VI). Five rocks of this series have been examined under the microscope. One sees a very fine mixture of isodiametric quartz granules, chlorite scales and calcite particles. The latter mineral, however, is sometimes of little importance in the groundmass, and then appears more frequently in larger dimensions. In addition we observe a varying quantity of ore particles, and sometimes greenish sericite scales. These components may be distributed evenly. Quartz-mosaic may be seen between the chlorite scales. The chlorite forms nests, the calcite irregular masses. In the almost massive types splendid calcite porphyroblasts occur. In the schistose types the coarser calcite masses and the chlorite spots are oblong and have an even trend. Strings, principally consisting of calcite are present.

Other rocks are allied to the types just described, and show likewise a variety of details. In a sample from Brokopondo, Suriname river (V. 1391) there are besides the fine quartz also coarser quartzes which are considered as novel formations. The albite may become more conspicuous on account of its size and on the one hand give an impression of porphyroblasts, on the other hand show traces of cataclasm (V. 1543 from Grinwisburg, Suriname river). Of an other type is the albite in a rock from Locus creek (V. 1638). Here we find almost as much albite as quartz; the feldspar forms with the quartz a fine granoblastic mixture. This rock, and also one from Witlage placer (to the West of Bonidoro V. 2249) contains an abundance of sericite by the side of chlorite. The calcite may be replaced more or less by pseudomorphs of limonite (see V. 76 from the Tapanahony near Clementie). These rocks vary largely in the sample; one of them (V. 1543) is distinctly schistose; it shows a sericitic lustre, and on this account is has been termed by Du Bois phyllitic schist [1]).

Lastly we still have rocks of this mineral combination from Toeval placer (V. 2273), from the Suriname river below Grinwisburg (V. 1525, 1526) and from the Marowyne (V. 452).

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[1]) G. C. Du Bois. **40.** p. 17. Nr. 61.

Other rocks are in every respect comparable with those just described, but they differ only in that feldspar is lacking almost entirely, or seems to be so. Considering the very fine grain of the rocks it is next to impossible to know whether there is albite concealed in the groundmass. The mineral combination is quartz, chlorite, calcite with a varying amount of sericite, and sometimes ore. There is always parallel texture and many rocks are schistose.

A sample from Tompi creek (V. 1621) appears to be very rich in calcite and chlorite, so that the other components are scarcely of any significance (viz. quartz and ore). Microscopically the parallel texture of the sample is very distinct: a calcite mass is traversed by chlorite cords. The chlorite displays very distinct anomalous polarization colours. Ore-dust is located exclusively in the chlorite cords. Pyrite may be traced in the sample.

In the very fine grained, greenish-grizzly, chlorite-rich rock from the Dabikwen trail ore has been replaced by titanite particles (V. 1539). The sample may be considered as a chlorite schist. A rock from Ballijn (Suriname river) is rich in fine ore (V. 1537). Another rock is conspicuous by its fine and even grain (V. 2226 from Witlage placer). In another again calcite occurs as distinct, small rhombohedra, chiefly replaced by limonite (V. 1691, from Poeloegoedoe fall, Marowyne). Other rocks, fine-grained, and calcite-rich show the latter mineral in irregular particles (V. 1433, from New Star island, Suriname river; V. 2276 from Toeval placer).

Sericite containing types have been collected at Grinwisburg, Suriname river, rich in relatively coarse calcite masses and patchlike chlorite spots (V. 1544 and 1545). In the sample the rocks have the habitus of phyllitic schists and are mottled bluish green, with a vivid lustre.

In the sample a rock from the Sara creek (V. 1581) is very rich in sericite and graywacke-like. Chlorite has receded into the background. The ore is of an octahedral shape. Rocks from Brokopondo (Suriname river, V. 1522) and from the Lower Saramacca (V. 1743) are also very rich in sericite. Both are fine-grained distinctly schistose. The first might be termed for the sample sericite schist. Chlorite is very insignificant. There is a great amount of calcite particles. By these the rocks differ from sericite schists. There are in one of the samples (V. 1743) a great many pyrite cubes to the size of ½ cm.

B. *Calcite-free forms.*

Some calcite-free rocks show a considerable difference with the preceding rocks as regards mineralogical composition. They possess the mineral combination quartz, chlorite, albite, with or without sericite. It is above all the often copious amount of albite that suggests a close relationship to the previous rocks.

We have representatives from the Suriname river, respectively from Boschland (V. 1506, 1521); from New Star island (V. 1549); from near Ceder creek (V. 1389) and from Ballijn soela V. 1533); from the Man a Sam placer, at the Upper course of the Commewijne (V. 1721, 1724); from the Lawa (V. 487). In the sample they are greenish, very fine-grained rocks, with parallel texture and irregular fracture. One of the rocks contains pyrite cubes of the size of some mm.

The rocks from the Suriname river look very much like each other microscopically. We observe groups of albite crystals located in a finer mass containing quartz, albite, and chlorite (and a trace of muscovite). The quantity of albite is surprisingly large, being about the same as that of quartz and chlorite separately. The porphyroblastic, coarser albites undoubtedly have recrystallized. The feldspar of the groundmass is always oblong and polysynthetic. In a number of places we also see peculiar bundle-like arrangement of the finest, oblong albite laths. Some very unimportant particles of epidote occur. Ore is absent.

One of the rocks from Man a Sam placer appears to be rich in chlorite and almost without sericite, while in the other an about equal amount of finely scaled chlorite and sericite are to be observed. The firstmentioned rock contains ore particles that are beyond doubt novel formations. The albite appears here in somewhat coarser crystals, which possibly are no porphyroblasts. In the rock from the Lawa (V. 487) ore has been replaced by titanite.

SOME CHEMICAL DATA.

Table 31 shows the chemical composition of two schists of this group. The

Niggli values have been added. The first rock shows the combination quartz, chlorite, albite and calcite. The second is calcite-free. The analysis of the first rock betrays at first sight its sedimentary origin, in view of the values for Al_2O_3 and Fe_2O_3. The original material cannot easily be pointed out. The small amount of aluminium oxide implies that there was only little clay in the sediment. The analysis falls in with the variable composition of altered basic tuffs and their metamorphic equivalents, viz. palagonite tuffs, and Schalsteine, but the Al_2O_3-, and the MgO-content is most often larger there.

	Quartz calcite chlorite albite schist V. 1391	Quartz chlorite albite schist V. 1506
SiO_2	51.08	64.95
Al_2O_3	5.23	18.31
Fe_2O_3	24.92	7.00
FeO	0.79	0.63
MnO	—	—
MgO	0.60	1.37
CaO	4.22	0.70
Na_2O	3.12	3.00
K_2O	1.70	2.95
H_2O+	0.02	0.07
H_2O-	0.31	0.14
CO_2	6.88	0.05
TiO_2	1.01	0.81
P_2O_5	0.12	0.02
	100.00	100.00

Anal. Dr. K. Brauer, Kassel.

NIGGLI VALUES.

	V. 1391	V. 1506
si	158	268
al	9.5	44.5
fm	63.5	32.5
c	14	3.0
alk	13	20.0
k	0.26	0.39
mg	0.05	0.26
Section	2	1

Findspot: V. 1391: Suriname river, first rapid near Brokopondo.

" V. 1506: Suriname river, near the landing of Boschland.

TABLE 31.

It would seem that the calcite-albite-rich types of the group have been made up of similar tuffs, possibly with an admixture of fine, sedimentary quartz. As said, fragmentary albite crystals resemble remains of clastic feldspars. These albites may possibly be remains of basic feldspars from which the anorthite percentage has been carried off. The irregular calcite masses may very well correspond with amygdaloidal calcite in indurated tuffs.

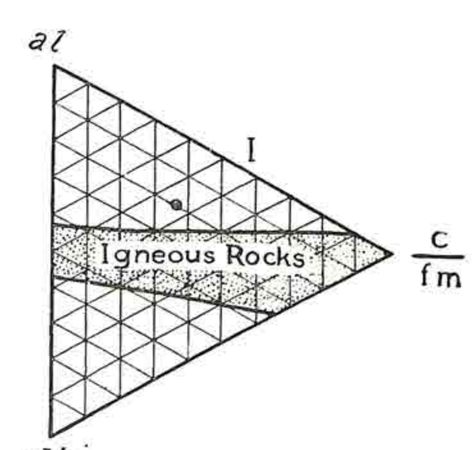

Fig. 60.
● = projection of the quartz chlorite albite schist V. 1506.

In the same way the less calcite- and albite-rich schists may have arisen from a mixture of tuffs with detritic quartz etc. The calcite-free schists must, however, have been of a different origin, considering the analysis of the second rock. At first sight this analysis bears a resemblance to that of igneous rocks. In the tetrahedral projection, however, it lies out of the igneous field (see fig. 60). The analysis agrees with that of sandy clay, without any admixture of organic remains (CaO) of some significance. This analysis shows the predominance of MgO over CaO, as is generally the case in clays. The predominance of Na_2O over K_2O is less characteristic for in clays the reverse is generally the case.

THE QUARTZ SERICITE CALCITE SCHISTS AND ALLIED ROCKS.

But few schists of this mineral combination are present. They show great variations in the quantitative relation of the components. The schists exposed in a shallow shaft and borings at Gros placer on the Colonial railway are specially interesting. They are occasionally very rich in calcite and show remnants of original structures.

In the sample the schists are light grey, dark grey or bluish grey, fine-grained to compact. A more or less distinct parallel texture has been developed, but the rocks are never distinctly schistose. The bluish grey types may offer a splintery fracture with a dull glistening on the faces (V. 802, 1707). A few of the light coloured types are perfectly massive (V. 1733); moreover the last mentioned sample comes off powdery. The calcite porphyroblasts, found in a number of samples draw the attention (see e.g. V. 1729, 1730). They fetch as much as 2½ mm. Some have been substituted by limonite pseudomorphs. The calcite induces in most samples some effervescence with hydrochloric acid, even though calcite is not identificible macroscopically. In one of the samples we distinguish pyrite cubes, larger than the calcite porphyroblasts (V. 1729). The hardness of the rocks varies; most often they can be scratched with a knife.

Microscopically the rocks appear to be composed of quartz, sericite and calcite. The groundmass shows a very even tissue of colourless, or light greenish sericite scales, between which very fine quartz mosaic is vaguely seen. The sericite-scales lie parallel, and do not show any significant folding. There is a moderate number of ore-grains, also evenly distributed. Sometimes insignificant blue tourmaline needlets occur, and rarely an occasional epidote granule. Calcite forms distinct porphyroblasts with rhombohedron faces. Besides the crystals perceptible macroscopically, under the microscope also much smaller pieces appear, but their size always exceeds that of the components of the groundmass. The pieces are sometimes highly porous. Twinning-structure, probably caused by pressure seems to appear here and there. As inclusions occur a few ore granules and sometimes also numerous angular particles of quartz (see V. 1730). These calcite porphyroblasts have a tendency to be evenly orientated as to the longest axes. In case of weathering they are substituted by limonite.

In some rocks (V. 1729 to 1735, all from the same locality) there is moreover, a little chlorite, grass-green, showing anomalous interference colours. The chlorite shows small crystals but slightly coarser than the sericite of the groundmass, and their well-developed base is conspicuous. As to habitus they rather are like fine chloritoid porphyroblasts. They are scattered pellmell; sometimes they are arranged like a wreath round the calcite crystals.

We have these schists from the Marowyne, an hour by boat above "Langa-tabbetje" (V. 428, 1707), near Gonsoetoe (V. 802) and near the Upper Commewijne (V. 1729 to 1735).

More variable are the schists from Gros placer. As all the types occur together there and may be united by transitions in the same sample, so they will be discussed together. A boring-core from Gros placer (V. 64) shows on the polished surface a dark tint, but on the transverse fractures sericitic lustre. The rock is very fine-grained except numerous recognizable magnetite octahedrons, which attain the size of some mm. Under the microscope numerous rounded, in part also angular grains of quartz and pure plagioclase are to be observed; the latter will sometimes show twinning-lamellae. The quartz may be divided in a few fields interiorly. These relics are lying in fine quartz mosaic, rich in sericite and of an abundance of calcite particles. The sericite scales are evenly stretched. The calcite is distributed irregularly as coarse spieces and finer material which joins the mosaic. A few coarse pieces incline to rhombohedral shape. The ore is developed as comparatively coarse, nicely defined octahedrons.

A sample from a shaft on Gros placer has outwardly the same habitus (V. 696). The schistose rock has a greyishwhite colour with a sericitic gloss; many ore octahedrons are present, besides a few pyrite cubes to the size of ¾ cm. Microscopically, however, clastic relics appear to be all but entirely absent. The rock consists of a very fine sericitic tissue between which locally some fine quartz mosaic appears together with here and there some irregular pieces of calcite. The same ore is again present.

Another boring-core from Gros placer has intersected layers of heterogeneous composition at a small angle. The polished surface of the core in part shows a greyish brown, mottled, compact homogeneous rock with parallel texture. Another part of the core is of a slightly darker colour, but contains moreover numerous ore-grains. The divide between the two parts is sharply marked.

Microscopically the part first-described appears to consist of a very fine mass in which quartz particles are vaguely recognizable. Here still a second colourless component may possibly be hidden, perhaps albite. In some places calcite fragments and ore grains appear. The second part of the core is allied to the rock first-described. We see abundant sericite scales and finely distributed calcite-dust. Calcite also occurs in larger pieces. Some rounded-off quartz-grains are present. Again a number of ore octahedrons occur. Some albite is present locally. It show fine twinning-lamellae. The small crystals appear vaguely outlined among the sericite rich tissue of the groundmass.

These schists are beyond doubt of sedimentary origin. It may be possible that sericite schists originate from quartz porphyries, porphyroids etc. but this hypothesis is negatived here by the calcite percentage that is sometimes considerable. The remnants of original structures of the rocks from Gros placer are of special interest. The rounded-off plagioclases and quartzes are quite comparable with those described with rocks from the greywacke formation. They also point to the sedimentary origin.

In most schists quartz and sericite are by far the chief components. They probably originate from clays with a considerable kaolin percentage. The most irregular distribution of the calcite percentage is not typical of clayey marls, so that the latter are not to be considered as the original material of the calcite-rich types. They may have been clays in which organic matter, e.g. fragments of shells, were scattered irregularly.

THE QUARTZ CHLORITE AND QUARTZ CHLORITE SERICITE SCHISTS.

Some schists are characterized by the mineral combination quartz chlorite, with or without sericite. Contrary to the pure chlorite schists, which are not found in Surinam, they are quartz bearing. The term chlorite schists, however, has been applied in the Surinam literature to them.

In case sericite occurs to a fair amount, the rocks can no more be sharply distinguished from the sericite phyllites.

In the sample the schists are very finely granular of a greenish colour, with parallel texture, or distinctly schistose. In the latter case they look exactly like pure chlorite schists (see V. 1548). One of the samples has moreover a distinctly folded texture (V. 2382). Another contains a few coarse pyrite cubes (V. 2251). A third might rather be taken for a sericite schist, and shows small quartz lenses. In agreement with this Du Bois [1]) has termed it sericite quartzite (V. 1700).

Microscopically the rocks prove to consist only of two components, very fine quartz, and equally fine chlorite scales. In addition there may be also some leucoxene, an occasional piece of albite and sometimes also some newly formed cre. The two main components are evenly distributed over the rock, even orientation of the mica causes the parallel texture. In oblong masses where the two components are a little coarser, it is evident that the colourless material is quartz. However, in one of the rocks (V. 2251) the two components are extremely fine and the colourless material is difficult of determination (V. 2251).

Special mention should be made of the very chlorite-rich rock from New Star island (Suriname river), where anomalously polarizing chlorite masses exceed the amount of quartz. A number of titanite crystals occur here. In virtue of their idiomorphism (envelope-shaped sections) and their dimensions they play, so to say, the part of porphyroblasts (Pl. 45 fig. 3). Traces of ore suggest the formation of the titanite from ore. But beyond this also absolutely unmodified ore occurs, together with some pyrite, in small amount.

A quartz chlorite sericite schist has been collected at the Man a Sam placer (V. 1722). The sample is very fine grained and is obviously schistose. The colour is light greenish. Under the microscope we see delicate flakes of sericite, chlorite, and particles of ore, between which fine quartz mosaic occurs. The mica material shows locally a finely undulating detail-folding. The sericite and chlorite occur promiscuously, both are tinged greenish. Between crossed nicols one might be inclined to overestimate the amount of sericite in comparison with chlorite, because the very weakly, anomalously birefringent chlorite is little conspicuous between the intensely birefringent sericite. For that matter the

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[1]) G. C. Du Bois, **40**, p. 24 nr. 250. b.

distribution of the material is not equable, in some places we recognize little lenses of quartz mosaic.

A special type of quartz chlorite schist may be mentioned here separately. It is rich in chloritoid (V. 1523). It occurs together with a chloritoid quartzite at Brokopondo, Suriname river, and is petrographically closely related to the later rock (see p. 419). The sample shows parallel texture. In a greenish groundmass, rich in chlorite, black leaflets of chloritoid, up to 2 mm. are to be distinguished. Microscopically the components are quartz, chlorite and chloritoid. The quartz occurs as a very fine mozaic of polyhedral grains. Chlorite occurs among it, and may substitute the mozaic locally. Besides, larger, rounded-oblong quartzes are present. They are relics of clastic quartz, of the type described with the graywackes. The chloritoid is developed according to the base. It shows typical porphyroblasts, enclosing many quartz grains. Some limonitized ore is present. Du Bois has called this rock a metamorphic diabase (l.c. p. 16 Nr. 43), apparently after the habit of the sample.

The mineral combination and distribution of the components show that all the rocks described under this head are of sedimentary origin. Mineralogically they are closely allied to the calcite-free members of the preceding group, while they occur with them.

Pure quartz chlorite schists we have from the Man a Sam placer (V. 1720); from the vicinity of the Witlage placers (V. 1700, 2251) [1]); from New Star island on the Suriname river (V. 1548), and from the Coppename near Bitter creek (V. 2381, 2382). The only quartz chlorite sericite schist is from Man a Sam placer (V. 1722).

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[1]) Near the Djoeka creek and West of Bonidoro (Marowyne).

THE CHLORITOID SCHISTS AND CHLORITOID PHYLLITES.

Of this group we possess only a few representatives, viz. from the L. and F. de Jong placer (V. 1769) and from Guyana Gold placer (V. 4043, 4044).

Du Bois [1]) already called attention to the rock from the De Jong placer; he took it for a contact-metamorphic rock, which view is not adhered to here, because rocks of a corresponding composition are hardly ever considered as contact rocks, and also because its relation to the granitodiorites is not established.

The rock from De Jong placer is a phyllitic schist of a greenish grey colour; it splits along parallel planes. On the cleavage plane we see numerous small, rhombic grains of some millimeters in section; moreover oblong black flakes of chloritoid are to be observed. Under the microscope we see a texture of scaly sericite and chlorite, among which quartz granules are noticeable. Moreover there are numerous particles of ore and locally a fair amount of blue tourmaline prisms. The micas give the parallel texture to the sample. In this tissue much larger chloritoid crystals are scattered pell-mell. The crystals are distinctly flattened after the base, which is often very sharply developed. Polysynthetic twinning is common. Pleochroism passes from bluish green to greenish. The rhombic pseudomorphs, that may be recognized macroscopically are filled up with sericite and indeterminable colourless substance. We are inclined to regard them as pseudomorphs after calcite. The sericite shows typical bent texture around the porphyroblasts.

The phyllites from Guyana Gold placer bear a close resemblance to the preceding rock. One of the samples splits parallel and shows numerous dark chloritoid platelets on the cleavage planes. Some hollows in the samples show that once cubes of pyrite, of the size of one cm., probably have been present. Microscopically the rock resembles the previous one; the pseudomorphs and the tourmaline, however, are lacking here.

The other rock from the same locality is of finer grain and has phyllite habit, with a brownish grey colour (V. 4044). Sparse chlorite spots are recognized. The microscope shows very fine sericite tissue with some chlorite here or there; between it quartz mosaic is observed. Owing to their large size, the chloritoid porphyroblasts are sharply contrasted against the groundmass. Again they are arranged in a disorderly manner. Here they are thickly tabular. A time-glass structure is to be seen (Pl. 45 fig. 4). Polysynthetic twinning structure is vaguely developed.

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[1]) G. C. Du Bois. **40.** p. 36—37.

THE PHYLLITES AND CLAY SLATES.

It appears that phyllites and clay slates are distributed in Surinam on a much larger scale than is recorded in the literature, even though fresh rocks are in a minority. The rocks show a transitional series from phyllites, phyllitic clay slates to clay slates proper.

Mineralogically they are represented by the following types:

Sericite phyllites, composed of quartz and sericite with a considerable amount of ore.

Magnetite- or hematite phyllites in which beside quartz and sericite, ore is a main component.

Graphite phyllites, with a varying amount of graphite.

Limonitized phyllites. They form the weathered, limonite bearing equivalent of the preceding types especially of the first two.

Phyllitic clay slates and clay slates proper. They are composed besides of quartz and sericite, also of non-determinable components, whether crystalline or not.

PETROGRAPHIC DESCRIPTION.

Sericite phyllites.

The sericite phyllites are more or less thin-foliated very fine-grained to compact schists. Their smooth cleavage-planes show a more or less pronounced silky gloss. The colour varies from a silvery grey, to greyish green, greenish, brownish or grizzly, sometimes also bluish-grizzly. Plan parallel splitting types have the habit of true roofing slates (V. 1763, 3586). Mineral components are hardly recognizable, except a few impressions of pyrite cubes, or ore granules.

Microscopically the principal components quartz and fine-scaled mica are seen side by side, in variable ratio. Now the quartz forms a distinct mosaic (V. 490, 1494), now it is so fine that the mineral is only just noticeable among the mica (V. 910, 1763). Ore granules, in part already transformed into limonite, a few fine, bluish tourmaline columns, or some chlorite, may be present as accessoria. In one of the rocks (V. 910, from the Lely mountains) quartz grains occur that are conspicuous on account of their relatively large size and that, judging from their rounded or angular outline seem to be relics of a clastic material, side by side with a few small ore octahedrons, which change into leucoxene. The texture is rather distinctly planparallel schistose, through equal orientation of the mica scales, or (in the rock V. 910) it is finely undulating.

Similar phyllites we have from the Lawa river (V. 490), from the Lely mountains (V. 910, 913, 938, 939, 1033), from the "Blauwe Berg" near Berg en Dal (Suriname river, V. 1494), from the Sara creek (V. 1619, 1620), from the Toeval placer (V. 2272, 2274), from the Coppename below the Raleigh falls (V. 2404), from the Moeroe moeroe creek (Saramacca V. 2983).

Another phyllite type is closely allied to the preceding, but has a larger amount of ore. This amount affects the colour of the samples for many are darker, of a blackish grey. Ore here seems to be mostly developed as hematite (in V. 3586, 3624 and Y. 362 B anyhow). It reflects strongly. It is also inclined to crystal-shape and it occurs in spots or it is evenly distributed. The accessoria are fine tourmaline columns in varying quantities, sometimes together with shortly prismatic, distinctly yellow rutile microlites (for the latter see V. 1505, 3624).

Similar iron-ore bearing sericite phyllites were found to the West of the Suriname river (V. 1505), in the neighbourhood of the Witlage placer (V. 2211) [1]), at the Colonial railway not far from the waysidestation Gros placer (Y. 362 B), at Guyana Gold placer (V. 3586) and in the extreme upper-course of the Commewijne (V. 2211).

Magnetite-, or hematite phyllites.

These phyllites are closely related to the rocks last discussed, but the amount of crystalline ore is larger; it gives a distinct blackish colour to the sample. In one rock from Guyana Gold placer (V. 4042) the ore is apparently mostly developed as magnetite, while in a phyllite from the Tanjimama (a small affluent of the Coppename) hematite is the very fine-grained ore (C. 99). As accessoria tourmaline may occur again, while in the rock from the Coppename we also see an intensely refringent, extremely fine-grained, indeterminable mineral.

Graphite phyllites.

In the sample they are planparallelly, or undulatorily splitting, very fine-grained to compact schists. They show a silklike lustre. Under the microscope we see fine-scaly sericite with even orientation, so that the schistose texture is very pronounced. This texture is still corroborated by a fine quartz mosaic, partly being concentrated in mica-poor cords, extending parallelly to the mica-rich parts. In addition a varying quantity of graphite dust is strewn in such a way that it joins up to the sericite-richer parts.

The accessoria that may occur are some chlorite, ore grains, and tourmaline prisms.

We have such graphite-bearing phyllites from the Locus creek (side creek of the Suriname river, V. 1625) and from the Witlage placer near Djoeka creek (V. 1697, 1699).

Limonitised phyllites.

On account of weathering, limonite formation takes place in these phyllites

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[1]) West of Bonidoro, Marowyne.

in a larger or smaller measure. The colour then becomes a pale brown, or brown, and often also reddish brown or red, now evenly distributed, now appearing in stains or spots. If the latter is the case, large accumulations of limonite may be recognized already macroscopically; often these weathered rocks come off powdery. In a number of rocks fine ore-octahedrons are to be recognized macroscopically. The pseudomorphs of limonite to pyrite are startling (e.g. C. 87). They attain to one cm. and the pyrite is partly intact (V. 2215, 2216).

The microscope reveals very fine sericite side by side with very fine quartz. Only in few rocks the ore is partly unchanged; for the rest it has been replaced by limonite. This appears now as an evenly strewn pigment, now it is accumulated locally to cords and stains. Tourmaline needlets occurs here and there as accessoria; a large number in one rock (V. 2216). In three rocks also considerable chlorite occurs (V. 921, 925 from the Lely mountains and V. 2241 from a locality near Witlage placer) [1]). The rocks from the Lely mountains might as well be called chlorite phyllites, and are allied to the quartz chlorite sericite schists (see page 404).

The texture of these rocks is again more or less distinctly planparallel. In a single rock we observe beautiful helicitic detail folding (Pl. 45 fig. 5, V. 1642 from Tompi creek).

Evidently these phyllites are nothing else but the weathered equivalents of the phyllites discussed above, in so far as they have contained a fair amount of ore or pyrite.

Limonite-bearing phyllites were collected in the Lely mountains (V. 781, 921, 925, 1810, 1817) at the Suriname river (V. 1436, from Brokopondo; Vtz. 178 from Victoria), in the Tompi creek (branch creek of the Suriname river, V. 1642), in the basin of Miendrineti creek (L. and F. de Jong placer, V. 1760, Pakira creek V. 1767), in the vicinity of Witlage placer (V. 431, 2197, 2215, 2241) [1]), in the upper course of the right Coppename (C. 87).

The phyllitic clay slates and clay slates proper.

These slates are closely related to the phyllites that have been discussed, and are united with them by transitions.

In the sample they are more or less distinctly schistose rocks which macroscopically do not show any minerals at all, putting aside a sparse ore grain or mica leaflet. Many of them, especially the clay slates, are strikingly soft and clayey. The colour changes often, brownish, reddish brown, red, grey-blue, greenish, or some times a dirty white. It are especially the clay slates that show the greatest variety in the colour. Some might be mistaken for perfectly weathered schists when secondary limonite formation has set in. Under the microscope it becomes evident that one has to do with fine grained rocks having but little recrystallized. Sericite and quartz of the same nature as in the finest phyllites occur, but in combination with an extremely fine

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[1]) West of Bonidoro, Marowyne.

substance; the latter is brownish or light greenish, now apparently crystalline, now amorphous, and cannot be determined. If the tint is brownish, it seems that limonite has been admixed. Besides, rocks occur, in which limonite appears as a weathering-product of fine ore grains. According as the material is more or less crystalline we may differentiate phyllitic clay slates from the clay slates proper. But this differentiation is artificial, for in one and the same thin section we can see spots of the one and of the other, side by side. It is especially the degree of the coarseness of the quartz grains that may differ largely locally. Ore grains and tourmaline needlets occur as accessoria rarely, also the extremely fine rutile needlets, which are oftener met with in clay slates from other localities. The tourmaline needlets are conspicuous by their slender forms and idiomorphism. In a rock from Japanau on the Saramacca (V. 3624) there appears to occur an important amount of hematite. The accessoria of the soft clay slates may best be studied by pulverizing the rock and by examining it in a liquid under the microscope. In some clay slates and phyllitic clay slates the microscope reveals the presence of graphite dust, that affects the colour of the sample, which is then greyish-black (V. 289, 881) or black (V. 1015). The last-named rock is very soft and crumbles into fragments on the least pressure. However, it appears to be less graphite-rich than the colour would suggest, and contains a rather great amount of distinctly crystalline material.

Phyllitic clay slates, mostly weathered and then contaminated by limonite-formation and discoloured to brownish or reddish brown, have been collected at Guyana Gold placer (V. 165), on the Lower Marowyne (V. 418), in the vicinity of the Lely mountains (V. 883, 908, 917, 935, 948), near the Gran creek (V. 988), N.W. of the De Goeje mountains (V. 217), at the Saramacca near Janapau (V. 3624), at the Von Hemert placer (Sara creek V. 1789), in the vicinity of the Nassau mountains (V. 2258), at the Dieu Merci placer (V. 289).

Clay slates proper, in part weathered, with limonite formation have been collected from the Lower Marowyne below the Sipariwini creek (Vtz. 343), from the environs of the Lely mountains (V. 881, 884, 885, 911, 940, 1015, 1038), from the Lawa (Cie. des mines d'or V. 719, 720, 721 ┌, 722), from the surroundings of the Witlage placer (V. 2221, 2222, 2228, 2233, 2236, 2258, 2259) [1]), from Guyana Gold placer (V. 3596, 3599, 3600, 3601, 3602), from Von Hemert placer, Sara creek (V. 1812, 1813).

The original material of the phyllites and clay slates.

The assumption is admissable that all the members of this group have a sedimentary origin. It might possibly be suspected that the sericite phyllites (sericite schists) have been derived from metamorphic quartz porphyries, under sericite formation from potash feldspar and the development of schistose texture by recrystallization. As alluded to before, there are among the porphyroids a few that are closely related to sericite schists (see p. 147). The sericite phyllites, however, are of much finer grain. Little lenses of extremely fine

[1]) West of Bonidoro, Marowyne.

mosaic are present. They seem to represente detritic quartz material; tourmaline columns and newly formed ore grains appear; relics of phenocrysts are absent; broadly speaking the habit is different from the sericite schists of an ortho-character.

In the magnetite- and hematite phyllites ore is present to such an amount that it is certain that we have not to do wih mtetamorphic rocks of igneous origin. Organic matter must have copiously been enclosed in the graphite-bearing phyllites and clay slates. The original material of all the members of this group must have been clayey matter with variable percentage of extremely fine quartz and variable amount of iron. The series of rocks from clay slates proper to phyllites has undergone a stronger recrystallization in proportion to the strength of the metamorphism. Novel formations here arose: sericite, tourmaline, ore, and pyrite. It is still a matter of conjecture whether the material for the latter mineral always is of sedimentary origin. It is not impossible that mineralization in some schists has given origin to pyrite.

SOME DATA ON THE GEOLOGY OF THE QUARTZ CALCITE CHLORITE ALBITE SCHISTS, QUARTZ CHLORITE SCHISTS, PHYLLITES AND CLAY SLATES.

As has been stated in the introduction to the crystalline schists, no complete sections showing the contacts of the various schists-groups are available. Yet the above mentioned schists always occur in the same association. Concordant contacts are seen here and there, and these facts render it probable that they belong to one and the same formation. We shall discuss this association with reference to the following regions:

1. The Suriname river, especially between Berg en Dal and the mouth of the Sara creek.
2. The neighbourhood of the Witlage placer, West of Bonidoro (Marowyne).
3. The Placers on the Colonial railway.

Regarding the basin of the Suriname river, we have Martin's observations and material at our disposal; petrographically, the material has been considerably added to, especially by Du Bois. Martin has summed up the geology of these schists as follows:

„Die Stellung der Schichten ist überall eine steile; meist stehen sie annähernd oder völlig vertikal, und ihr Streichen ist mit wenigen Ausnahmen nahezu W.-O.[1]) Sie treten im Flussbette von der Judensavanne ab bis aufwärts zum Diëtifall auf, anfangs sehr vereinzelt, dann in zunehmender Zahl als Barrièren, je mehr man sich dem Oberlaufe des Stromes nähert, je weniger also die einschneidende Thätigkeit des letzteren wirksam sein konnte. Der von der Schichtenreihe eingenommene Raum, senkrecht zum Streichen gemessen, beträgt etwa 52000 m, und diese Ausdehnung in Verband mit der steilen Aufrichtung lässt auf ein System zusammengequetschter Falten schliessen, wenngleich eine Wiederkehr derselben Formationsglieder in dem untersuchten Gebiete nicht wahrgenommen wurde. Die Schwierigkeit und Unvollständigkeit der Beobachtung erklären dies zur Genüge." [2])

Let us now confine to the area where the bedrock of schists is visible frequently: between Berg en Dal and the mouth of the Sara creek. Here quartz calcite chlorite albite schists, quartzites, phyllites and members of the graywacke-formation occur.

Members of the quartz calcite chlorite albite schists-series are commonest, and distributed over the whole of the stretch: near Berg en Dal, Boschland, above the Ceder creek, in the neighbourhood of Brokopondo and the New Star island, below Grinwisburg and near it, at Ballyn-soela and above it, at the Dabikwen-trail etc.

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[1]) For strike and dip, see Martin. 26. p. 149—159.
[2]) l.c.p. 188—189.

Among these schists, others are inserted to a smaller extent: quartzites of the "Kansel" below Boschland, near the island of Brokopondo, above the latter etc.; phyllites on the hill near Berg en Dal and above Brokopondo; a significant number of graywacke-quartzites of Brokopondo and below the Dabikwen fall.

Schists of different composition are very frequently found next to each other, and alternating, within the short stretch of Brokopondo-Koffikamp (Map. VI. B). Besides this, a few schists of a different composition, in concordant contact with each other, are met with. Above Brokopondo there are quartzites (V. 1523, 1528) inserted in quartz chlorite albite schists; in the same rapids above Brokopondo, weathered phyllite (V. 1436) occurs in concordant contact with graywacke-quartzite (V. 1392). All these facts together, render it very probable that the different schists belong to one formation, of mighty development in the area mentioned. As long as unconformities are not known, we may safely accept this interpretation, given already by Martin.

We find the second schist-area West of Bonidoro (Marowyne), in the neighbourhood of the Witlage placer. The region comprises the spurs of the Nassau mountains. The following data were collected by the engineer Mr. Duyfjes. The schists here form low, but very steep hills. The schists dip very steeply. Of nine measurements of the trend, seven are N. 0—45° W. So the schists here show quite the same tectonics as we find in the graywacke-formation on the Marowyne between the Armina falls and Bonidoro. The schists are mostly members of the phyllite and clay slate group and their contact-metamorphic equivalents (tourmaline-phyllites, 13 pieces in all); next to these graywacke-quartzites (3); members of the group of quartz calcite chlorite albite schists (2) and quartz chlorite schists (1) occur. It is true they appear within an area of some square km., but several types were found to occur very close together. The latter is also true of quartz chlorite albite schist (V. 2226), quartz-chlorite-schist (V. 2251) and members of the phyllite-clay slate group (V. 2220, 2221, 2258, 2259). Besides in the neigbourhood graphite-bearing phyllite (V. 1699) and quartz chlorite schist (V. 1700) have been found together. Of other formations in this region only epidiorites, porphyroids and quartz porphyry have been found.

A third area from which we may learn something about the mutual relation of the schists, is the Placer-region along the Colonial railway between the Saramacca and Suriname rivers. Tectonically, the schists again yield the same. According to what Prof. van Nes told me, the schists at the Gros-, De Jong-, and Mayo-placers dip very steeply. The weathered upper parts sometimes show considerable creeping. Data concerning the schists at other placers in this area, confirm the preceding. The steep dip has also been mentioned by Verloop [1]). We know nothing about the prevailing direction of the strike. Verloop assumes an East-West trend at the Guyana Gold placer, but the only actual measurements are not in agreement with this [2]). Judging from the material collected, the schist-association mentioned above is present in the placer region;

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[1] J. N. Verloop. **78.** p. 24.

[2]) Prof. J. A. Grutterink's measurements on clay slates and phyllite rich in ore at the Guyana Gold placer, yielded respectively N. 70° W., dip 73° to the S., and N. 35° W., dip 45° to the W.

it principally consists of members of the phyllite- and clay slate group, with all their varying forms, of the quartz sericite calcite schists, chloritoid schists etc. Further, there are sparse representatives of the quartz calcite chlorite albite schists, as well as some quartzites. There are also a few members of the gray-wacke formation viz. graywacke-quartzites, graywacke-conglomerates and con-glomerate-schists. Unlike that of the two preceding regions, our knowledge of this region is too scanty to indicate examples of concordant contacts of repre-sentatives of the different schist-groups. The same association and also the intense tectonic disturbances, however, are again found here.

Lastly we know the same association to occur at the Lely mountains, but we know nothing concerning the tectonics there. Numbers of samples of the phyllite and clay slates besides quartzites and a few graywacke-quartzites, were col-lected here.

On the Man a Sam placer on the extreme upper course of the Commewyne we find phyllites, quartz chlorite schists, quartz chlorite albite schists and quartz sericite albite schists.

On the Sara creek, Locus creek and Tompi creek (tributary creeks of the Suriname river) we have similar associations, but the rocks were collected too far from each other to serve as an argument for connection; a graphite bearing-quartzite (V. 1625) and a graphite-bearing phyllite (V. 1628) excepted.

THE QUARTZITES.

The group of quartzites is mineralogically taken in a broad sense here. Besides pure quartzites a number of rocks are included containing, besides quartz, also other important components.

In the collections of Surinam rocks quartzites of three different geneses are found to be represented, which will, however, not all be discussed in this chapter.

a). Quartzites of sedimentary origin.
Relics of clastic structure, or various accessoria, or the geological occurrence may show that these rocks are derived from sediments which consisted almost entirely of quartz.

b). Quartzites of igneous origin.
Of a number of quartzites it is probable that they represent a hydrothermal-pneumatolitic differentiation of the granitodiorites; they cut them as veins, like pegmatites and aplites (cf. p. 162).

c). Quartzites formed from the silicium that is set free by weathering from various rocks and deposited on fissures etc. This group of quartz veins is not least important, as secondary concentration of gold has been repeatedly ascertained in them.

Quartzites of the various groups are abundantly represented in the collections in connection with the many prospects for gold. With the pure quartzites it is very difficult to judge to which of the three groups the rocks belong, and of the numerous samples only those will be treated which are likely to belong to the first group, while the other two groups have been discussed already.

The following types may be distinguished:
Pure quartzites.
Quartzite schists.
Quartzites with magnetite.
Sericite quartzites.
Sericite chlorite quartzites.
Chloritoid quartzites.
Staurolite kyanite quartzites.
Epidote quartzites.
Graphite quartzites.
Quartzites with other components.

PETROGRAPHIC DESCRIPTION.

Pure quartzites.

In the sample the pure quartzites are massive rocks, or they show some parallel texture. The irregular fractures are often tinted brown by some limonitic infiltration.

Let us begin with those quartzites which microscopically display a clear mosaic of nearly polyhedral fields, i.e. preeminently the quartzite structure. The sizes of the grains of this mosaic vary considerably. In some rocks they are extremely small ($< 25\ \mu$). Such very fine-grained quartzites have, in the sample, partly a flinty habit with conchoidal fracture (V. 1692; Y. 366). They appear to consist almost entirely of quartz, with extremely insignificant impure admixtures which defy further defining. We have such flinty quartzites from the Browns' mountain (Y. 366), from the Marowyne (boulder, V. 1692) and from the Lely mountains (V. 1017, 1030, 1032).

Other quartzites which also consist of almost pure quartz mosaic, are considerably coarser than the preceding type, but the grains are smaller than 1 mm. Such pure quartzites are represented among the samples from the Suriname river near Brokopondo (V. 1390, 1435, 1528).

Another structure-type is found in a rock described already by Beekman.[1]) The size of the grain of quartz varies to a high degree between 0.01 and a few mm. The quartz-fields have phantastic shapes and penetrate each other instead of forming a mosaic. The quartz contains enclosures of dust, etc., and shows undulose extinction. Macroscopically also some zircon grains are said to be visible in the white sample; for the rest it is pure quartz matter. This rock occurs in the region of the watershed between the Nickerie and the Coppename (V. 2117).

A pure, in the sample, massive and dense quartzite from the upper course of the Paloemeu (V. 1210) shows, under the microscope a mass of quartz, which, by undulose extinction, is divided into innumerable fields with sutured borders. Dust strings running through all of them indicate that the fields originated from coarser quartz through cataclasm.

Strong signs of pressure are shown by some quartzites, which are almost white rocks with parallel texture and show grains of irregular sizes under the magnifying-glass. Viewed in the microscope their schistose texture is clear. Strongly oblong and evenly drawn quartz fields in a finer mass of quartz mosaic are seen. The large fields are internally undulose and show on the borders a crumbling into fine mosaic (Pl. 46 fig. 3). It is obvious that the oblong quartz fields have been large quartzes rolled out by pressure, and the mosaic is formed in this process. Dust strings intersect the larger fields, in general cutting the longitudinal axis obliquely. The rocks consist of quartz only. They might be called schistose quartzites; their internal structure does not correspond to that of typical quartzite-schists. We have this type from the Grutterink mountains (V. 822, 823).

Quite the same composition is found in a rock from the watershed between the Nickerie river and the Coppename (V. 2114, 2115), already described by Beekman as „schiste quartzeux".[2]) He also mentions orthoclase and microcline among the minerals, and considers it as a dynamometamorphic pegmatite or

[1]) E. H. M. Beekman. **63.** p. 169. Nr. 158.
[2]) E. H. M. Beekman. **63.** p. 169. Nr. 156.

aplite. In the thin section at Delft the said minerals do not occur; Beekman has probably examined another sample of the same number.

Another structure again is met with in some quartzites from the Saramacca (V. 1299, 1300, 1301, 1302, 1303), and from the De Goeje mountains (V. 541). They consist of grey sugar quartz intersected by numberless cracks and tiny flaws. Microscopically they resemble a breccia. In a very irregular quartz mosaic one recognizes more or less distinctly shardlike larger or smaller fragments cemented together by finer quartz matter or coalesced on the edges (Pl. 46 fig. 2). These fragments lie pell-mell without any regularity as to direction and size. The quartz may be undulose in addition, and also shows in some spots formation of "Streifenquartz"-structure which points, therefore, to pressure action. In some of the rocks feldspar (potash feldspar, with vague microcline structure here and there, and acid plagioclase, cf. V. 1299, 1301, 1303) may belong to the shards. For the rest, with the exception of a few epidote grains, they are pure quartz. We have to do here with quartzites showing relics of mylonitic structure.

In a quartzite [1]) from Sabakoe creek (a tributary of the Para creek) macroscopically quartz grains are recognized in a compact groundmass. Microscopically the rock proves to consist of very fine quartz in which rounded and also shard-shaped, comparatively coarse grains lie scattered in disorder. Here one has to do with clear relics of sedimentary origin.

Quartzite schists.

Of typical quartzite schists we have only one from the Saramacca (findspot unknown, V. 2330). It is a very fine grained, pure white, clearly schistose rock and easy to crumble. Microscopically elongated fields of undulosely polarising, almost pure quartz are observed. These fields may intersect the whole thin section, and split up on the edges into very fine-grained quartz mosaic. It is an open question whether the quartz-mosaic has, by coalescence, produced the quartz fields which later on were submitted to pressure bringing about the wavy extinction, or whether the whole is nothing but strongly rolled out quartz or quartzite.

Quartzites with magnetite.

The above-discussed quartzites are all characterized by their pure quartzitic composition in which quartz is practically the only component. The quartzites now to be discussed contain a considerable quantity of magnetite.

In the sample the ore may cause an equally distributed bluish-black colour (V. 451, 668, 1579), or the ore is accumulated into small strings, in a grey, very fine-grained mass of quartz (V. 597). Microscopically the ore appears to have developed into crystalline dust.

A rock from the Sara creek shows another type (V. 1579). The fine-grained massive sample is black by the great quantity of magnetite. The microscope

[1]) This rock is present in the "Collection Benjamins" at Leyden.

shows undulose quartz fields, against which comparatively coarse magnetite octahedrons are set off with sharp outlines (Pl. 46 fig. 1). The magnetite may be twinned. In Du Bois's list of rocks [1]) it is stated to be itabirite, but it cannot be classed so on account of the fact that the characteristic main constituent hematite of the itabirites is lacking.

In a very fine-grained quartzite from the Marowyne accessory magnetite and also calcite-grains are found (V. 451).

In addition to those from the places mentioned we have quartzites containing magnetite from the De Goeje mountains (V. 668), from the Lawa (V. 597), from the Lely mountains (V. 902), from the Sara creek region (V. 856), and from the Blanche Marie falls, Nickerie river (V. 1954).

Sericite quartzites.

A few quartzites contain a considerable quantity of sericite, so that they pass into sericite quartzites. They are very fine-grained rocks, splitting along planparallel or bent planes. They show, more or less distinctly, sericite scales on these latter, sometimes producing a silvery lustre. With the microscope one sees quartz mosaic and little sericite scales, with accessory ore and rutile. In one case also fine sillimanite needles embedded in quartz occur (V. 214).

We have sericite quartzites from the Lawa river (V. 596), from the Dieu Merci placer (V. 288), from the Sara creek (V. 1580, 1595), from the Marowyne creek (V. 1675) and from the De Goeje mountains (V. 214, 215).

A special structure-type is seen in a sericite quartzite from the source of the Gran-rio (Y. 150). It has a massive habit and white and greyish white tints. Microscopically the rock appears to consist of quartz fields between which a considerable quantity of muscovite. Locally only quartz is present; the fields are undulose and are sutured into each other. Mostly, however, the fields are separated by a very irregular confused mass of sericite which, in some spots, passes into normal muscovite leaves. Some uniform trend in the undulose quartz faces appears to be present. Other components are lacking. To sum up it is a quartzite rich in muscovite.

Sericite chlorite quartzites.

Closely related to the above-mentioned quartzites is a single rock, which contains, besides sericite, also chlorite (V. 1634, from the Locus creek, a tributary of the Suriname river). The very fine-grained sample shows a clear parallel texture. Greenish and brownish, harder and softer parts are present. Microscopically the composition locally appears to be purely quartzitic with a very fine quartz mosaic; for the rest it is very rich in extremely minute sericite and chlorite, as they are found in phyllites. The rock is, therefore, an intermediate form between the latter and quartzite. Possibly a rock of the Lely mountains may be classed here (V. 949).

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[1]) G. C. Du Bois. **40.** p. 18. Nr. 103.

Chloritoid quartzites.

We possess only one single rock of this composition, and this from the Suriname river, from the first rapids above Brokopondo (V. 1437). The rock occurs there together with chloritoid-bearing schist (see p. 405). The very fine-grained sample shows a slight parallel texture and irregular cleavage. The colour is dark grey to pale pink. On the transverse cleavages we see numerous greenish, rounded spots, which appear to be chloritoid.

The microscope shows a very fine-grained isodiametric quartz mosaic, turbid by limonite dust, and besides a considerable percentage of chloritoid. The latter forms typical oblong or rounded aggregates. They are made up of numerous lamellae arranged more or less radially like spherolites (Pl. 46 fig. 4). By the distrubition of the polarization colours, however, one perceives that in the section of a spherolite two groups of lamellae may be distinguished, telescoping into each other like two sheaves with diverging extremities. The separation between the two groups of lamellae is, however, little sharp. The spherolites are minutely porous. The colour is light-greenish. Pleochroism is not strong. The aggregates lie without any regularity scattered in the groundmass. The limonite dust in this latter winds through it in strings.

Staurolite kyanite quartzites.

Also of this particular type we have but a single representative (from the Sara creek below the Lourdes placer, V. 1599). The fine-grained massive sample has a typical quartzite habitus. The light-brownish colour is evenly distributed; not a single mineral can be recognized macroscopically. Microscopically a quartzite mosaic of small irregular quartz fields is seen, in which a considerable quantity of staurolite, less kyanite, some muscovite, sericite and microlites occur. Staurolite, kyanite and muscovite are mostly united in interrupted strings intersecting the mosaic. None of these three minerals show idiomorphism. The small pieces differ little in size from the quartz grains. The yellowish staurolite forms irregular grains. In the colourless kyanite which occurs as frayed particles, different systems of cleavage are discernable. Both the quartz and the kyanite may be slightly undulose. (The rock is mentioned by Du Bois in his list, l.c. p. 19. Nr. 123, as "Epidotführender Quarzit", but does not contain any epidote).

Epidote quartzites.

Amply provided with epidote, and in addition some chlorite is a greenish grey, planparallel cleaving quartzite from the Sara creek, which, in the sample, might be mistaken for a sericite quartzite (V. 1591).

Much richer still in epidote is a quartzite from the Tosso creek region (V. 184). The fine-grained light-greyish sample, with some parallel texture, does not suggest anything of its composition. Microscopically it shows a quartz mosaic with weakly double-refracting epidote grains. The latter mineral makes up about $\frac{1}{4}$ of the whole. Microscopically fine strings, either richer or poorer in epidote alternate.

Graphite quartzites.

Some quartzites contain a considerable quantity of graphite. They are very fine-grained rocks with parallel texture and for the greater part of a black colour. This black colour is now distributed equally, now limited to some parts, between which bands and streaks of light coloured matter are visible (cf. e.g. V. 1663). The fracture may be conchoidal (V. 1663). Microscopically they appear to consist of very fine, almost isodiametric quartz mosaic, with a strongly varying admixture of graphite. One rock contains a not insignificant quantity of tourmaline prisms (V. 16).

We have graphite quartzites from the Locus creek (a tributary of the Suriname river, (V. 1628), from the Tompi creek, idem, (V. 1641), from the Marowyne creek (V. 1663) and from the Montana Mine (V. 16), from Brokolonko (Saramacca V. 789).

Quartzites with other components.

We have a fine-grained quartzite from the Suriname river (V. 1384), already described by Kloos [1]) in which some acid plagioclase may be recognized in very fine-grained quartz mosaic. Moreover it shows a considerable percentage of scales (for the greater part chlorite), some ore, etc.

A peculiar, diverging association of accessoria is found in a quartzite from the Sara creek (V. 1615). The sample is a very fine-grained to dense rock, black-coloured, and with parallel texture. It might be taken for a graphite quartzite. Microscopically it appears to be a quartzite rich in accessoria, consisting of a minute quartz mosaic, here and there turbid by carbonaceous pigment. This pigment causes the colour of the sample. As an accessory a mineral of the epidote group is present. It is granular to oblongshaped, and shows the polarization colours of zoisite. Perhaps it is this mineral or clinozoisite. The carbonaceous pigment may be enclosed in it. In addition some very insignificant fragments of epidote occur. Whereas the zoisite-like mineral in some parts of the thin section is quantitively important, this cannot be said of the other accessoria, green hornblende, sericite, titanite, ore and pyrite. The hornblende is of the usual green kind; the very minute crystals may show crystalloblastic shapes. Titanite appears in irregular masses possibly derived from ore. An indication of parallel texture by a tendency towards regular orientation of the components is present.

A fine-grained quartzite from the Tosso creek region (V. 134) appears microscopically to contain a considerable quantity of calcite grains, and in addition octahedral ore and some pyrite.

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[1]) J. H. Kloos. 28. p. 195.

THE "SCHALSTEINE".

Under this name we have placed rocks of sedimentary origin, which seem to be formed almost entirely from basic tuffs. Clastic material from diabases seems to take up a foremost place. Schalsteine have been mentioned already from Surinam, especially by Du Bois. These rocks, however, are not all conceived as Schalsteine here, and new types have been found later on. Our Schalsteine are composed of plagioclase remnants, uralite, chlorite, epidote, calcite, leucoxene, ore and quartz, in varying amount and ratio. Mineralogically these rocks are related to the epidiorites, but they differ from them in structure by the clastic character. It is not always easy to distinguish the Schalsteine from the epidiorites, as fargoing recrystallization and decomposition may have effaced the original structure.

Petrographic descriptions.

Schalsteine have been collected from the Lawa near Soemanjere fall (V. 1105), from Maripa soela (V. 1106), from Rufin (Cie. des mines d'or, V. 724) and from the Lower Tapanahony (V. 1055).

The rock from Soemanjere fall is characteristic. The vivid green, very fine-grained almost compact sample is on the outside strikingly homogeneous. There is an indication of parallel texture. With a hand-lens a little black spot of hornblende is to be seen here and there.

Under the microscope parallel texture becomes manifest, as plagioclase fragments, still clearly visible, are evenly stretched with their longest axis, in a fine mass of chlorite scales, very fine epidote, and leucoxene granules. At numerous spots large pieces of secondary epidote have been formed, and here and there also bundles of fibrous, uralitic hornblende. Of all these components the plagioclases are the most conspicuous. They are fragments of lath-shaped or oblong crystals. The faces of the zone (001) — (010) have often been well preserved. The polysynthetic twinning according to the Albite-law is very distinct, while here and there even a Baveno-twin is recognized. The crystals are limpid, with the exception of a few extremely fine mica scales and epidote granules. The plagioclase has the composition of albite; apparently demixture of basic plagioclases has taken place.

Many plagioclases exhibit signs of cataclasm. Either they have been broken, or the twinning has been twisted. Transverse faults traverse the crystals, along which corresponding lamella-groups have been shifted, and material of the groundmass penetrates there. A few crystals are completely crumbled inside.

The other components contribute to the parallel texture. The scales and fibres are directed equally, and the granules are arranged in cords.

Another picture is presented by the rock from Rufin (V. 724). It shows porphyry-like structure owing to numerous black, short hornblende prisms, not longer than $1\frac{1}{2}$ mm., contrasting against a greenish groundmass. Sprinkled pyrite occurs. The sample has a massive texture. The larger crystals appear under the microscope to be uralite pseudomorphs to what at one time was probably pyroxene. In the polygonal or rounded forms the outlines of pyroxene phenocrysts can still be recognized distinctly. Now they have been replaced by uralite fibres, partly evenly orientated. The twins, sometimes with an intermediate lamella may be reproduced by the uralite. The latter is, in most cases, not confined to the crystal-outline, but grows with its fibres into the adjacent groundmass. This groundmass consists of a varying mixture of chlorite scales, uralite fibres, extremely fine epidote grains, and locally calcite particles, and coarser epidote fragments, between which a delicate quartz mosaic may be vaguely distinguished. Feldspar-rests are no longer recognized, they have probably been substituted by the fine epidote granules. Most probably this is an altered basic tuff, considering the numerous pseudomorphs to pyroxene, with some admixture of sedimentary (?) quartz. The distribution of the latter namely is not consistent with that in a metamorphic igneous rock, though for the rest the rock is closely related to the partly altered augite porphyrites, described on page 139.

The sample from the Lower Tapanahony (V. 1055) has a quite different composition. It is very fine-grained and homogeneous. Slight parallel texture is present. It consists of a very fine mixture of much chlorite scales, and calcite particles, between which quartz and also feldspar rests are faintly perceptible. The components are unevenly distributed. None of the components has crystal shape, not even a few coarser calcite particles. Only some accumulations of leucoxene grains represent in their distribution the outlines of small pseudomorphs to ore. Of plagioclase fragments only the dim outlines are distinguishable. More numerous are angular particles of quartz, which probably have a clastic origin. When looking sharply we observe besides that quartz can surround small rectangular pseudomorphs. These pseudomorphs are filled with chlorite- and epidote-granules and probably substitute for what at one time were fine plagioclase-laths. It is not improbable that we have to do here with new quartz, formed in situ. The distinction of this very fine rock of highly altered diabase is problematical.

In a rock from Maripa soela, Lawa (V. 1106) the sedimentary origin is shown better. The greenish, almost compact sample with distinct parallel texture, has a homogeneous habitus. However, we see in the thin sections parts with the composition of Schalstein, between which groups of very fine quartz mosaic are intercalated. The Schalstein is chiefly made up of very fine epidote granules, fibres and needlets of vivid greenish hornblende, between which colourless material is looming. Remarkable are the numerous pseudomorphs to pyroxene; at all events they have the shape of that mineral. Now they are filled up with fibrous uralite, together with quartz-like material. In some places we see twinned albites which are the remnants of plagioclase phenocrysts. All these altered phenocrysts, and above all the oblong plagioclases, are evenly directed with their greatest length, while the fibrous material of the groundmass joins up to it. Lenticular parties occur, composed of a fine quartz mosaic, with an inferior amount of sericite scales and also sparse cords of calcite granules. These light-coloured parts have the composition of sericite bearing quartzite.

Both components of the rock work into each other and there is no doubt but that the Schalstein parties have been deposited coincidently with the quartzite so that this argues for the sedimentary origin of both.

SOME CONTACT-ROCKS.

We have a number of contact-rocks that appear to be metamorphosed sediments. As we do not know anything about their geology it is not certain which of the schist-groups have furnished the original material, and in how far the rocks have formed part of vast contact-zones, or were inclusions in igneous rocks. They will be discussed in groups after their petrographical composition. Other contact-rocks of which the geology is known have been discussed already with the schist-groups. The following types are represented:

Andalusite hornfelses.
Cordierite andalusite hornfelses.
Sillimanite-bearing hornfelses.
Tourmaline muscovite schists (or hornfelses).
Mica hornfelses.
Andalusite bearing sericite schists.
Tourmaline-bearing spotted schists.
Tourmaline schists.
Kyanite quartzites.
Tourmaline quartzites.

Andalusite hornfelses.

Hornfelses of a very divergent composition and habitus are classified with this denomination. We have a massive, normal- to fine-grained hornfels from the extreme upper course of the Gran-rio (Y. 143). The colour is partly grayish-white and partly pink. We observe macroscopically that the rock bears numerous grains of quartz with sparse biotite-scales. We might mistake it for a granite, poor in biotite. Microscopically it appears to consist of quartz, sericitic mica and andalusite, and in a less measure also of potash feldspar, biotite, and sillimanite. Clear quartz grains predominate. Among them appears scaly sericite, now in minute quantities so that the quartz-grains touch each other, now again in larger quantities so that the quartz lies scattered about in a sericite mass. Potash feldspar, partly with microcline-structure, appears amongst the quartz-grains and shows no idiomorphism. A considerable portion of the thin-section is occupied by the andalusite. It is mostly oblong without idiomorphism (Pl. 46 fig. 5). The characteristic pleochroism varies in clearness and may occur in the form of spots in the same crystal. (110) cleavage is invariably seen. It is obvious that the andalusite passes into sericite, the former mineral being invariably surrounded by the latter, and the pieces being frayed at the edges. Greenish-brown biotite is of little significance. Here and there we observe sillimanite-fibres. A few, insignificant grains of ore pass into leucoxene.

From the Central Wilhelmina mountains we have andalusite hornfelses from the western foot of summit 1280. They are fine-grained, almost dense in the sample, bluish-gray or reddish-brown, having quartzitic habitus (see Y. 215, 218 A, 218 B). Microscopically we observe chiefly andalusite, sericite, and quartz. The andalusite is of a remarkable type. It shows innumerable extremely small, oblong-shaped grains having a maximal length of 90 μ. The relatively coarse ones allow of the prism-zone being distinguished: they are two or three times as long as they are broad. The comparatively strong refraction, the very feeble double-refraction, and the negative character of the main zone point to andalusite. Most of the grains, however, are smaller, oblong-shaped and rounded-off, and diminish in size down to the smallest dimensions (Pl. 47 fig. 1). Black dust may be enclosed. These granules of andalusite are heaped up so that whole fields of the thin-section mainly consist of them. The oblong-shaped ones sometimes show a tendency towards radial arrangement. In other places we observe isodiametric quartz-grains, smaller than 0.01 mm. Where they are accumulated they form a mosaic. The sericite, now among the other components, now constituting the main element, is of more importance. Ore, partly octahedral, and varying considerably in size, is found dispersed throughout the whole thin-section in abundance. Muscovite-leaflets are observed here and there. The percentage of chloritoid that one of the rocks (Y. 218 A) contains, is noteworthy. It shows bluish-green crystals, clearly developed according to the base.

mostly smaller than 0.35 mm. It sometimes encloses numbers of andalusite- and ore-granules. In some sections polysynthetic twinning-lamellae are recognizable.

An andalusite-hornfels from the De Goeje mountains (V. 631) is not of much importance. The sample is very fine-grained, gray, and has indistinct parallel texture. It shows dark spots. Sericite-scales are the only recognizable components. Microscopically we observe copious yellowish-brown mica, lying in an angular quartz-mosaic. Here and there it is possible to recognize the original rounded-off or splinter-like shape of clastic quartz, so that we are concerned with relics of a sedimentary material. Andalusite appears as accessory mineral. A tendency towards development according to the c-axis is present, without distinct faces being seen. The non-pleochroitic crystals are sometimes crowded with dust. Some ore and a single zircon-grain, showing zonal structure, belong to the accessories.

Cordierite andalusite hornfelses.

We have a very beautiful example of this type of hornfels from the Coppename near the Toetoe creek. Material from here is present at Leyden (B. 21) and at Delft (V. 1476, 2400). Bergt has already given a detailed and accurate description of this interesting rock. We refer to Bergt's publication [1]) here.

Beekman mentions a cordierite hornfels from the Kabalebo river near the mouth [2]); Du Bois mentions a cordierite-bearing muscovite hornfels from the Sara creek [3]). I have not met with these rocks in the collections.

Sillimanite-bearing hornfelses.

A rock from the Manakoa fall, Coppename, has already been described in detail by Bergt [4]). Material is present at Leyden (B. 23) and at Delft (V. 1469, 2376, 2377, 2378). We may refer to Bergt's description.

Tourmaline muscovite schists (Hornfelses).

At the landing of the Bushnegrovillage of Pisjang, on the Sara creek, there is an exposure of this type of hornfels. The material occurs in Voltz's collection (Vtz. 117, 121). Martin (V. 1400) and Du Bois (V. 1553, 1554) have also collected material from this spot. These hornfelses are normal- to fine-grained rocks showing parallel texture but schistosity is not well-developed in them. On a plane of fracture we observe numerous nests of tourmaline and leaflets of muscovite in a gray groundmass of quartz. The tourmaline attains to a size of several mm. (see V. 1553 and 1554 especially). In a few samples spots occur of a greenish material, which turns out to be chloritoid. Microscopically the composition appears to be comparatively simple. The rock consists principally of copious muscovite and quartz. The quartz forms a quartzitic fabric. In a few thin-sections, inclusions, not admitting of further definition, occur. In others, however, the quartz is clear. As we can observe macroscopically, the muscovite appears in the form of patchy crystals capable of attaining to a considerable size. They are irregular in shape. The tourmaline of the nests shows grains and short prisms. The composition varies. In some thin-sections (V. 1554) the tourmaline has distinct zonal structure: showing alternating lighter- and darker-tinted zones. In other thin-sections (Vtz. 117, 121) however, the pleochroism is evenly distributed, ranging from dark bluish-green to pale rose. The tourmaline behaves idiomorphically towards quartz and muscovite. Chloritoid is only met with in one single thin-section (Vtz. 117), partly as fine scales difficult to identify, partly as distinct crystals developed according to the base, with pleochroism ranging from a bluish-green to pale rose, and with the typical polysynthetic lamellae.

Mica hornfelses.

We particularly have mica hornfelses from the Lower Coppename river. We possess material from between the Pireen- and Weri creeks (V. 2370, 2371) and from the Makambo island, somewhat farther upstream (B. 22). All these rocks have much in common and may be discussed together.

In the massive sample we observe numerous black, sparkling particles of biotite, which, on account of their relatively large size, form a contrast with the groundmass. Nests of biotite appear locally. Microscopically the rocks shown quartz, acid plagioclase, greenish-brown mica, epidote-granules, and ore. They possess a strikingly even texture. They consist of a very fine mosaic of isodiametric quartz-grains, epidote and ore-granules, mostly smaller than 80 μ. It is possible that untwinned plagioclase lies concealed in this mosaic. Somewhat coarser quartz and especially coarser pieces of ore occur locally (magnetite). Numerous

[1]) W. Bergt. **45.** p. 130—132.
[2]) E. H. M. Beekman. **63.** p. 175. Nr. 3.
[3]) G. C. Du Bois. **40.** p. 19. Nr. 114.
[4]) l.c. p. 123—127.

greenish-brown biotite-leaves are of considerably larger dimensions. Their patchy and intensely perforated forms are conspicuous. Pleochroitic haloes, sometimes with a double zone, are common.

A rock from the Lucie river (Y. 271, 271 B) must probably be classified with the mica hornfelses. The very fine-grained sample shows parallel texture, but is only slightly schistose, so that the tendency towards cleavage is but little pronounced. With the aid of a magnifying-glass it is possible to distinguish innumerous sparkling scales of mica in the greenish-grey mass. Locally they are accumulated, in which case, the rock is mottled with black spots. Microscopically the composition appears to be simple. The rock consists of a very fine-grained quartz-mosaic, epidote granules and well-developed crystals, and mica-scales of a green colour, almost all smaller than 80 μ. Groups of somewhat coarser mica appear locally. Ore is confined to a few octahedra. As accessories we can only recognize a few granules of apatite and zircon. Here and there we may also observe some non-twinned plagioclase-fields. This rock in any case belongs to the metamorphic sediments. The structure is that of the hornfelses, although the typical sieve-structure does not occur.

Andalusite-bearing sericite schists.

We have a schist of this type from the extreme S.-West of the Colony, found on the trail of the Tumuchumac-Expedition (V. 1255). A provisional description has already been given by Gutterink [1]).

In the sample it is fine-grained, with thin-leafed, parallel texture. It shows a silvery lustre on the planes parallel to this texture, caused by fine mica-leaves. A few, larger, rounded-off pieces of quartz are conspicuous. Mcroscopically the main mass appears to consist of an aggregate of quartz-grains and sericite-scales, in which ore-grains and andalusite occur. The larger quartzes, already mentioned are conspicuous on account of their comparatively large size and their rounded-off oblong shape. They run parallel and are slightly undulose. Between the predominating sericite, quartz-grains of very small dimensions are visible. Feldspar has not been recognized. Ore is present in abundance; the coarser grains have a tendency to octahedral shape. Here and there in the groundmass there are small groups of ore-granules and quartz, such as are often seen in hornfelses. Zircon-grains occur as accessories. The andalusite appears in the form of oblong-shaped crystals, developed according to the c-axis. The faces are not well-developed. The mineral has porous structure. Notwithstanding this, the (110) cleavage in the longitudinal and cross-sections is visible. Sometimes cross-fractures are to be seen. The comparatively strong refraction, the feeble double-refraction, the very large axial-angle which renders the determination of the optical character impossible, and the negative character of the main zone, fix the identity. Pleochroism is wanting in the very thin sections. The characteristic, enclosed black dust may be present. The crystals have a maximum length of 1 mm., and show a tendency to run parallel to the large quartz-grains.

Tourmaline-bearing spotted schists.

Some tourmaline-bearing spotted schists were collected to the East of the Suriname river east of Boschland (V. 1508, 1509, 1510). They are very fine-grained rocks, clearly schistose, and variegated on the cleavage-planes; on account of weathering the spots cannot be clearly recognized, but they become more distinct when viewed with the aid of the microscope. One of the samples (V. 1509) is in parts rich in relatively coarse, black tourmaline-grains.

Microscopically they appear to have the composition of tourmaline-bearing sericite schists. The sericite lies in a fine mosaic of quartz-granules smaller than 50 μ. The former, however, is considerably larger. It has parallel trend, and gives the rock its schistose texture. Detailed folding is shown by the arrangement of the sericite. Ore-dust appears in the quartz-grains, but is negligible. Locally, however, we see innumerable ore-grains heaped up. They have the same dimensions as the grains of the quartz-mosaic; these clusters are oblong-shaped spots and are undoubtedly the same as we see macroscopically. The tourmaline shows shorter and longer prisms ranging from dark blue to pink colour. Now the prisms are scattered about, now collected into clusters; they may also be arranged radially. In some thin-sections, groups of coarse ore-grains occur, sometimes together with tourmaline-nests. The sericite wraps itself around these groups. As an accessory, we also find some green mica.

Tourmaline schists.

We have real tourmaline schists, very rich in tourmaline, from the neighbourhood of the Witlage placer, West of Bonidoro (Marowyne). They are extremely fine-grained rocks. One of them is distinctly schistose, splitting in a planparallel direction, black in colour, with a dull lustre on the planes. It may be called a tourmaline phyllite (V. 2220). Outwardly it looks like the graphite- or ore-bearing phyllites. Another rock from here (V. 2240) exhibits

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[1]) J. A. Grutterink. **73**.

parallel texture, is poorly schistose, and has a more quartzitic habitus. It is black, with bright weathering-tints.

Microscopically the composition of these schists appears to be simple. We observe innumerable, short tourmaline-prisms. In general they run parallel to the prism-zones in the same plane. The darkest absorption-tint is greenish. Among the tourmaline appears a slightly transparent mass. On being strongly magnified, it may be resolved into minute rods of tourmaline of the smallest dimensions, colourless scales of mica, and here and there also recognizable quartz-granules, together with some black dust. The latter also appears enclosed in the tourmaline.

Kyanite quartzites.

Interesting kyanite-bearing quartzites were collected by Du Bois, to the East of Boschland (on the Suriname river) and have been described and illustrated by him [1]).

In the sample they are fine-grained, gray-tinted quartzites, with a grain either even or uneven in size. In the latter type we distinguish pale needles of several mm. in length, which, microscopically, appear to be kyanite. In the sample, too, a sprinkling of pyrite occurs (V. 1511, 1512, 1513, 1514, 1515). Microscopically we observe a mosaic of polyhedral quartz-grains. In this there lie oblong or short and broad rods of kyanite. The kyanite varies considerably in quantity, and a fifth part of the thin-section may be taken up by it. So it constitutes one of the main components. The quartz-mosaic is composed of polyhedral grains, such as we may see in quartzite. The grains do not generally exceed 0.3 mm., but sometimes larger ones occur. Enclosed dust, among which we now find granules of pyrite, now microlites of all sorts, has a wide distribution. Most of the kyanite-crystals are irregular in shape and considerably perforated (Pl. 47 fig. 4). The cleavage is very well developed according to (100), (010) and (001). Characteristic twins according to (100) occur. They are often polysynthetic, too. Sections according to (100) show the acute bisectrix. Some sections show indistinct pleochroism ranging from a pale greenish-blue tint to colourless. Du Bois determined the composition of the kyanite, which was isolated by heavy liquids, as being pure aluminium-silicate. As an accessory pyrite having a well-defined cube-shape occurs in particular. It may be enclosed in the kyanite. Rutile can be recognized among the microlites. Slight signs of pressure sometimes occur, judging from the undulose quartz.

Among the material collected by Du Bois there is also a sample that practically wholly consists of confusedly intergrown, pale-gray kyanite-aggregates. The crystals composing the mass, attain to a size of more than a cm. A few samples are weathered. Limonite has in this case copiously filtered in, and the pyrite has been replaced by pseudomorphs. The kyanite, however, has remained quite unaltered.

Tourmaline quartzites.

It is not impossible that a few tourmaline quartzites discussed already must be regarded as contact-rocks. We may regard, however, as such the rocks from the Charmes creek, and the L. and F. de Jong placer in the Miendrineti-region.

One of the rocks from here practically consists of tourmaline-needles (V. 1766), another shows layers and spots of tourmaline, which alternate with almost pure quartz-masses (V. 1762). Microscopically they appear to be of very simple composition; we observe a mosaic of quartz-grains such as is met with in quartzites, and beside it we see tourmaline-rods. The latter show, for the greater part, a parallel trend. The strongest absorption tints are olive-green, greenish-blue or brown. Other components are not met with.

In another tourmaline quartzite, from the same find spot, we observe with the aid of the microscope, innumerable tourmaline-rods arranged in radial groups, in a quartz-mosaic. The tourmaline-rods are, locally, accumulated into masses which only betray their heterogeneous structure between crossed nicols. Unlike the preceding one, this rock is massive (V. 114).

A fine-grained quartzite from the De Goeje mountains (V. 936) shows accumulations of tourmaline-rods, which in respect to the quartz, are inferior by far.

With reference to these rocks we may add the following remarks. In all probability the andalusite hornfels from the Upper Gran-rio (p. 423) is connected in the field with the graywackes and quartzites locally exposed there. Its metamorphism must be attributed to the Gran-rio granites.

The andalusite hornfelses from the Central Wilhelmina mountains (p. 423) have no doubt also been metamorphosed by granites.

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[1]) G. C. Du Bois. **40.** p. 37—38; Table I. fig. 2—6.

Probably the tourmaline-bearing spotted schists are to be considered as contact-rocks, seeing the large dimensions of the tourmaline-crystals. Very likely this also holds good for the tourmaline schists on account of their great abundance of tourmaline.

Regarding the tourmaline muscovite schists Du Bois [1]) mentions that they have been metamorphosed by granitodiorites, and that the abundance of tourmaline increases towards the contact.

The sillimanite-bearing hornfelses, and likewise the mica hornfelses observed on the Lower Coppename are probably connected with schists belonging to the complex of the graywacke formation, which is very much developed there. Bergt [2]) was the first to refer to it.

Special attention should be given to the interesting kyanite quartzites. Kyanite often occurs in quartzites, but quartzites so rich in kyanite do not seem to be mentioned anywhere in petrographic literature. Du Bois ascribes the recrystallization of these rocks to contact-metamorphism. This I doubt very much. Their occurrence may as well be accounted for by other metamorphisms, but provisionally we may class the rocks here. The original material of these rocks may have been kaolin-bearing quartz-sand, and kaolin or equivalent minerals many have furnished the kyanite:

$$\underset{\text{Kaolin}}{H_4Al_2Si_2O_9} = \underset{\text{Kyanite}}{Al_2SiO_5} + \underset{\text{Quartz}}{SiO_2} + \underset{\text{Water}}{2\,H_2O}$$

As for the tourmaline quartzites it may be observed that they bear a close resemblance to the tourmaline pegmatites described on page 162 as being allied to pegmatites. Du Bois [3]), however, states that the rocks from the Charmes creek, and the L. and F. de Jong placer form part of a contact-zone, in which tourmaline quartzites were most metamorphosed. So in all probability we have to do here with contact-rocks.

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[1]) G. C. Du Bois. **40.** p. 36.
[2]) W. Bergt. **45.** p. 108.
[3]) G. C. Du Bois. l.c.

GENERAL DATA ON THE PARA-SCHISTS.

There now remain for discussion some points relating to the para-schists in general, viz. a summary of their distribution, tectonics, relation to other formations and age.

Let us begin by treating the distribution in the Colony. Our present knowledge of the distribution of the sedimentary schists points to the fact that these schists principally occur in the eastern half of the Colony. On the sketch-map I the areas are marked, where schists are frequent. A vast area lies to the West of the Marowyne, between Guidala to near the junction of the Lawa and Tapanahony. The boundaries of this region, cross the Suriname river below the island of Tafra and near the Dieti fall; the Saramacca near the Moeroemoeroe creek and Brokolonko and the Sara creek in three places; they comprise the Lely mountains, and join the Marowyne again.

This region has been constructed from the following data: Para-schists occur along the Marowyne and cover the whole stretch just indicated. To the West of this we find schists on the Upper Tempati, on the extreme uppercourse of the Commewyne, West of Bonidoro in the Nassau mountains, on the Gran creek, on the Djoeka creek, in the Lely mountains, at the placers along the Upper Sara creek, in the basin of the Marowyne creek, on the Sara creek near the mouth, along the Suriname river downstream to the island of Tafra, at the placer-region along the Colonial railway and between the latter and the Mindrineti creek, on the Saramacca near Janapau, Brokolonko, and on the large tributary creek of the Saramacca: the Moeroe moeroe creek, on the Coppename from the Pireen creek upstream to a short distance below the Raleigh falls.

It should be borne in mind that this area is not exclusively occupied by schists. This is only true regarding the stretch along the Marowyne, and regarding the Suriname river between the mouth of the Sara creek and Boschland. In the remainder of the region we also find members of other formations, especially granitodiorites, intrusive diabase-gabbros and their metamorphic equivalents; *hence this region simply indicates where schists are frequent.*

The area of course continues right into French Guiana. To the North it is partly bounded by ortho-gneisses (Marowyne), but more to the West the exposures disappear under the latest deposits. The long spur in Westerly direction might just as well stretch up to the Nickerie-region, for there, too, some schists are known. They are not known to occur in the Courantyne-region, however. The southern boundary of the area shows a deep inlet on the Suriname river, for neither Martin nor myself, have met with a single sedimentary rock upstream in the latter.

Outside of this area para-schists are only known very locally. For the sake of completeness, the findspots are summarized here, a few quartzites, whose origin is dubious, having been left out of consideration. Para-schists have been found on the north side of the De Goeje mountains, near the Cie des mines d'or on the Lawa, on the Tapanahony near Clementie, on the extreme upper course of the Gran-rio, at a single point on the right Coppename, south of the Raleigh falls on this river, in several places on the Upper Courantyne or Curuni, and here and there on the Lucie river and in the Central Wilhelmina mountains.

Concerning the tectonics of the schists all that we can say with certainty is that in general they are considerably disturbed, showing steep dips in the field. In a few regions where we have a series of observations at our disposal, the trend is strikingly constant. The schists on the Marowyne and to the West of it (at any rate near Bonidoro), run N. 0—45° W.; those along the Suriname river between Berg en Dal and the Sara creek run East-West. It is evident that along the profile of the Marowyne, which is 45 km. in length, we have to do wit many folds. We are, however, ignorant of the morphology and the genesis of the folds in the Surinam schists. We do not know whether important overthrusts took place, whether the schists were already folded when the granitodiorites intruded them, or whether the disturbances were partly or wholly associated with the intrusion of the magmas.

That stress has also been active after the intrusion of the granitodiorites into the basal complex, is proved by signs of intense cataclasm in the granitodiorites. Whether the appearance of these signs in the granitodiorites was accompanied by important movements of the schists, or whether the schists behaved as tectonically little affected, is quite unknown.

As to the important question whether the para-schists constitute or constituted part of one single formation, in the sense that all are about of the same age, the following may be remarked. We have already given our reasons for assuming the geological connection between the schist-groups IV, V, VI, VII and VIII [1]). It remains the question whether the same holds good for the following schists-groups, viz. the graywacke formation and the strongly metamorphic schists (groups I, II and III). Do all these schists represent different facies and different stages of metamorphism in one formation? As long as no direct connection has been ascertained in the field or no important unconformities have been met with, this question must remain unanswered. We can only state that the same schist-types occur side by side in several areas. Some rock-types which are of frequent occurrence in the graywacke formation on the Marowyne are to be met with among the schists of Groups IV—VIII on the Suriname river and the reserve. The same holds good for the graywacke formation on the Coppename. But what about the highly metamorphic schists (groups I, II and III) and the others? We have seen that a garnet staurolite schist was collected by Voltz among the graywacke formation if, at any rate, the labels were not mixed up later on (p. 378). This fact does not give any definite answer, for sediments of the same composition may very well be of different age and may show any degree of recrystallization.

The schists of the Suriname river and to the West of Bonidoro show the same tectonic main direction and steep dip as the members of the graywacke

1) See for I, II, III etc. the scheme on p. 360.

formation together with which they appear; moreover the tectonic maindirection in the last-mentioned region corresponds with that of the graywacke formation which crops out in the Marowyne. These last facts render it probable that at least an important part of the schists should be affected by the same tectonic disturbances, but they do not give us any positive data regarding the respective ages of the rocks.

Petrographically it is quite possible that the sillimanite-cordierite- and garnet-staurolite schists are nothing more than the advanced metamorphic equivalents of the other sedimentary schists. If we consider the petrographical features of the sedimentary schists we see that the rocks show features of epi-, meso- and kata-zone. The phyllites, and clay slates are but sligthly metamorphosed. The same holds good for the quartz, chlorite, calcite, albite and sericite-bearing schists. All show the characteristics of the epi-zone. The rocks of the graywacke formation, in so far that they are rich in chlorite and sericite, may be ascribed to the epi-zone, those rich in biotite to the meso-zone. The mica gneisses show mineral combinations, either of the meso- or of the kata-zone; the schist-groups I and II partly of the meso-zone (those bearing garnet and staurolite) partly of the kata-zone (those bearing sillimanite and cordierite). The place the quartzites occupy varies: a few (those bearing staurolite and kyanite) probably belong to the meso-zone; for the rest, they may represent all the zones. Quartzites even appear in very slightly disturbed formations; in Surinam e.g. in the Roraima formation.

It appears that this scheme is not at variance with the schist associations found in the field. Rocks that may be ascribed to the kata-zone have, up till now, always been met with at considerable distances from representatives of other groups; to some extent they are also found enclosed in the granitodiorites. The rocks of the epi-zone invariably appear together as described in detail above. Of the rocks of the graywacke formation only those, which are least metamorphic, have been found together with other schists showing epi-zone features. The graywacke-quartzites, namely, being the least metamorphic representatives of the formation, may occur together with schists of groups IV—VIII.

Let us now consider the important question of the relative ages of the paraschists and the granitodiorites. As we have already seen, the graywacke formation is undoubtedly older than the granitodiorites and the same holds good for part of the schists of groups I and II. Doubtful, however, is the relation between groups IV—VIII and the granitodiorites. The occurrence of a few contact-metamorphic rocks which can be traced back to these schists renders it not improbable that the latter, at least partly, are older than the granitodiorites; [1]) the possibility that these contact-metamorphic schists, may also have been metamorphosed by the quartz porphyries or by the intrusive diabase-gabbros must be taken into consideration, however. *We have no observations on direct contact between the granitodiorites and the schists-groups IV—VIII,*

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1) As mentioned on p. 427, Du Bois has stated in the field a relation between granitodiorites and the tourmaline-percentage of some schists. Possibly this also holds good for the kyanite quartzites discussed on p. 426. Unquestionable observations, however, on granitodiorites intruding the schists under consideration, are lacking.

the field-work in this direction is still far from complete. This is all that can be said about this important question.

Let us now turn to the question of absolute age of the sedimentary schists. No evident fossils have ever been found in any of the schist-groups. The slightly metamorphic members, the clay slates, the phyllitic clay slates etc. are not unsuitable for harbouring fossils. It is highly probable, moreover, that part of these schists contained organic substance. We have seen that some phyllites and quartzite-schists are very rich in graphite. This graphite-percentage points to original organic material.

The established relation between some of the schist-groups and the granitodiorites implies that the former must be pre-Paleozoic. Indeed, as we shall see when discussing the granitodiorites in the basin of the Amazon, we find there the continuation of our basal complex of granitodiorites unconformably covered by sedimentary formations, whose Paleozoic age has been recognized. This sedimentary series begins with the Upper Silurian. It is likely, therefore, that the granitodiorites in the Northern part of the basin of the Amazon are pre-Paleozoic. *This implies that the sedimentary schists in Surinam are all or nearly all also of pre-Paleozoic age.*

It remains the question in how far this conclusion also holds good for the schist-groups IV—VIII. The slighter recrystallization which these schists partly underwent might speak for later age than that of the other schist-groups. In this connection it may be stated, however, that similar slightly recrystallized rocks indeed occur in pre-Paleozoic formations elsewhere.

THE AMPHIBOLITES, HORNBLENDE GNEISSES AND RELATED ROCKS.

INTRODUCTION.

Among the ortho-schists amphibolites and hornblende gneisses are abundantly represented. Many petrographical groups may be distinguished according to the mineral-assemblages. An important part of all these rocks appears to belong to massifs in the South-East of the Colony. We have no data, however, on many others, but all the rocks are discussed together, because of their petrographical affinities.

Mineralogically the following types of rock may be distinguished:

a. Plagioclase amphibolites.
b. Epidote amphibolites.
c. Hornblende gneisses.
d. Garnet amphibolites.
e. Garnet hornblende gneisses.
f. Pyroxene amphibolites and Pyroxenites.
g. Deviating amphibolites.

We subjoin here the principal mineral-assemblages of these rock-groups. The plagioclase amphibolites are characterized by the mineral-combination: hornblende and basic plagioclase. Some of them possess a considerable percentage of epidote, and are closely related to the epidote amphibolites. In the latter the feldspar has been entirely replaced by epidote. The hornblende gneisses are characterized by the combination of hornblende, plagioclase and quartz. The percentage of anorthite of the plagioclase varies considerably. They often contain epidote; rarely all feldspar has been replaced by epidote, in which case we have the equivalent of the epidote amphibolites.

The garnet amphibolites are plagioclase amphibolites with a considerable percentage of garnet.

In the same way the garnet hornblende gneisses are related to the hornblende gneisses.

Of rare occurrence are the pyroxene amphibolites; besides hornblende they contain an ample amount of monoclinic pyroxene.

"Deviating amphibolites" is the title given to some rocks whose mineral-assemblages and texture deviate from those of the preceding groups.

First we shall discuss the minerals. Secondly we shall give their petrographic description. Thirdly we shall see what is known about the geology of these rocks.

THE MINERAL COMPONENTS.

As mineral components we meet: hornblende, plagioclase, quartz, potash feldspar, biotite, monoclinic pyroxene, epidote, clinozoisite, garnet, titanite, ore, pyrite, apatite and zircon.

Hornblende.

Different types of hornblende occur. It is mostly the usual green kind. The form is irregular. Large crystals are perforated. In some rocks, however, the prism-zone is more ore less clearly developed (cf. V. 978, 979). Twins are rare. In several rocks a hornblende occurs which has the same form as the green variety, but differs from the latter by a peculiar pale tint. Part of the mineral-grains show a very pale green, and sometimes are even colourless. The deviating colour may extend over a whole mineral-grain, or appears locally (V. 140, 333, 342, 733). The colourless type is often twinned polysynthetically; in that case a single crystal may show as many as ten lamellae, twinned according to (100).

Especially in the ordinary green hornblende, and also in the pale variety cleavage according to (001) may be developed. This unusual cleavage is extremely delicate, and shows in cross-sections numerous lines, running quite parallel and close together (V. 126, 140, 342, 535, 634, 733, 734).

The green hornblende may be fringed at the edges. Besides, actinolite occurs in some rocks. We shall discuss these types briefly, when describing the rocks.

Large hornblende-crystals may enclose numerous grains of the colourless minerals. Ore-grains are also frequently enclosed.

Plagioclase.

The anorthite-percentage of the plagioclase varies considerably. We have ascertained, however, that the percentage is constant in the plagioclases of the same rock-sample. If the refraction is about the same as that of quartz, it may be very difficult to distinguish the plagioclase from quartz, as plagioclase in many rocks is hardly twinned at all. If the plagioclase is basic the discrimination from quartz is rather easy. The anorthite-percentage varies from oligoclase to bytownite (about 80% of An.). Zonal structure is rare and always of little significance. The same applies to inclusions. In a hornblende gneiss from the De Goeje mountains, however, relatively large plagioclases may enclose numerous droplets of quartz (V. 124). In light of small intensity, we see a network of plagioclase, riddled by feebler refracting circlets of quartz-droplets (see Pl. 48 fig. 1). The difference in refraction with the plagioclase is very marked, because the plagioclase is basic here.

Quartz calls for no remarks.

Potash Feldspar. It is found only in one hornblende gneiss, in irregular lumps, which may show delicate microcline-structure.

Biotite. Greenish brown biotite seldom occur. It is sometimes strongly flattened according to the base.

Pyroxene. In the normal amphibolites pyroxene rarely occurs. In an amphibolite containing epidote, found to the South of the Grutterink mountains (V. 848) colourless monoclinic pyroxene occurs with a large angle of extinction (viz. about 55°). The mineral grains show irregular forms; the larger ones are perforated. Data concerning the other pyroxenes may be found in the descriptions of the rocks.

Epidote, Clinozoisite and Zoisite.

Epidote occurs in very different forms: as grains, in irregular pieces, or developed according to the orthodomatic zone. Especially small crystals may show distinct prisms. Quite irregular pieces are often perforated. In some rocks the epidote forms rims round crystals of hornblende, ore etc. The rims have porous structure: their habitus is the same as that of the reaction-rims in igneous rocks. The double fraction of the epidote varies considerably.

Clinozoisite is not frequent in these rocks. It shows grains, or irregular pieces, often strongly perforated. Distinct prisms, showing the same development as epidote according to the orthodomatic zone, were found here and there. The mineral is connected by transitions with epidote, but in its typical form it differs from the latter mineral by its positive optic character and by an axial angle that is somewhat smaller than that of epidote (judging from the curve of the hyperbole in the interference-figure).

Zoisite is nowhere distinctly recognizable, not even in the epidote amphibolites. In the plagioclase there is sometimes a dusty mass, which is strongly refractive and which might be called zoisite.

Garnet. Garnet is only found in the garnet amphibolites and garnet hornblende gneisses under which heading it receives special attention.

Titanite and Ore. Ore seems to be developed in nearly all these rocks as ilmenite, possibly also partly as titanomagnetite. In some samples we have ascertained by prolonged boiling of the ore in hydrochloric acid, that we had to do with ilmenite. In most cases it is evident that titanite has developed from the ore [1]). Very often there are rims of titanite round the ore. In that case the latter shows every phase of decay. In an advanced stage only ore-dust is recognizable in the titanite. This secondary titanite is always devoid of crystal-form. Titanite also occurs as rounded-off grains, so-called "insects-eggs".

In a number of rocks, however, we find ore in an unchanged state.

Pyrite. This mineral occurs in a few rocks (e.g. V. 333, 733, 734).

Apatite. Apatite is mostly met with as rounded-off grains (V. 981, 1084, 1085), occasionally also as prismatic ones (V. 174). A small zone which occurs in an amphibolite from the De Goeje mountains (V. 72), and which is composed of plagioclase, contains comparatively big apatite-grains, amounting to 0.5 mm. in diameter.

Zircon. Zircon is only found in rounded off grains; besides it is of rare occurrence.

Rutile. Rutile is a rare component. It has only been found in a few hornblende gneisses (e.g. V. 849). It occurs as thin needles and as prisms, with pyramids. The colour is a greenish yellow. Globular grains occur likewise. Quantitatively the mineral is of little importance.

Spinel. This mineral has been found in one rock (V. 41). It is pleonaste.

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[1]) V. 84, 91, 843, 958, 981.
[2]) e.g. V. 89.

The colour is grass-green. Octahedral shape may be observed here and there. For the greater part, however, it occurs as grains, often heaped together.

PETROGRAPHIC DESCRIPTION.

The plagioclase amphibolites.

The normal plagioclase amphibolite is widely spread in Surinam; it consists of hornblende and plagioclase. It is a normal-grained, also often a very fine-grained to dense rock. Parallel texture may be developed in the sample. Types which have moderately developed parallel texture are most frequent. Several rocks are very fine-grained; besides, they show very distinct parallel texture and split in planparallel plates, in such a way that they might be looked upon as hornblende schists, judging from the habitus of the samples. [1]) Microscopically the hornblende and plagioclase in it appear to be evenly distributed. Parallel texture is constantly met with; it is rarely slightly folded (cf. the rock from the Sara creek, V. 1610). Generally speaking, the size of the grains of the two chief components does not differ very much.

The plagioclase and hornblende impede each other mutually, and are polyhedric and often oblong. They show the well-known granoblastic structure of the normal hornblende amphibolites. Sometimes, however, the hornblende shows perforated structure (Pl. 47 fig. 2).

It is important to note that the plagioclase always has a basic composition.

In the plagioclase amphibolites the following accessories have been found: quartz, biotite, titanite, ore, pyrite. Traces of epidote may occur. Besides, veins, filled with epidote, may cut the sample. The rocks are either devoid of quartz or contain only a very scanty percentage of it.

In view of their monotonous composition many of these plagioclase amphibolites do not call for discussion [2]). Local deviations from even texture we find in a rock from the De Goeje mountains which shows large plagioclases: the latter enclose hornblende poikilitically (V. 556).

Great variability in structure is shown by a number of plagioclase amphibolites from the De Goeje mountains, which, mineralogically, show no essential differences from the former rocks. They show great variation in the size of the grains. [1]) Parallel texture is mostly indistinct. The hornblende often shows base-cleavage. Many hornblende crystals are in part, or wholy discoloured. Some types of structure will be briefly described. In one of the types hornblende-grains of irregular, polyhedric form, differing much in size, lie in a mozaic of smaller plagioclase-grains (V. 140, 733, 734) (Pl. 47 fig. 2). In another type we also have large and small crystals; the small ones, however, seem to secede from the larger crystals, for they have grown out from the larger ones and have the same optical orientation as the latter. In another type again the small crystals are separated from the larger ones and lie

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[1]) See e.g. V. 178, from the vicinity of the Tosso creek.

[2]) V. 1, 20, 47, 56, 72, 178, 532, 535, 536, 556, 661, 687, 699, 703, 765 ⌈, 843, 1114, 1597, 1600, 1609, 1611.

scattered about in the mozaic (V. 34, 50, 126). There may be a likeness to uralitic hornblende, but there is no question of pseudomorphs (Pl. 47 fig. 6). Especially when larger hornblende crystals enclose oblong plagioclases at the edges, the structure reminds us of the ophitic structure of uralitized diabases: nowhere, however, does the plagioclase cutt off the hornblende sharply (V. 340, 342, 356, 508, 526, 528). If, lastly, most of the hornblende is needle shaped and the whole has a disorderly structure or shows some inclination towards fluid arangement, nematoblastic structure has developed (See V. 569, 570).

The rocks of this area are never zonal, except a few (e.g. V. 634) in which colourless zones, some millimetres broad occur, consisting almost exclusively of plagioclase. As has been stated, these amphibolites do not differ from the preceding ones in a mineralogical sense. The hornblende only is much more variable.

One of the rocks is so rich in hornblende that it might be called a hornblendite (V. 131). In an occasional rock spinel occurs (V. 41).

Closely connected with the previously discussed plagioclase amphibolites, are some others, in which the plagioclase has been partly replaced by epidote: *Epidote-bearing plagioclase amphibolites.*

The epidote shows the various shapes recorded above. The plagioclase may have been half replaced by this epidote (see the rocks of Grancreek, Marowyne area V. 979, 987). Quartz is present as an accessory only. The same variation in granular size and structure occurs as in the previously discussed amphibolites. A few rocks call for comment.

Rocks, found E. of the Upper Sara creek show very distinct parallel texture and are very finegrained; they look like hornblende schists (V. 1602, 1610). On account of their percentage of plagioclase, however, these rocks belong to the amphibolites. In other rocks the habitus of the hornblende partly suggests uralitic hornblende, partly actinolite (V. 1613, Upper Sara creek basin). We meet with quite the same type in rocks from the Babona creek, Kleine Saramacca (V. 782 and 785). Actinolitic hornblende is seen in a rock from the Pedrosoengoe-falls, Marowyne (V. 437). Through the microscope we see hornblende in a fine mosaic of untwinned plagioclase which now partly, now entirely makes room for numerous grains and prisms of clinozoisite. As accessoria occur strongly pleochroitic, brown biotite, and some titanite-grains passing into leucoxene.

Remarkable for the occurrence of prehnite is a very fine-grained, outwardly compact rock collected (by Voltz) near "Post Huguesburg", on the Suriname river; the pale-green sample is intersected in all directions by yellowish green veins, which, on microscopic examination, appear to be filled with prehnite.

An enumeration of the numbers pertaining to the epidote-bearing plagioclase amphibolites, is found below [1]).

The epidote amphibolites.

These rocks are characterized by the mineral-combination hornblende and epidote, which latter replaces the plagioclase almost entirely; they are epidote amphibolites in a narrower sense. They are normal- to fine-grained rocks, mostly with some parallel texture. The spaces between the hornblende-crystals are filled up with epidote. If larger fields consist only of epidote, the crystals blunt each other to polyhedra (see the rocks from Barklak creek near Grancreek, Marowyne, V. 982, 986).

[1]) V. 138, 152, 173, 175, 204, 979, 987, 1598, 1610, 1613, 1630, 1636, 1666; Vtz. 156.

A rock from the Sara creek (V. 1569) consists chiefly of epidote with a smaller number of little oblong or needle-shaped hornblende crystals; it was called "Epidotfels" by Du Bois [1]). An amphibolite very rich in epidote, from the Lawa near Langa tete soela, moreover contains a considerable percentage of calcite (V. 808). Of this group we have only seven representatives, the numbers of which are given below. [2]) It is remarkable that we do not have zoisite amphibolites, which, elsewhere, frequently occur together with epidote amphibolites.

The hornblende gneisses.

Outwardly these rocks cannot be distinguished from the amphibolites. They are again normal-, or fine-grained, sometimes almost dense. The percentage of hornblende in them seems to be either the same, or larger than that of the colourless minerals. Some parallel texture is nearly always present. Some rocks are schistose. Microscopically we see hornblende, plagioclase and quartz, sometimes together with epidote and pyroxene. The composition of the plagioclase varies greatly, ranging from very basic to oligoclase-andesine or even somewhat more acid. It always constitutes a considerable percentage of the rock. We have grouped the gneisses in accordance with the composition of the plagioclase in the following discussion.

a. Hornblende gneisses containing basic plagioclases.

Fine-grained hornblende gneisses, with a large percentage of ordinary green hornblende as the only important dark component, we find South of the Grutterink mountains (V. 845, 849), in the De Goeje mountains (V. 124, 174, 348) on the Tosso creek (V. 968), and near the Tompi creek (a tributary creek of the Suriname river V. 1654).

More variable is the mineral combination of an epidote-bearing gneiss from the Marowyne creek (V. 1660), and of epidote and pyroxene-bearing gneisses from the Upper Courantyne (Y. 307, 310) and from South of the Grutterink mountains (V. 846).

As accessoria may occur ore, calcite, titanite, apatite, and epidote.

The gneisses with simple mineral-assemblage show a granoblastic mozaic of hornblende plagioclase and quartz. A Rosiwal measurement of a rock from south of the Grutterink mountains (V. 845) showed the following percentages: 64 % of hornblende, 23 % of plagioclase, 13 % of quartz and a negligible quantity of titanite and ore. The anorthite-percentage of the plagioclase was fixed at 85 %.

Other rocks join directly up to this one and differ only in details. Thus a hornblende gneiss also from South of the Grutterink mountains (V. 848) only having different percentages of the components, viz.: 43 % of hornblende, 32 % of plagioclase, 20 % of quartz and 5 % of ore. The anorthite-percentage of the plagioclase was fixed at 80 %.

Whereas in the preceding rocks the distribution of the mineral-components may be called even, this applies less strictly to two others from the De Goeje mountains (V. 124 and 174). The hornblende, greatly differing in size lies in a fine polyhedric mosaic, which now consists of nearly basic plagioclase only, now contains a considerable percentage of quartz. Locally relatively large quartzes occur. In one of these rocks (V. 124) the plagioclase encloses numerous quartz-droplets; see Pl. 48 fig. 1.

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[1]) G. C. Du Bois. **40**. p. 18. No. 93.
[2]) V. 131, 808, 980, 981, 982, 986, 1569.

About the gneisses with more variable mineral-combination we may remark the following. The epidote-bearing equivalent of hornblende gneiss with basic plagioclases, is represented by some rocks.

A very fine-grained sample from the Marowyne creek (V. 1660) contains a considerable percentage of epidote. Microscopically it appears that now hornblende and epidote occur together in such a quantity that they constitute the greater part of the whole (either epidote or hornblende predominating), now again a delicate mosaic of plagioclase and quartz predominates. The epidote is often distinctly developed according to the orthodomatic zone. The hornblende and plagioclase cause parallel texture. There is a profusion of fine titanite-grains.

Again another hornblende gneiss (from the Upper Courantyne Y. 307) locally shows an entirely deviating composition. Of this rock several samples were collected. Most of them are fine-grained, with parallel texture, and have the same composition as the afore-mentioned hornblende gneisses. The percentage of anorthite in the plagioclase was fixed at 80 %. In the sample there occur locally strings and nests of somewhat coarse grain. They contain much glittering quartz, besides white plagioclase. These minerals may also occur together as lenses and spots of some cm. in diameter, together with minerals of a greenish tint. Much pyrite is present. Microscopical examination shows that the nests consist of much quartz, basic plagioclase, epidote, and monoclinic pyroxene, and besides, of some ore, titanite and traces of green hornblende. All components are distributed and amassed without order. Idiomorphism does not occur, an occasional epidote-crystal excepted.

A hornblende gneiss from the Upper Courantyne below the Malawini creek (Y. 310) shows green hornblende, basic plagioclase, quartz, epidote and pyroxene with titanite, apatite, and a few pieces of calcite as accessoria. Some zones are rich in epidote, which may be distinguished macroscopically. The distinctly greenish pyroxene is of little moment. The oblong pieces show no crystal-faces. The calcite is in all probability a crystalloblastic component, and not the result of weathering.

More interesting is a gneiss from South of the Grutterink mountains (V. 846). The sample is fine-grained with parallel texture. Its principal components are hornblende, monoclinic pyroxene, epidote and clinozoisite, plagioclase and quartz. On minute inspection some potash feldspar may be observed. Titanite and traces of ore, pyrite, and apatite occur. The distribution of the components is not regular enough for a Rosiwal-measurement, but in general it may be said that the sum of the dark components will not differ much from that of the colourless ones; locally, however, the dark components undoubtedly predominate. The hornblende often shows perforations in which quartz or plagioclase are visible. The colourless pyroxene has no idiomorphism; it shows partly perforated fields; the angle of extinction is large; only the pseudo-quadratic cleavage is developed. The epidote has for the greater part developed into clinozoisite. By far the majority of the crystals show very weak double refraction and an anomalous steel-blue tint. Besides these, however, there occur some pieces showing the normal characteristics of epidote. The plagioclase contains 85 % of an. Some potash feldspar occurs; it shows very fine microcline structure. Titanite only occurs in the shape of irregular pieces. Traces of ore and pyrite are present, while an occasional globular grain of apatite has been found. This gneiss shows typical crystalloblastic structure; it is impossible, however, to distinguish a crystalloblastic sequence.

b. Hornblende gneisses containing plagioclases of intermediate composition.

Closely related to the preceding hornblende gneisses are others in which the plagioclase has a somewhat less basic composition.

The plagioclase contains 50 % of An. in a rock from the De Goeje mountains (V. 551), and 40 % of An. in a rock from the same mountains, which is poor in hornblende (V. 43).

Besides types which contain ony hornblende as dark principal component we may distinguish others rocks, which at the same time show a variable quantity of epidote.

Of the first type we have representatives from the Grutterink mountains (V. 95), from the De Goeje mountains (V. 43, 551, 533 A) and from the Upper Courantyne (from above the mouth of the Kamani river). Some percentage of epidote occurs in the gneisses from the Grutterink mountains (V. 89), from South of the Tosso creek (V. 177) and from Langatete near the Lawa (V. 804). Of all these rocks two call for comment. The gneiss (V. 43) is poor in hornblende (abt 20 %). The minerals are irregularly distributed, especially the plagioclase and quartz. Microscopically we see zones in which both minerals are equally represented, and in which they form a mosaic. These zones alternate with zones and lens-shaped parts that contain only quartz as colourless principal component. The hornblende is also scattered more or less irregularly. Remarkable is the occurrence of numerous fine grains of apatite, rounded-off and rarely bigger than 70 μ. They are confined to the plagioclase-quartz zones. The gneiss V. 533 A is relatively poor in hornblende, so that the sample has a dark grey colour. It contains a quartz-zone, running parallel to the texture. Microscopically too, the texture is irregular in appearance, because in places only plagioclase occurs as a colourless component. The grains of the granoblastic mozaic are often clearly twinned and only little quartz is present.

c. Hornblende gneisses containing acid plagioclases.

A large series of hornblende gneisses contain plagioclase varying between oligoclase and andesine. With these rocks it may be very difficult to define the respective percentages of quartz and plagioclase. Both the pure hornblende gneisses, in which hornblende is the ony dark principal component (sometimes with accessory pyroxene) and the types in which a variable percentage of epidote occurs (sometimes also accompanied by pyroxene) are richly represented.

Of the first type we have gneisses from the Grutterink mountains (V. 91, 92, 97, 100, 101, 791, 792, 794, 815), from between the Wilhelmina river and Emma river (V. 758) from near the mouth of the Tosso creek in the Tapanahony (V. 84, 85) and from the De Goeje mountains (V. 17, 48, 51, 533). They require little comment. They are partly fine-grained rocks, showing distinct parallel texture (V. 91, 92, 97, 100, 101, 815).

Of deviating composition is one of the rocks from the Grutterink mountains (V. 97), as it contains large quartz-lenses. Against the very fine-grained, dark gneiss masses, the bright, sugar-like quartz-lenses stand out very sharply. Possibly these lenses are of secondary nature in respect to the hornblende gneiss. Irregular distribution of the hornblende is seen in a rock from the De Goeje mountains (V. 17). Another rock from the De Goeje mountains besides green hornblende contains the previously discussed, almost colourless variety; both types of colour are connected by means of transitions. The base-cleavage is developed both in the colourless and in the green crystals. The colourless ones may show polysynthetic twinning. In another gneiss again from the Grutterink mountains, the hornblends-crystals differ considerably in size (the biggest amounting to some mm.); between them occur spots rich in quartz and poor in plagioclase, in which moreover some diopside is present (V. 791).

The epidote-bearing equivalents of these gneisses are present in profusion. We have samples of these rocks from the Grutterink mountains (V. 90, 94, 96, 812, 827, 834, 838), from the Tosso creek (V. 15, 121, 137, 202, 203, 205, 674, 718, 965), and from south of this creek (V. 180), from the Lely mountains (V. 795), from near the Wilhelmina river (V. 749), from the De Goeje mountains (V. 40) from the Gran creek (V. 978, 988) and from the Djoeka creek (V. 2207). The epidote varies greatly in quantity, and shows different forms. Remarkable are the wormlike, crooked channels occurring at the edges of large pieces of epidote (in V. 812 and less clearly in V. 40). This epidote may surround hornblende, pyroxene or ore in such a manner that it resembles "reaction rims".

Some of these epidote-bearing gneisses deserve special mention. A gneiss from the De Goeje mountains (V. 40) is remarkable for its structure and its percentage of pyroxene. The sample is normal-grained, massive and comparatively rich in dark minerals. Microscopically we see green hornblende, greenish diopside, plagioclase (oligoclase-andesine), quartz, with accessory epidote, ore, titanite, and apatite. Remarkable are the relatively large dark minerals, which, have developed as skeletons. They show irregular fields, which are perforated in such a manner that only about half the field is occupied by the dark mineral. Evidently the pyroxene and hornblende have, during their growth, enclosed the colourless minerals.

The ore is partly octahedral and is surrounded by a small border of titanite. The epidote is quantitatively unimportant.

In a gneiss from near the Wilhelmina river (V. 749) irregular pieces of monoclinic pyroxene occur besides hornblende. The pyroxene is discoloured. Formation of opal begins, superseding the plagioclase.

Deviating texture is shown by an almost schistose rock from the Tosso creek (V. 674) in which greenish zones stand out against a dark background rich in hornblende. The dark parts appear to be a gneiss rich in hornblende; the bright-coloured parts are composed of very much epidote and much less quartz, without plagioclase.

A fine-grained almost schistose rock, collected south of the Tosso creek (V. 180), is very rich in epidote. Quartz is the only colourless mineral in it. The epidote takes the place of the plagioclase here. This rock may be considered to be the equivalent of feldspar-free epidote amphibolites.

One of the gneisses from the Tosso creek (V. 203) is cut by aplite-veins. The gneiss is fine-grained, rich in hornblende and poor in quartz. The veins, are somewhat coarser in grain: microscopically they appear to consist only of plagioclase (oligoclase-andesine) and quartz. This plagioclase is partly irregular in shape, partly, however, the crystals show unmistakable idiomorphism, so that the veins are not to be considered as parts of the gneisses, but as aplite-veins of later date than the gneisses.

The Garnet Amphibolites.

The garnet amphibolites are the garnet-bearing equivalents of the plagioclase amphibolites. We have samples from two localities: from the De Goeje mountains (V. 527) and from the Grutterink mountains (V. 206, 817, 820). We shall discuss these rocks more in detail.

A rock from the Schroeder creek, De Goeje mountains (V. 527) is fine-grained and has parallel texture; it shows numerous pale red garnets. A Rosiwal-measurement, carried out microscopically along a number of lines drawn perpendicular to the parallel texture produced the ratio: 62 % of hornblende, 19 % of plagioclase, 13 % of garnet and 6 % of ore. So garnet and ore are abundant. Striking is the large number of polysynthetic twins shown by a colourless hornblende-variety. The plagioclase has acid composition: 35 % of An. The crystals sometimes do not show twinning-structure. Hornblende, as well as plagioclase, show granoblastic structure. The garnet is conspicuous because of its idiomorphism. Repeatedly we find grains with sharply defined faces and angles wich point to rhombendodecahedra. The mineral is colourless in the thin section. Inconsiderable pieces of hornblende and a single large grain of ore may be enclosed. The garnet is now larger than, now of the same size as the two other principal components. The ore is relatively coarse, with indications of crystal-forms. Other components are not found.

A garnet amphibolite of another type is known to occur in the Grutterink mountains (V. 820). It is a fine-grained amphibolite with parallel texture, with red garnets of some mm. in size. Microscopically the hornblende-percentage appears to be uncommonly large. It is a bicoloured green hornblende with clear development of the prism-zone, in as far as the crystals do not impede each other. At the edges the crystals are interrupted by irregular grains of plagioclase. The plagioclase crystals are much smaller than the hornblende ones, and consequently are of small quantitative importance. The composition of the plagioclase seems to be moderately basic. A single grain of garnet has been struck by the thin section. It is a comparatively large crystal, of a somewhat pink colour. Some pieces of hornblende and grains of ore are enclosed. Pale brown titanite-grains are present in great quantity. It is apparent that this titanite has developed from ore.

The other garnet amphibolites from the Grutterink mountains locally contain some quartz (V. 206, 817). The fine-grained rocks clearly show parallel texture. Here and there pale-red oblong garnet crystals may be recognized. Judging from the index of refraction they contain acid plagioclase with only 25 % of An. Quartz is of local importance, so that the rock inclines towards the hornblende gneisses. Garnet occurs here and there as very strongly perforated crystals, which enclose so many colourless mineral-grains (plagioclase and quartz) and pieces of hornblende that they are hardly more than skeletons. The quartz may show a trace of undulose extinction, in contra-distinction to the plagioclase. Whereas the texture in the rock is strictly parallel, we see in places how the hornblende individuals are ranged round the garnet-skeletons. As accessories ore and titanite are found.

The garnet hornblende gneisses.

Of these rocks we possess a number, largely varying in composition and texture, so that separate treatment is desirable. We have samples from the De Goeje mountains (V. 665, 666), from the Grutterink mountains (V. 88, 93, 832) and from Gran creek (V. 864).

The rocks from the De Goeje mountains are very fine-grained, massive, black rocks. With the acid of a magnifying-glass we are able to recognize garnet and scarce pyrite. The minerals in these rocks are distributed fairly evenly. We observe hornblende, plagioclase, quartz, ore and garnet. According to a Rosiwal measurement along lines, perpendicular to the indistinct parallel texture, the composition is: hornblende 26 %, plagioclase 34 %, quartz 18 %, ore 5 %, garnet 17 (!) %. The pieces of garnet are relatively large and are not evenly distributed, therefore this quantitative relation is not very reliable. The hornblende shows again two varieties of colour. The plagioclase strikes us at once by its very large relief, as compared with that of the much more feebly-refractive quartz. Without this relief the quantitative relation between the two could not be determined, owing to the insignificant size of both components (mostly smaller than 0.015 mm.) and the poor development of the twinning-structure. On comparison with liquids, it appears to be basic plagioclase with 85 % of An. Plagioclase and quartz together form a fine angular mosaic. The ore, which at first sight seems to be present in much larger quantity than is shown by the measurement appears under reflected light to consist for the greater part of pyrite, partly coalesced with black ore. The garnets, amounting to some mm. in size are almost colourless, strongly perforated crystals. They enclose grains of quartz and ore and also some feldspar.

Another type from the Grutterink mountains (V. 88, 832) macroscopically as well as microscopically at first sight shows a very great similarity with the garnet amphibolites of the same area. When examined microscopically it appears to be composed of the ordinary green hornblende, plagioclase, quartz, titanite, ore and garnet. The plagioclase and quartz are hardly to be distinguished from each other because the index of refraction of the two hardly differs. The plagioclase must be oligoclase-andesine. Yet a considerable amount of quartz seems to be present, judging from the interference-figures, while the quartz may show slight undulose extinction, which has not been observed with the plagioclase. Oblong hornblende-crystals may locally surround the garnet. Ore is restricted to sporadic pieces of pyrite. Titanite is present in great quantities as very fine, oblong globular grains, probably developed from ore. The perforated garnet is almost colourless and devoid of crystalline shape: it encloses chiefly quartz.

Whereas the preceding rocks, apart from their parallel texture, show even distribution of the minerals, the following ones display slight deviations.

A rock from the Grutterink mountains (V. 93) shows in the sample clear parallel texture besides fine strings of green material, which repeatedly split up and re-unite. Red garnets of some mm. in size are conspicuous. Microscopically the dark parts appear to resemble to the preceding rocks. The plagioclase is oligoclase-andesine. The light strings have an entirely different composition. They show a combination of quartz, clinozoisite, monoclinic pyroxene and some hornblende. So the plagioclase and garnet are restricted to the parts rich in hornblende. In the groups rich in quartz the epidote and pyroxene dominate with respect to the hornblende. The texture is dominated by the relatively coarse, skeleton-like pieces of pyroxene, which include grains of quartz and angular grains of epidote. The epidote and quartz are partly polyhedric. The rock has a strikingly crystalloblastic structure. The pyroxene is very bright-green with hardly visible pleochroism. The extinction is large, the (110) cleavage is distinct. Remarkable is the feeble double refraction of the epidote, which shows in a great many sections steel-blue colours such as are generally found in zoisite.

Again another habitus is shown by a rock from the Gran creek (V. 864). The sample might be taken for an amphibolite with slight parallel texture. Microscopically hornblende, garnet, quartz, plagioclase, ore, epidote and apatite appear to be present. The components are irregularly distributed. Some parts consist chiefly of the dark minerals: others of the colourless ones. In the dark parts hornblende and garnet of extremely irregular structure may be observed. Locally hornblende predominates, in other places again garnet. The hornblende may surround the garnet in the shape of rims. In this case it certainly seems as if the hornblende is in the act of developing out of garnet. Where this takes place the rocks approach hornblende eclogites in composition. Ore is scattered profusely as grains in the dark parts, and occurs both enclosed in hornblende and in garnet. The colourless parts consist chiefly of quartz and in a less degree of acid plagioclase; locally hornblende, ore and apatite are met with. The quartz and plagioclase show irregular and partly undulating course of the border-lines. The plagioclase (oligoclase-andesine) mostly shows clear twinning. Locally the plagioclase is superseded by zoisite-like epidote, while epidote with spongy structure may also occur in the dark parts. The quartz is slightly undulose; apatite shows rounded-off grains. As a whole this rock shows a remarkable quantitative relation between the components, which neither agrees with that of the garnet amphibolites (owing to the very large amount of quartz) nor with that of typical gneisses (owing to the scarceness of plagioclase).

The Pyroxene amphibolites and Pyroxenites.

These amphibolites are represented by three rocks only. All of them were collected in the neighbourhood of the De Goeje mountains.

A very fine-grained, almost opaque black rock of massive texture was collected in the northern part of this area (V. 323). The rock has in part undergone a considerable change. Microscopically we see in those places where the rock is unchanged, plagioclase (basic and untwinned) together with much pyroxene and hornblende. The pyroxene is granular or indistinctly oblong. It has a clearly greenish tint. The (110) cleavage is distinct, the angle of extinction is large. Now the pyroxene grains huddle close together with green hornblende, now again both minerals lie in a polyhedral mosaic of plagioclase. There is a profusion of octahedric ore, while here and there some titanite is found. Epidote appears to be secondary; in some places, namely, pyroxene as well as plagioclase have been replaced by a mass of epidote, in which the hornblende may still be vaguely discerned. Consequently the rock there passes into an epidote amphibolite. There is no reason to suppose that the hornblende has developed from pyroxene.

Of another rock we only have a slide; the sample is wanting. Microscopically we see only two principal components, viz. pyroxene and hornblende. They are irregularly distributed. Locally only pyroxene, or only hornblende is present, whereas elsewhere both occur promiscuously. Where only pyroxene is present, the grains blunt each other polyedrically, thus producing the typical figure that is often seen in pyroxenites (Pl. 48 fig. 2). As opposed to the preceding rock we have to do here with a completely colourless pyroxene. Here too, the cleavage is distinct and the angle of extinction large. The green hornblende, when oblong, as usual, only shows an indication of the prism-zone. Brownish titanite may occur in insignificant pieces. Some relatively large rounded-off apatite-grains are met with. Finally there is some chloritized biotite to be seen. This is of very small importance. Secondarily the rock has undergone partly important changes. We see namely how pyroxene has locally been entirely replaced by epidote. This process begins with a decrease in double refraction: at the edges the mineral passes into epidote, so that, where the pyroxene is amassed, we see a net-work of epidote with pyroxene in the meshes. The epidote in that case shows anomalous steel-blue polarization-colours. On account of the lack of feldspar, also in the unchanged parts, we might class this rock with the hornblende pyroxenites.

The third rock is very fine-grained black and shows indistinct parallel texture (V. 58). Microscopically we see a large amount of small, green hornblende (which passes into a completely colourless type), moderately basic plagioclase, and locally much pyroxene, and much ore. All these components except pyroxene, are evenly distributed. The profuse hornblende is elongated according to the c-axis. Fine base-cleavage has developed here, which not impossibly points to relationship with the former rocks, the more so as they originate from the same area. The very small plagioclases impede each other where they touch; they are too small to show any twinning-structure. In part of the rock, the hornblende has been replaced by a considerable percentage of pyroxene. The pyroxene-grains show strikingly distinct pleochroism ranging from greenish to brigt wine-red, that suggests hypersthene. Owing to the very small size (smaller than 0,02 mm.) it is hardly possible to see anything of the optic orientation. Where cleavage appears, oblique extinction dominates. As a whole this rock has the composition of a very fine-grained amphibolite, rich in hornblende, and containing pyroxene.

The deviating amphibolites.

By this name are called four rocks, which, in spite of the fact that they were found far asunder, (Gran creek, Grutterink mountains and Tosso creek) yet have a similar composition. They are all normal- to almost fine-grained, massive rocks.

Microscopically they appear to be extremely rich in hornblende, as well as to contain some quartz which bears a false resemblance to plagioclase. The relatively much larger hornblende-crystals are oblong, with variable distinctness of the prism-zone. Twins are frequent. They include grains of quartz. The extinction amounts to 17°: The pleochroism ranges from pale yellowish-green to green and bluish-green (respectively according to $n\,\alpha$, $n\,\beta$ and $n\,\gamma$). The quartz shows aggregates which must have arisen from the crushing of larger pieces. Accessories occur very rarely. In one of the rocks (V. 208 from the Tosso creek) occurs some greenish diopside. For the rest we see only here and there a grain of ore or a piece of titanite. We are in doubt about the origin of these rocks. It is not improbable that they are local complications in non-metamorphic igneous rocks. They may not be regarded as quartz-bearing hornblende schists because of their massive texture. For the present they are classed here with the amphibolites and indicated as such in the maps.

TABLE 32.

	Hornblende gneiss. V. 845 [1])	Hornblende gneiss. V. 92 [1])	Garnet hornblende gneiss. V. 665 [1])
SiO_2	54.19	49.78	54.52
Al_2O_3	13.30	15.28	12.23
Fe_2O_3	2.81	1.10	6.09
FeO	7.99	10.85	12.34
MnO	0.19	0.21	0.24
MgO	6.95	6.83	1.82
CaO	12.27	10.28	7.53
Na_2O	0.37	1.99	0.35
K_2O	0.84	0.60	0.58
H_2O+ / H_2O-	0.61	0.70	1.35
TiO_2	0.72	1.44	2.88
P_2O_5	0.13	0.09	0.57
	100.37	99.15	100.50
	[1]) 0.05 SO_3	[1]) 0.13 SO_3	[1]) 1.40 SO_3

Anal. Koning & Bienfait, Amsterdam.

	si	al	fm	c	alk	k	mg	Section
V. 845	132	19	47	32	2	0.60	0.54	5
V. 92	116	21	47.5	26	5.5	0.17	0.50	4
V. 665	91	21.5	52.5	24	2	0.53	0.15	4

V. 845, V. 92 } Grutterink mountains.
V. 665 De Goeje mountains.

Signs of cataclasm.

It is remarkable of how little importance signs of cataclasm are in any of the rocks mentioned. Neither the amphibolites, nor in the gneisses do we meet with any crushing, except for the plagioclase or quartz being undulose here and there.

SOME CHEMICAL DATA ON THE AMPHIBOLITES AND THE HORNBLENDE GNEISSES.

Table 32 (p. 443) gives the chemical composition of some typical representatives of the group. The Niggli-values have been added. From these values it appears that we have evidently to do with the equivalents of basic igneous rocks. The analyses agree with those of gabbros and diabases of the calc-alkali series. A few values call for some remarks. In the first rock the value for c. is rather high, in accordance with the large anorthite percentage of the plagioclase. In the first and in the last rock the values for k. are too high for normal gabbros. This is not consequent on a large potash-percentage, but on the small percentage of Na_2O given by the analyses.

The chemical composition of some rocks has been computed from the percentages of the minerals in them, in accordance with the Rosiwal method. For the chemical composition of hornblende and garnet the average of a number of analyses of analogous rocks from elsewhere has been assumed. The epidote is supposed to be a type rich in iron. The composition of the plagioclase has been ascertained with the aid of liquids having known refractive indices.

Table 33 gives the result of the computations. It goes without saying that this method is inaccurate. The composition of the hornblende gneiss V. 845 has been determined by means of chemical analysis and Rosiwal-measurement; cf. the result in the two tables (first column). The Rosiwal-measurement once more proves that the hornblende gneisses and amphibolites are the equivalents of basic igneous rocks.

DISTRIBUTION AND GEOLOGY OF THE AMPHIBOLITES AND GNEISSES.

Part of the amphibolites and hornblende gneisses form massifs. By the Government Mining Exploration some massifs were discovered between the Lawa and Tapanahony, on the Tosso creek, and possibly also in the region of the Gran creek. These massives, several km. in diameter, form groups of hills of apparently more resistant composition than the neighbouring rocks.

The distribution of the samples collected in these areas informs us on the connection between hornblende gneisses, amphibolites, etc. The following sketch represents the Grutterink mountains, an area of 6 km. in diameter (fig. 61).

The low mountains are situated at Lat. 4 N., between the Tapanahony and Lawa river (see Map VI). The prospecting-trails and findspots of the rocks-samples are marked. Locally granites, acid diorites and related ortho-gneisses have been found in this area consisting chiefly of metamorphic basic rocks. The hornblende gneisses are represented by the types with acid or moderately basic plagioclase (mostly oligoclase-andesine, sometimes also approximately andesine). Epidote is now entirely lacking (V. 88, 91, 92, 95, 97, 100, 101, 791, 794, 815), now present in diverging quantities (V. 89, 90, 94, 96, 812). That the presence or absence of epidote makes but a very small difference, may be inferred not only from the petrographic relationship between the several

TABLE 33.

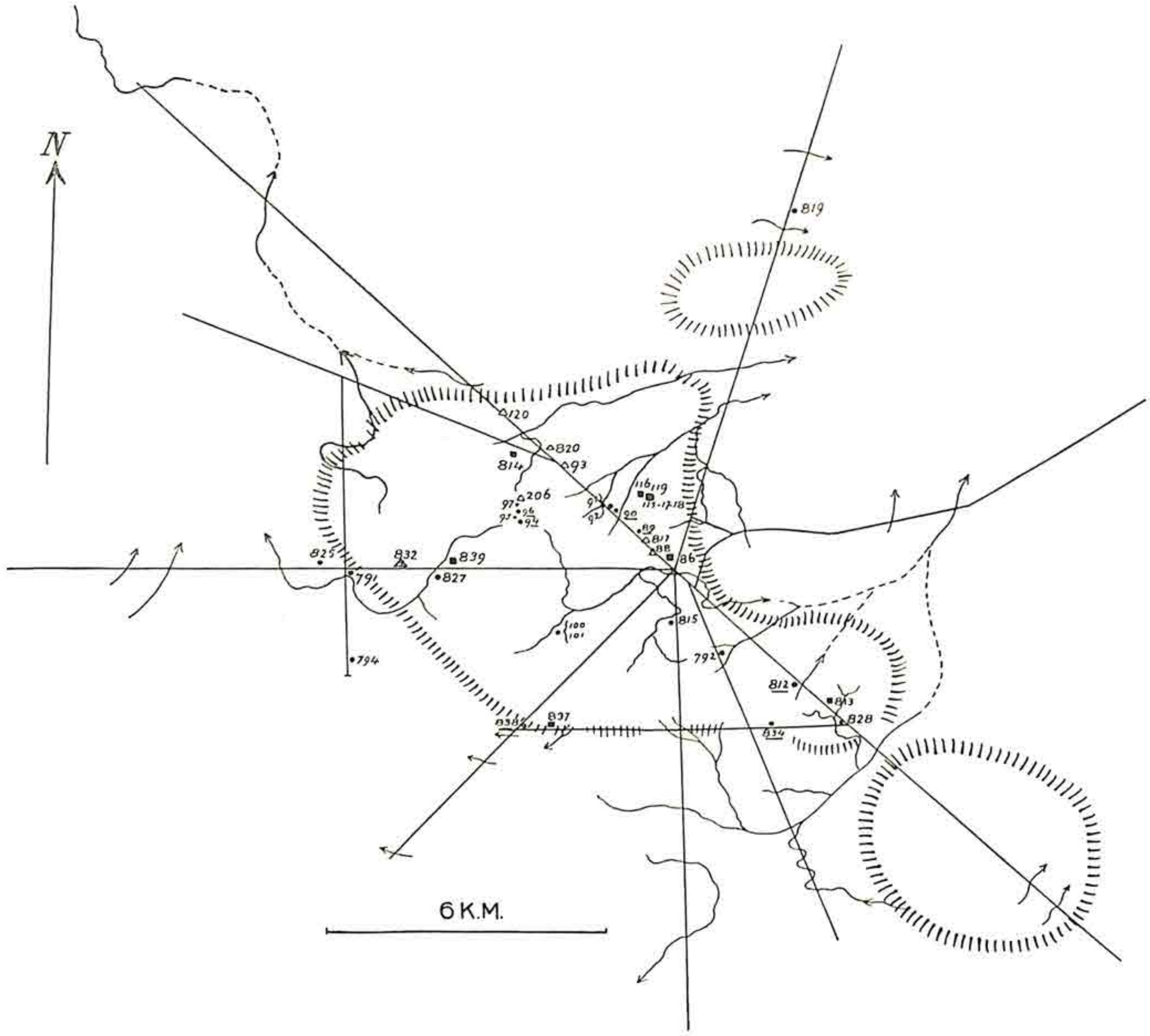
	Hornblende gneiss V. 845	Garnet hornblende gneiss. V. 848	Garnet Amphibolite V. 527	Epidote Amphibolite V. 982
SiO_2	57.5	52.5	46.3	46.4
Al_2O_3	13.4	15.1	13.1	13.9
Fe_2O_3 / FeO	9.5	13.1	19.9	15.5
MgO	7.8	5.2	8.6	8.3
CaO	10.6	9.6	9.7	14.1
Na_2O	1.2	4.5	2.4	2.0
	85% of An.	65% of An.	35% of An.	—

types, but also from the fact that they occur by the side of each other. They are all rocks with even distribution of the mineral components and variable parallel texture; only a few gneisses form an exception to this, through the occurence of quartz-lenses, the genetic significance of which is not quite clear (V. 97).

We also know garnet hornblende gneiss and garnet amphibolites from this area, both of them containing acid or moderately basic plagioclase (nearly andesine). The relation between these rocks and the preceding hornblende gneisses, appears again from the regional distribution: garnet hornblende gneiss (V. 93) occurs by the side of garnet amphibolite (V. 820), garnet hornblende gneiss (V. 88) by the side of hornblende gneiss (V. 89); and garnet amphibolite (V. 206) by the side of epidote-bearing or epidote-free hornblende gneiss (V. 94, 96 and 95, 97). It should be mentioned that a rock of doubtful origin which is very rich in hornblende but contains no plagioclase (see p. 442), and which has been discussed with the amphibolites, possibly is a facies of the gneisses. The promiscuous occurrence of all these types points to the fact that all the types mentioned are genetically related.

A second, not less important area is known at the Tosso creek, a tributary of the Tapanahony. There however, the variability of the rocks is not so large as in the Grutterink mountains, and is consequently less instructive. The vicinity of the Tosso creek was explored in 1907 by the Government Mining-Exploration. The data that are at our disposal, were found nearly all along the creek itself, and near the mouth, in an area of 10 km. in length and some km. in breadth (fig. 62).

Besides the hornblende gneisses some granites and acid diorites occur. It is probable that the hornblende gneisses predominate, and form one or several massifs. We find chiefly hornblende gneisses with acid plagioclase (nearly oligoclase-andesine), some of which contain only hornblende as a dark mineral (V. 84, 85), others in which it occurs together with a variable percentage of epidote (V. 121, 137, 202, 203, 205, 674, 718, 965). Besides them we have also plagioclase amphibolites, which differ from the gneisses only by the

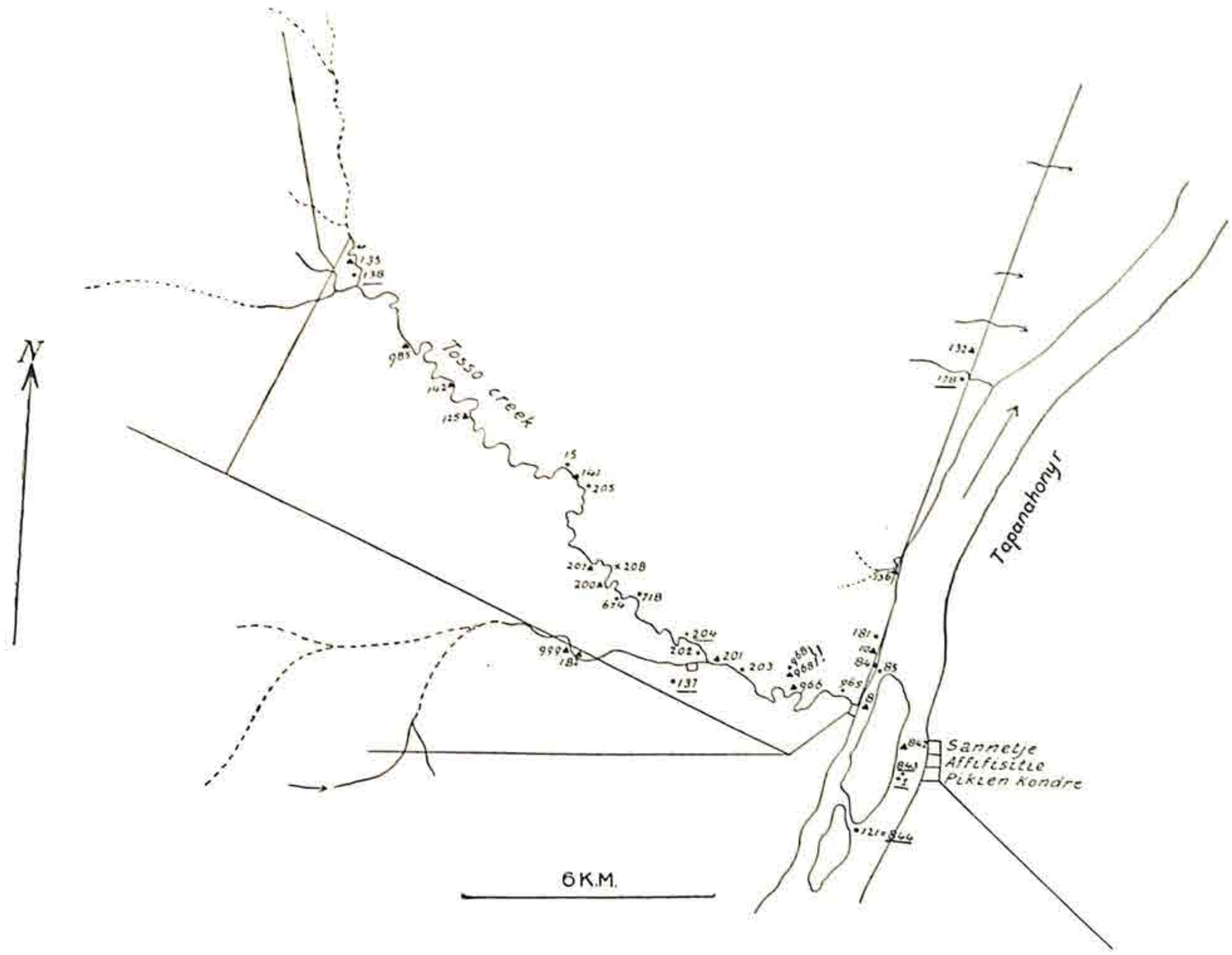


● 91 hornblende gneisses.
● 90 hornblende gneisses, epidote-bearing.
△ 88 garnet hornblende gneisses and garnet amphibolites.
■ 814 granitodiorites and related ortho-gneisses.
— prospecting trails of Government Mining Exploration.

Fig. 61.

absence of quartz, or by a very low percentage of it. They are now free from epidote (V. 178, 843, 844), now again contain epidote (V. 138, 204). Also one of the rocks of doubtful origin, with a very large amount of hornblende and for the rest only quartz, originates from here (V. 208, see p. 442). If we look at the distribution of the several rocks on the map, the hornblende gneisses and the plagioclase amphibolites appear to occur promiscuously, which again may serve as a proof of their geological connection.

A third important area is found in the De Goeje mountains. There amphibolites and hornblende gneisses form a hilly country North and North-East of



● 138 Hornblende gneisses partly epidote-bearing.
● 85 Plagioclase amphibolites partly epidote bearing.
× $\overline{208}$ Deviating amphibolites.
▲ 200 Granitodiorites.
— Prospecting trails of Government Mining Exploration.

Fig. 62.

the important gabbro-, and diorite massifs, which have been discussed on p. 262 to 265. Besides, we have numerous other rocks there; the geological relation between amphibolites and hornblende gneisses mutually as well as that in which they stand to many others metamorphic or nonmetamorphic rocks, is entirely unknown. In the area under discussion we find plagioclase amphibolites with very variable structure. Locally occur garnet hornblende gneisses (V. 665, 666) together with a plagioclase amphibolite (V. 667). We have several garnet-bearing gneisses and amphibolites from here (V. 45, 527). A pyroxene-bearing amphibolite (V. 58) was found here near a pyroxene-bearing gneiss (V. 40) and a hornblende gneiss (V. 43). This pyroxene amphibolite is the only one that gives an indication about the geological connection with other members of the group. As has been said, however, we are in the dark about the geology of most of the types here.

Some hill groups consist of amphibolites and hornblende gneisses namely

South of the Tosso creek, South of the Grutterink mountains, East of Affifisitie (on the Tapanahony) between the Wilhelmina- and Emma-rivers, near Langa tete (on the Lawa), and in the Gran creek area. Some of these localities inform us on the connection between the several types of rock. South of the Tosso creek we find epidote-bearing gneiss (V. 47) together with a gneiss in which all plagioclase has been replaced by epidote (V. 180).

South of the Grutterink mountains we find hornblende gneisses with basic plagioclase (V. 845, 848, 849) occurring together with a pyroxene epidote hornblende gneiss (V. 846), which points to a connection between these types. Near the Gran creek were collected a series of hornblende gneisses and amphibolites within a few hundred yards' distance, from which the connection between the two types clearly appears. Besides we know there: hornblende gneisses with acid plagioclase (oligoclase-andesine) and with a strongly varying percentage of epidote (V. 988, 978; the latter rock is a hornblende epidote gneiss), epidote bearing plagioclase amphibolites (V. 979, 987) and epidote amphibolites (V. 980, 981, 982, 986). Special attention should be paid here to the epidote amphibolites, here clearly connected with the other rocks.

It appears that amphibolites and hornblende gneisses are especially known to occur in the Eastern parts of the Colony, in the river-basins of the Lawa, Gonini, and Lower Tapanahony, in the upper course of the Gran creek, Sara creek and Marowyne creek, and, locally in the Upper Courantyne.

The most probable suggestion is that the amphibolites and hornblende gneisses, at least in so far as we know them in massifs, are older than the granito-diorites of the basal complex. An argument for this supposition is the occurrence of a vein of aplite in a epidote-bearing gneiss from the Tosso creek (V. 203), as has been stated on p. 440. The massifs occur together with granito-diorites which are mostly not highly metamorphic, in contradistinction to the total recrystallization of the basic rocks; this fact is a strong argument for the greater age of the latter.

It is very probable that the metamorphic basic rocks, geologically, have nothing to do with the epidiorites, which are in all probability derived from the later diabases and gabbros. We have discussed this question amply on p. 135. In connection with it, however, the amphibolites from the neighbourhood of the De Goeje mountains, call for special remarks. In this area metamorphic rocks are very frequent, and, as they alternate with para-schists and granito-diorites, the area seems to have a complicated structure. Many of the amphibolites occur in the vicinity of the gabbro- and diorite-massifs, which we have discussed on p. 263. One might suggest that the amphibolites are the metamorphic equivalent of these rocks. They might, for example, belong to metamorphic border-zones of these massifs; this relation has already been supposed by the leader of the Government Mining Exploration [1]). Petrographic examination has shown arguments for and against this supposition. As we have seen, some of the gabbros of the massifs have changed by the appearance of secondary hornblende into epidiorites. We refer to p. 259, and also to the chapter on allo-metamorphism (p. 323) for this phenomenon. It should be emphasized

[1]) E. Middelberg. **64.**

that these epidiorites do not differ essentially from some amphibolites from the De Goeje mountains which we have discussed on p. 435—436. We mean those amphibolites which show very variable structure, reminding us sometimes of the original structures of igneous rocks. They are quite massive in contradistinction to the many recrystallized amphibolites which mostly show some parallel texture. We may construct a transitional series between the (gabbro-) epidiorites and the moderately recrystallized amphibolites. This fact might suggest the same age for both groups. It should be emphasized strongly, however, that we do not know a clear transition-series from the epidiorites to the highly recrystallized, sub-equigranular plagioclase amphibolites, hornblende gneisses etc., which occur in the same area. This important fact suggests that there we have amphibolites possibly belonging to different geological systems. One group of amphibolites, namely, which has recrystallized moderately, passing by transitions into epidiorites which in their turn pass into gabbros, may contain rocks which belong to the same intrusion-period. And as we have supposed these gabbros to be closely related to the granitodiorites of the Gran-rio massif (see p. 262, these amphibolites may stand in the same relation to these granitodiorites. Another group, however, comprising highly metamorphic amphibolites and hornblende gneisses seems not to be geologically related to the former group, and for reasons easy to understand, is probably older than the latter. The amphibolites and gneisses of the massifs of the Grutterink mountains etc., do not at all show transitions to epidiorites.

About the geological relation between the amphibolites and para-gneisses in Surinam we know nothing. Did the basic massifs at one time intrude into part of the para-schists? Were both groups of metamorphic rocks metamorphosed by the same processes? Or do these ortho- and para-schists represent different phases in the development of the basal complex? These questions, and many others, must be left unanswered.

THE QUARTZ HORNBLENDE SCHISTS.

Some rocks, schistose or massive, containing the mineral combination hornblende and quartz, are called quartz hornblende schists here. Mineralogically they differ from the amphibolites and hornblende gneisses in that they lack plagioclase. They differ from the few rock termed "deviating amphibolites" (p. 442) in that with the latter hornblende is by far the most important component, and quartz of secondary importance. Here, however, hornblende is present as much, or only a little more, than quartz.

We do not know the original material and the geological behaviour, so that a brief discussion may suffice.

It may be that the types, richer in hornblende, are completely recrystallized, basic igneous rocks. They are closely allied to the amphibolites and hornblende gneisses. This applies to the fine-grained rocks from the Lely mountains (V. 889), from Tompi creek basin (a side creek of the Suriname river (V. 1644) and a rock from an unknown locality (V. 3613)). In the sample they are nearly massive or show parallel texture. The microscope reveals a foliated to ragged, green hornblende, between which a quartz mosaic is present. Epidote varies locally in quantity. Some titanite and ore appear as accessoria.

A few other rocks might be contact metamorphic, as they comprise needle-like hornblende, for the major part with disorderly orientation, while the texture of the previously discussed rocks may rather be conceived as an effect of stress metamorphism.

One of these rocks, collected by Martin near Kouroewatra, on the Lower Suriname river downstream of Mawasi creek, has already been described by Kloos [1]) (V. 1385). It is a compact, tough, greyish-green rock. On its rough planes of indistinct schistosity it shows a silky gloss caused by fine hornblende needlets. Under the microscope it appears to consist of very fine needle-shaped actinolite, showing a light-green to green, and bluish green pleochroism. This hornblende occurs partly accumulated in bundles lying parallel, partly as separate, very small individuals. The hornblende lies in a very fine grained quartz mosaic. This mosaic is in some places coarser, and then it appears that it is composed exclusively of quartz, and not of non-twinned plagioclase. Moreover epidote, calcite, and ore occur as accessoria. The epidote was not derived from augite, as Kloos records, the latter mineral is completely absent. The epidote partly shows the characteristics of clinozoisite. Now calcite is present between the densely amassed hornblende needlets, now again it forms with quartz colourless cords. Kloos rightly points out that this rock should not be conceived as being uralitized and directly derived from the diabases, which occur in unaltered condition in the vicinity (l.c. p. 186).

Another rock, apparently of the same exposure, or very near it, has been

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[1]) J. H. Kloos. **28.** p. 185.

collected by Voltz (Vtz. 163, from Victoria). It is almost massive, but for the rest it looks like the former rock. Microscopically we see the same main components, actinolite and quartz.

In conclusion there is still a massive rock from the Wilhelmina mountains (Y. 220). It is very fine-grained, and has a green colour. Under the microscope it presents indistinctly defined, somewhat coarser actinolitic hornblende, in a ground mass of very fine quartz mosaic. These hornblende individuals, not to be compared with phenocrysts, enclose an abundance of ore-dust. Relatively coarse ore-grains are frequent.

THE HORNBLENDITES, HORNBLENDE SCHISTS AND GEDRITITES.

This group comprises metamorphic, basic rocks, composed almost entirely of hornblende. The hornblende may to some extent be replaced by chlorite. Rocks, containing besides a large amount of hornblende also quartz or feldspar of some significance and exhibiting a parallel texture have repeatedly been termed hornblende schists in the Surinam literature. Similar rocks however have been treated by us when discussing the amphibolites etc.

The rocks are massive, show some parallel texture or are clearly schistose. The latter type is termed hornblende schist, the first hornblendite. Of the gedritites we have only one specimen, viz. hornblende gedritite.

So we distinguish the groups:

a. Hornblendites and hornblende schists.

b. Hornblende gedritites.

The hornblendites and hornblende schists.

In the sample they are normal to fine-grained rocks, of a light green, green, or blue-green colour. Some are massive (V. 311, 977), others show some parallel texture (V. 198, 221, 806, 989). Others are evidently schistose, and split along plan parallel planes (V. 806; Y. 364).

Under the microscope their composition appears to be slightly complicate. Hornblende is main component. The hornblende may be of several types: pale greenish, green, and bluish green. Actinolite occurs as needleshaped or prismatic crystals, with the typical transverse fractures (V. 198, 221, 806, 989). These actinolite crystals are chiefly evenly-stretched or, at all events, lying in parallel planes. The ends of the needles or prisms may be frayed (V. 198). Similar rocks might be given the special name of actinolite schists.

In addition to this also a foliaceous green hornblende occurs, pale green in various tinges (V. 977). In other very fine-grained rocks again the fibrous hornblende forms a tangled aggregate, or we observe fan-shaped hornblende (V. 1757).

In the foregoing the main facts have been mentioned. Accessorily many more components may occur. In the first place chlorite, as spots among the hornblende (V. 221, 977). In one of these rocks there are also talc scales (V. 977). In case chlorite should be abundant, the rocks might rather be called *hornblende chlorite schists* (V. 198; Y. 364). Epidote grains are few and far between. Sometimes polarisation colours only indicate that in the hornblende tissue there must yet be concealed an epidote mineral (Y. 364). Ore grains may occur, sometimes with titanite rims (V. 1757). These rocks do not show traces of cataclasm.

Special mention should be made of a hornblendite of anomalous composition (V. 311). The sample is highly fine-grained, massive, of a bluish black colour. In the thin sections we see that the rock is chiefly composed of actinolite, confusedly arranged oblong crystals, in part also needle-shaped. The actinolite is of a pale-green colour. In this mass of hornblende a rather large amount of a rusty brown, little transparent iddingsite occurs. It has no crystal-shape but is cut up by the hornblende, so that around the larger fragments many small pieces may be distinguished, which appear to belong together as their equal optic orientation implies. The reddish brown mineral is biaxial, and shows a very large axial angle. The optical character is negative, with strong dispersion.

There is a rather great amount of grass-green spinel. This mineral is also cut by the actinolite. It is of smaller dimensions than the iddingsite.

A fourth component is some ore with a tendency to octahedral form (magnetite).

Hornblendites and hornblende schists we have from the Gran creek (V. 977, 989), from the Lawa (V. 806), from the De Goeje mountains (V. 311, 550), from between Gonini river and Assisi creek (V. 221), from the basin of the Tosso creek (V. 198), from the Suriname river above Koffikamp (Y. 364), from near the Saramacca river (Peito creek, V. 1757).

Hornblende gedritite:

This name may be given to a rock from Nooit Gedacht on the Suriname river. The material collected by Voltz (Vtz. 220, 234) has been described by Kloos as "Actinolithfels", and the amount of gedrite was overlooked [1]).

The almost massive very tough, black-greenish samples shows on the very rough fracture-planes numerous glittering spots, some of which can be identified with the lens as hornblende. Some of the samples have been discoloured through infiltration of limonite to red-brown. Microscopically the rocks appear to be composed of gedrite, actinolitic hornblende, and in a smaller measure also chlorite. The actinolite is pale green, prismatic, needle-shaped, or forms irregular pieces; the latter contain a large amount of ore. The gedrite, on the other hand, is colourless. It shows prisms, short and broad, oblong or needle-shaped (Pl. 48 fig. 4). Typical cross-fractures occur in this mineral, which reminds us of actinolite; our mineral, however, is distinguished from the latter by the straight extinction. The cleavage according to (110) is evident, as well in sections cut parallelly to the prism zone, as in the hexagonal section normal to it. The longest gedrite needles attain in the thin section a length of 2 mm. The mineral shows a very large optic axial angle, and an optical positive character if it is determinable. Foliaceous chlorite is in the minority. Ore-grains occur here and there. The hornblende, the gedrite and the chlorite from a confused mass. In one place gedrite predominates, then again we observe spots where the actinolitic hornblende prevails, or both appear together with chlorite.

A FEW REMARKS ABOUT THE GEOLOGY OF THE HORNBLENDITES AND THE HORNBLENDE SCHISTS.

It is evident that the rocks of this group may be the chemical equivalent of highly basic igneous rocks even though analyses are not at our disposal. Hardly anything is known about the geology. The only datum worth mentioning we dispose of, bears on a hornblende chlorite schist exposed at the upper end of

[1]) J. H. Kloos. **28.** p. 186.

the island near Koffikamp, in the Suriname river. With great drought one can discern a complex of steeply dipping schists that split plan-parallelly. On one side one sees the contact with the quartz mica diorites of the surrounding. The contact is sharp. At the contact the schists seem not to have been affected. The diorites intrude in some places into the schists. One sees a lenticular, weathered group of diorite which cuts through the schists parallelly to the schistosity. Here the schists are evidently older than the diorites. It is not known whether the metamorphism of the schists has been caused by the diorites.

ON THE OCCURRENCE OF CINNABAR.

Boulders of cinnabar were discovered at goldwashing in the creeks between Marowyne river and Tempati creek. West of Bonidoro in 1912. Here low. but steep ridges form the Northern outlier of the Nassau mountains and the watershed between the rivers mentioned; they are traversed by narrow valleys. So far as we can judge from the inadequate exposures the subsoil is formed by schists trending N. 10° W. in the western and N. 20°—30° W. in the eastern part of the region and dipping steeply. They are mica schists. occasionally very rich in quartz, phyllites and clay slates. Besides also quartz porphyries. porphyroids and epidiorites occur. The schists contain often cubes of pyrite. Tourmaline-containing quartz is frequently found in the gravel of the creeks.

The following data regarding the geology of the cinnabar have been collected by the engineer G. Duyfjes during his prospects in 1915. With his permission they are published here.

Of special interest is a light coloured, all but massive rock, which was mistaken for aplite macroscopically but which on microscopial examination appears to be a graywacke quartzite of the type described already (see p. 387). This rock occurs among the rocks of the schistformation.

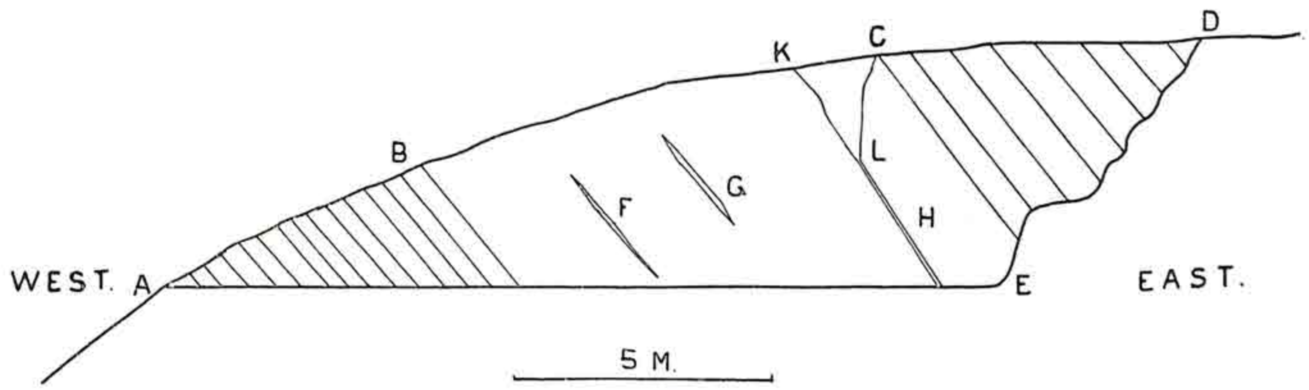

Fig. 63.

The prospects have shown that the cinnabar in situ is bound to the latter rock. The adjoined section (fig. 63) shows an excavation (A E D) in the declivity of one of the ridges. Between weathered sericitic schists (A B) and metamorphic basic schists (C D) the quartzites (B C) are inserted concordantly, all dipping steeply and trending N. 10° W. In the quartzites some lenses of quartz, and a quartz vein occur (F, G, H). The group K L C consists of red-brown, iron-rich, rather compact soil in which pieces of pure ore were found. As it extends downwards this mass becomes sphenoidal, and touches the quartzite, and a quartz-vein, 10 cm. thick (H). The situation led to the conclusion that we have to do here with an unremoved occurrence of ore. In other places the same profile appears, the ore ever seems to occur near the contact of the quartzites and the weathered schists. The quantity of ore is nowhere large, at most some tens of kgs. Towards the depth all the masses wedge-out; longitudinally the ore can be traced only over a short distance so that the ore-masses have no dyke-shape. They are rather irregular masses generally running parallel to the strike of the surrounding rocks. Impregnation of the adjoining rock with ore has nowhere been found. Most probably we have to do here with an exhalation of an igneous rock hidden in the depth.

THE DEVELOPMENT OF OUR GEOLOGICAL KNOWLEDGE OF SURINAM.

The geological survey of Suriname dates from the middle of the last century. Interest in Geology, Mining, Topography and the researches in the province of General Natural Science have directly or indirectly contributed to our knowledge. A systematic, geological survey of the whole Colony has never been put in hand; a Geological Service does not exist in Surinam. Some explorers have added to their own publications a conspectus of what was known at the time. We have no monographs in which all the accessible data are treated comprehensively. The knowledge to be gained from a large number of publications, which have come out here and there, is not easy of access for foreigners.

In the past century our knowledge principally grew by purely geological exploration; after 1900 Mining-work came to the fore in connection with the Gold-industry; the topographical survey of the southern part of the Colony then also indirectly increased our stock of knowledge; of late years investigations have been multifarious.

In our discussion we shall stick to this scheme. For the time up to 1900 we shall ascertain what the geologists did individually; for the period after 1900 we shall do the same in connection with the Gold-industry. The work of a more recent date will be described according to the nature of the subjects.

Voltz was the first to conduct a serious geological study of Surinam. He was a member of a committee that tried in 1853 and the following years to ascertain whether the country was fit for German colonization. Voltz restricted his exploration to the lowland. He only examined the exposures along the principal rivers upstream to a little way beyond the first rapids. Still, Voltz has established a great many fundamental things. He has established the structure and the age of the coastal plain with the sand- and shell reefs, so far as an opinion can be formed of them by observations on the surface. He rightly refutes the supposition of the explorer Robert Schomburgk [1]) that coal is found in the basin of the Courantyne river. He states that the basal complex, exposed in the lower rivers, is chiefly composed of granites, diorites, and gneisses, and, in a smaller measure, of schists. He supposes that the granitodiorites have broken through the schists. He states that diabase dykes cut the preceding rocks and holds that diabase has extended over them as extrusive sheets. The schists he found were mica schists, in part garnet-bearing and also clay slates. According to him the distribution of "Grünsteine" is significant. His conception of greenstone, however, refers to the outward habitus afterwards it appeared to include very different rocks. Voltz's research was performed under great difficulties. After his work had

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[1]) Vide R. H. Schomburgk. **2.** p. 168 and 170.

repeatedly been interrupted by tropical fevers he died at Paramaribo (1855). Voltz's work is characterized by purposeful and accurate research; he takes an interest in economical possibilities as well as in the advancement of science. In the scarcely metamorphic schists he has looked for fossils. It was not allotted to Voltz to publish his results in a comprehensive report. Some of his letters and reports have been preserved. [1])

Voltz's endeavours seem to have awaked some interest in Holland for the geology of Surinam. Anyhow, in 1855 a prize question was set about a geological description and map. [2]) But no answer came in.

After Voltz many years passed before there came a revival of significant research. The contents of some unimportant articles by Van Sijpesteijn [3]), Sloet tot Oldhuis [4]) seem for a large part to have been borrowed from Voltz.

Brown and Sawkins's [5]) publication is of greater importance. It is remarkable how seldom this publication has been recorded in the Surinam literature. Most likely this is because it gives data chiefly concerning on areas outside Surinam. Brown's report, however, of the Courantyne concerns the boundary river, which falls just within Dutch territory. Brown is the first geologist who has penetrated into the real interior, and has extended his researches as far as the southern boundary of the Colony. It was on his Courantyne journey that Brown discovered the New river. He states that along the Western boundary of Surinam in the North especially granites are exposed, whereas in the South gneisses prevail (in the basin of the Upper Courantyne or Curuni). Brown states that locally the granites pass into gneisses. Here we have the first indication of the connection between the wo rock-groups. Brown reports numerous observations regarding the dip and strike of the more or less distinctly schistose rocks. Schists, according to Brown, must have a large distribution along the Upper Courantyne (Curuni). Our petrographical examination tells us, however, that we have to do here especially with ortho-gneisses showing distinct parallel texture. Quartz porphyries appear to occur locally on the Courantyne. Observations regarding the relation between their age and that of the granites are not recorded. At the mouth of the Kabalebo river and a little way upstream the Courantyne sandstones have been detected. According to Brown they belong to the Roraima formation, which has a large distribution in British Guiana. On the Courantyne diabases cut granites and gneisses, which had already been established by Voltz for other parts of the Colony. Brown had never worked microscopically. To sum up we can say that Brown's research has largely contributed to our knowledge of the extreme West of our Colony.

While English researchers furnished notable information about the Western

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[1]) Vide F. Sandberger. **3.** W. C. H. Staring (Translation of the preceding article), and **4**, and **8**.
For Voltz's preserved notes see K. Martin. **26**. p. 173—188. A large collection of rocksamples of Voltz's is present at Leyden. The findspots of most of the material are, however, unknown. Some of the rocks are described in this publication.

[2]) Tijdschrift West-Indië. **5**. I. 1855. p. 79.

[3]) C. A. van Sijpesteijn. **6**.

[4]) B. W. A. E. Sloet tot Oldhuis. **7**.

[5]) Ch. B. Brown and J. G. Sawkins. **10**.

part, data were also collected concerning the Eastern side of the Colony. Let it be observed parenthetically that the Franco-Dutch border-committee [1]) (1861) collected rocks along the Marowyne and the Lawa rivers: so far as I am aware nothing has ever been published about them. Vélain, a Frenchman, however, has recorded the geological notes of the explorer Crevaux, together with a petrographical description of his material. [2]) For the present we are interested only in the data borrowed from Crevaux's journey along the Marowyne across the divide (Tumuchumac mountains) to the Yari (Amazon basin) (Vélain 1879). Vélain is the first author who published microscopical-petrographic data about Surinam rocks. Vélain goes too far, however, in his interpretation of Crevaux's partial (and no doubt injudicious) observations; besides Vélain's petrographical views are obsolete. According to Vélain-Crevaux the rocks found along the Marowyne are mainly gneisses and mica-schists, the former prevailing; in the upper course (viz. the Lawa and the Litanie) "quartzites" and "schistes terreux à minérai de fer" occur. The last two groups of rocks are supposed to be of later date than the first two and all are supposed to be traversed by rocks of a granitic and dioritic mineral combination.

Indeed, on the Lower Marowyne especially gneiss occurs, and Vélain rightly observed that this rock "se distinguerait mal d'un granite franc" (1879, l.c. p. 390). The short descriptions he gives of the schists, show that he has not touched any material of the extensive graywacke-formation. Regarding the schists from the upper course of the Marowyne and the Lawa, mentioned by Vélain, it may be stated that we know a large number of schistose rocks of widely different composition in that region, but also igneous rocks. Granites are supposed to occur only on the lower Marowyne. They cut through the gneisses (1879, l.c. p. 392). "Granulites" [3]) form the watershed between this river and the Amazon basin, but also break through the schists (ib. p. 393). Again and again the researcher tries with regard to the chief minerals of the igneous rocks to distinguish between two groups after the sequence of crystallization. In these groups the same main components may return, without the presence of porphyritic structure. This view is held in imitation of Michel Lévy. It is absolutely obsolete now.

Vélain's information concerning contact-metamorphism from these igneous rocks caused to the gneisses is erroneous. His petrographical arguments in which the "quartz de corrosion" is of prime importance, are based on a misinterpretation of the structures. In a summary of the results drawn up after Crevaux's last expedition (Vélain 1885), the author assumes for Surinam and its environs mutual superposition of a number of granitic and dioritic

[1]) A. Kappler who joined the border-expedition reports in his "Holländisch Guiana, Erlebnisse und Erfahrungen während eines 43 jährigen Aufenthalts in der Kolonie Surinam." Stuttgart, 1881, p. 383: „wohl wurden von Felsen und Geröllen Stücken abgeschlagen und mitgenommen, aber Untersuchungen im inneren Lande oder Nachgrabungen unterblieben, theils aus Mangel an Zeit, theils weil Niemand geologische Kenntnisse besasz."

[2]) M. Ch. Vélain, **13** and **22**.

[3]) Vélain adopts the nomenclature of Michel Lévy and Fouqué, in which "Granites" stands for biotite granites, and "Granulites" for bi-mica granites.

rocks, the latest members being the "Granulites". [1]) A chiastolite-bearing schist [2]) is reasonably adduced as evidence for the respective ages of granites and schists. We should take note of Vélain's elaborate description of a "Greisen" which contains wolframite and veinlets of tinstone. [3]) Up to the present this rock is unique for Surinam.

From the foregoing it will be clear that the geological map accompanying Vélain's last publication (1885) can be of little value so far as the Marowyne and the adjoining Western part up to the Saramacca are concerned.

Two articles on the geology of Surinam that appeared at the same time we shall pass by in silence. [4])

In 1884—1885 Professor Martin of Leyden made a journey to the Dutch West-Indies. During several weeks he resided in Surinam. His geological work in Surinam deserves to be discussed at length. [5]) His merits are twofold. First we have his field-observations; secondly Martin has given an impetus to important research performed by specialists.

Martin's field-work was restricted to a survey of the Suriname river as far as the village of Toledo (now deserted; Toledo was situated abt. 40 km. beyond the place where now the Colonial railway crosses the Suriname river). He also made excursions in the lowland. He describes a schist-formation from the Suriname river that appears to form a complex of intensely compressed folds. Towards the South the schists make room for an extensive area of granitodiorites. Various complications in this igneous mass are discussed. The schist-formation is considered to be Archeic and older than the granitodiorites. He is of opinion that the granitodiorites not only traversed the schists, but also extended over them. The intrusive diabases traverse the older formation, as dykes and cupolas, and also extruded over them as sheets.

Martin has found few indications of formations of later date than the basal complex, and older than the latest deposits. He deems it possible that Cretaceous age must be assigned to a coral-bearing boulder collected by himself, likewise to clay slates found by Voltz on the Marowyne (in connection with the occurrence of clay slates of the same age in Venezuela), and to the sandstone occurring in the West of the Colony. The latest deposits he examined especially along the Suriname river. He gives a vivid picture of the formation of simple terraces and of the building up of the islands and sandbanks. The interaction of the dry and the rainy season as well as the tidal waves on the lower river, have a great influence on this process. Martin discussed the meanders that have been cut off. The savannah-sands he ascribes to granites. He published important data concerning the sand- and shell reefs. According to Martin the peculiar bends of many Surinam estuaries from East to West are bound up with the formation of these reefs. He presumes that

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[1]) Cf. Vélain. **22.** 1885: granulite later than granite (p. 465—466), granulite later than hornblende granite (ib. p. 468—469), granulite later than gneiss (do. p. 483), granite later than granite-gneiss (ib. p. 479), granite later than hornblende granites (ib. p. 467) etc.

[2]) Vide Vélain's descriptions of a chiastolite-bearing schist from the Awara fall. **13.** 1879. p. 391 and **22.** 1885. p. 492.

[3]) l.c. **12.** 1879. p. 393.

[4]) G. P. H. Zimmermann. **11**, and Prince Roland Bonaparte. **19.**

[5]) K. Martin. **26.**

the root-cause of the two phenomena is to be found in the equatorial stream. In addition to his personal observations Martin gives a survey of what is known about other parts of Surinam. While engaged on his work he came across Voltz's letters of which he published a summary. [1]) Martin was the first who ventured to draw a geognostic map of Surinam (Scale: 1 : 1.600.000). It appeared in the year 1888. [2]) Two categories of signature are marked on the map, the first is the result of observations over great distances, the second signature gives constructions resulting from sporadic observations. Martin draws conclusions from the connection between the morphology of the riverbed and the nature of the rock, as observed by him at the Suriname river. Where the bed is formed by granites it is very broad, with a number of islands of considerable size. A sharp contrast is formed by the deep and narrow beds, free from islands, that have cut their way into the schists. On this ground Martin has drawn conclusions from the topographical maps for areas not explored by geologists. He concludes that the interior of the Colony is occupied by a territory of granite. To the North of it there is a diabase and schist-zone, which in turn makes room for the latest deposits in the lower country. This diabase-schist zone traverses the Colony over its whole breadth, and is broadest at the Marowyne, slightly narrower at the Courantyne.

Although this map contains many correct data, the synthesis is less reliable owing to the supposed connection between the form of the riverbed and the distribution of granites and schists. Nevertheless Martin's conclusion has still remained valid that the subsoil of the interior of Surinam is chiefly composed of granites: "alles samengenomen, valt het niet te betwijfelen, dat het binnenste gedeelte van Hollandsch Guiana, waarin de bovenloopen der rivieren zich bevinden, in hoofdzaak door een granietterritorium wordt ingenomen, in welk territorium, evenwel, ook nog enkele andere gesteenten bekend zijn, die intusschen slechts over eene zeer geringe uitgestrektheid voor den dag komen." (**27**, p. 450).

There are some other short publications by Martin. [3])

Martin's petrographic collection has been studied by Kloos. [4]) The diabases appear to belong to different types. Kloos points out that some of them resemble the types occurring in the West-Indian Islands; others again are quartz diabases, like the Konga diabases described by Törnebohm. It appears that the schist-formation encompasses mica schists, quartzites, quartzite schists, chlorite schists and porphyroids.

The majority of the igneous rocks from the Upper Suriname river are classed as granites, while of some the gneiss-habitus is signalized. Kloos's work is significant because of its novel character, but there are more or less serious mistakes in it. Martin's granites from the Upper Suriname river (termed by Kloos "Granite aus dem Massiv des Innern" l.c. p. 174) are, strictly speaking, for the most part diorites. To some degree plagioclase has been mistaken for

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[1]) l.c. p. 178—188.
[2]) K. Martin. **27**.
[3]) K. Martin. **23**, **31** and **38**.
[4]) J. H. Kloos. **28**.

orthoclase.[1]) According to Kloos augite granites are widely distributed on the Suriname river. This mistake is due to an erroneous identification of the mineral combination.[2]) A large part of the material shows the structural characteristics of gneissic types and ortho-gneisses. Martin recorded the connection between the several types in his field observations. The petrographer, however, has neglected to emphasize the remarkable connection between granitic and gneissic rocks. A few typical components of some schists have not been identified (e.g. chloritoid in a quartzite, gedrite in a hornblende gedritite etc.).

At Martin's instance the well-known mollusca-specialist Schepman[3]) has identified the fossils of the shell reefs collected by Voltz and come to the conclusion that they are recent species.

Martin's visit to Surinam was succeeded by more than a decennium (up to 1900) of little importance. Van Panhuys[4]) has published some observations regarding the geology of the Lower Marowyne. Compared with Voltz's data they do not give many new insights. Raymond[5]) gives a note on limonite pseudomorphs to pyrite from Surinam. Van Cappelle gives some insignificant communications on the Surinam geology.[6]) In 1898 there appeared Levat's "Guide pratique pour la Recherche et l'Exploitation de l'or en Guyane française."[7]) In this book there is to be found a section along the Marowyne river (l.c. Pl. III fig. 4). Although this section is very schematical, some important matters are revealed: the large distribution of schists in this region and the dyke-shape of the diabases that cut the schists and the granites. Data on the Nickerie region, published by Van Cappelle in 1899 are of little interest.[8])

In the first decennium after 1900 the Gold-industry contributed largely to our knowledge. We shall trace the development of this industry and ascertain its influence upon geological and petrographical research.[9]) The first impulse to this industry was given by the Governor C. A. van Sijpesteijn (1873—1882). Considering that in French Guiana gold had long been known in an exploitable quantity, he sent an expedition to the Marowyne river in 1874. Indeed in the alluvia along the banks gold was found. This favourable result led many to apply for concessions along the Marowyne and the Suriname rivers. The next year (1875) the export of gold amounted to several thousands of pounds. Seeing that gold-digging was restricted to the neighbourhood of the riverbanks the Government caused trails to be opened towards the interior. This was carried out by the surveyor Loth.[10]) These trails, and others that were cut afterwards, contributed largely to our knowledge of the geomorphology of the interior.

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1) See p. 175 of my book.
2) do. p. 178.
3) M. M. Schepman. **25**.
4) L. C. van Panhuys. **30**.
5) R. W. Raymond. **36**.
6) H. van Cappelle. **37**.
7) M. E. D. Levat. **34**.
8) H. van Cappelle. **35**.
9) J. A. Polak. **69**. (1908) wrote an exhaustive history of the Surinam Gold-industry and all that is connected with it.
10) W. L. Loth. **12**, **15**, **16**, **17** and **29**.

New finds on the Suriname river, the Saramacca and the Upper Marowyne drove people into the primeval forest, in large masses. This led to a boom-period in the years 1877—1882. In 1880 it had reached its climax. Then came a relapse, which was succeeded again by a great revival after 1883, consequent on discoveries at the Upper Sara creek. This tract together with that of the Mindrineti creek has for years produced a large part of the Surinam gold.

In 1885 Frenchmen discovered new goldfields on the Dutch bank of the Upper Lawa. The fields lay on Dutch territory (according to the decision of the Franco-Dutch border delimitation-committee in 1861): in spite of this the Government of Cayenne connived at thieving trespassers. The difficulties finally came to an end after the arbitration of Czar Alexander III (May 1891). Especially in the years 1893—1901 this field yielded a large produce (apart from a large quantity of gold clandestinely dug before). In those years the progress of the Gold-industry came to a standstill, the principal fields having been discovered. It is remarkable that no gold worth mentioning has been found in the West of the Colony, inspite of laborious researches at the Coppename, the Courantyne and the Kabalebo rivers in 1879—1880.

In the latter part of the last century machinery was introduced at the placers. The results were negative. This failure was especially due to the very irregular distribution of alluvial gold in the soil. This led to a considerable reorganization of the industry. Subtenants partially took the place of the large industries. [1]) After a decrease of the gold-production in the first years after 1900 it increased again under this system, and reached its maximum in the years 1905—1910 (1000—1200 Kgs. per year). Decrease followed, especially after 1920. In these days Surinam is no longer reckoned among the prominent gold-producing countries.

Towards the end of last century petitions were addressed to the Government from different quarters for a systematic investigation by Mining experts. The petitioners pointed to the deficient geological knowledge, and maintained that a systematic investigation would open up new goldfields. They also set forth that traces of other minerals furnished support to their belief that Surinam would have a future as a Mining country, if the interior were opened and explored. There they surely underestimated the thoroughness with which the population had searched the interior. Not only the fields that yielded exploitable gold, but also the other accessible tracts had been searched again and again, but the results had not been recorded. Later investigations have verified this. As for other minerals the petitioners might have remembered that the wealth of gold had drawn many foreign Mining-engineers, prospectors and adventurers to the interior, whose attention would no doubt have been attracted by other minerals, had they been present there. Before the matter had been taken up by the Government the "N.V. Maatschappij Suriname" obtained the right to explore the tract between the Suriname and the Marowyne rivers. At the same time the company got the right, to lay down and exploit a railway

[1]) Cf. E. Middelberg. **59.**

from Paramaribo to the Lawa basin, and to reclaim a territory of 1.250.000 acres in the region examined (1897). The Limited Company set about it vigorously. As early as 1898 the measurements for the railroad began. After some alternations the present track for the railway was chosen.

In 1903 the Government took over the rights of the Limited Company on conditions which were very favourable to the latter. It goes without saying that people began to doubt the utility of the railway that was now being laid down by the Government. The limited company had shown that, from a Mining point of view at least, no great hopes could be entertained of the field along the railway. The promises of the Lawa basin, however, seemed to be better. This territory had not been explored by the Mij. Suriname Ltd. Its reputation as a gold-country increased during the boundary-quarrel with French Guiana. In fact the local abundance of gold had been demonstrated, but it had been disregarded that after the discovery of gold, the greater part of the field had been examined with a negative result by the gold diggers.

The exploration of the Lawa basin was taken up by the Government. After Professor van Loon [1]) had projected a plan for this exploration (1904), and after the engineer Von Faber had reconnoitred the banks of the Gonini river, as a member of a topographical expedition (1903), the work begun. It started in the Grutterink mountains. Under the leadership of Middelberg the work was continued in the basin of the Njam creek and the upper course of the Assisi creek (Drie tabbetjes creek), in the De Goeje mountains and southward along the Assisi creek. The northern spurs of the Oranje mountains were also examined. Prospect-lines united the Lawa with the Tapanahony. Also on the North the tract was entered at different points (1904—1906). As early as in 1905 it was clear that the slight amount of gold found in some creeks did not justify the extension of the railway to the Lawa-basin.

Taking the possibility of giving the railway another terminus into account, the research-work was transferred to the left bank of the Tapanahony (Tosso creek-basin), and to the south-eastern part of the Lely mountains (beginning 1907). Then the Gran creek basin was explored. In all these districts the quantity of gold proved to be slight; only in the Gran creek basin exploitable territories were found and afterwards given in concession.

Consequently the Colonial railway was not extended so far as was intended originally. It was opened in 1912.

The development of the Gold-industry brought on the following increase of our geological knowledge. [2])

The engineers of the "N.V. Maatschappij Suriname" worked almost exclusively between the Suriname river and the Marowyne. The geological results have been recorded in Du Bois's "Skizzen aus Surinam". [3]) New

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[1]) C. J. van Loon. **51.**

[2]) In this review of geological literature we left out of consideration the numerous articles in periodicals etc. published about the Surinam Gold-industry. The articles especially refer to Mining; the geological data being unessential. It follows that these articles are not taken up in the list of literature at the end.

[3]) G. C. Du Bois. **40.**

were the surveys along the Marowyne river, and along the Sara creek, Marowyne creek and Lawa and in some fields between the principal rivers. The hills in these areas appear to be built up by diabases and granitodiorites but also by schists. The graywacke-formation of the Marowyne is very remarkable. Du Bois has rightly called attention to its sedimentary origin. The significance of his research has still been enhanced by the microscopical investigation of his collections (at Freiberg). He has pointed out the gneiss-characteristics of the granitic rocks at the Lower Marowyne in contradistinction to those of the other tracts. Besides diabases and uralitized diabases he also found related tuffs (Schalsteine). Among the schists it is especially the kyanite quartzites, the ottrelite- and the tourmaline schists that are worth mentioning. Du Bois considered them as contact-metamorphic rocks. He says that the basal complex consists of crystalline schists which are intruded by large granite massifs (Du Bois distinguishes three of them) 1° the massif of the Lower Suriname river and the Marowyne; 2° that on the Upper Suriname river with the Saramacca, Sara creek and Marowyne creek; and 3° that on the Tapanahony, l.c. p. 10). The diabases and diorites are considered as later intrusions. Later formations are of very little importance. Du Bois draws attention to the steep dip of the crystalline schists. Of great importance are his investigations of the Surinam laterites (1903).[1]) We shall revert to them.

Now let us consider the geological results of the Governmental Mining-exploration. Middelberg has worked them out and has embodied them in two reports[2]) (1907—1908). We shall discuss them together and give his opinion about the geology of Surinam and the connection between the occurrence of gold and the geology.

Middelberg (1907) points out that the southern part of the Colony is chiefly composed of granites. This applies to the part South of a line that from East to West cuts the Lawa near the Oelemari creek, the Tapanahony river below the Jai creek, the Suriname river in the part that flows East—West below the island of Kordonsanti, the Saramacca river below Pakka Pakka and the Coppename river below the Raleigh fall. In this area the granites also build up the mountains.

To the North-East and the North there lies an extensive tract, where crystalline schists, diabases, diorites and granites occur alternately, without any regularity. The tract dips towards the North under the latest deposits. It has about the shape of a triangle, the sides of which are formed by the Marowyne from Albina up to and including the upper course of the Lawa, by the limit of the latest deposits between Albina and the Coppename near the Raleigh fall, and by the limit of the granite tract in the South.[3]) About the same shape of the area is given by Middelberg in his publication of 1908, the triangle being recorded by him to extend as far as the Courantyne.

According to Middelberg's writings there is a remarkable connection between the peculiar course of the rivers and the triangle of mixed composition

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[1]) G. C. Du Bois. **46**.
[2]) E. Middelberg. **64** and **66**.
[3]) This assumption was criticized by Beekman. **65**.

just mentioned. Middelberg points out that the Coppename, Saramacca, Suriname and Tapanahony rivers change their direction over some distance from S.S.West—N.N.East, to West—East, and then again resume their original direction.

As this change of direction is said by Middelberg to coincide with the limit of the granites, and the triangle of different composition, the phenomenon might obviously be ascribed to a difference in resistance of the rocks at the limit of the triangle. We cannot agree with this opinion, however. [1]) In the triangle above-mentioned the granites and the gneisses are the subsoil of level or undulating country, differing from the southern part of the Colony, where the granites build up the mountains. From this Middelberg infers that the granites and the gneisses occurring in level areas are older than the granites in the South. The later granites, we are told, force their way through the older granites and gneisses. This assertion is not based on observations of contacts and since the difference in geomorphology may as well result from selective erosion, we are not of Middelberg's opinion.

Diabases and less important porphyries and porphyroids may also build up the hills in the triangle.

Middelberg thinks that the crystalline schists are metamorphic igneous rocks, i.e. ortho-schists, whose metamorphism he attributes to contact-metamorphism. He thinks he can show a connection between the appearance of metamorphic schists and later basic igneous rocks: "de samenhang tusschen vele kristallijne schisten, welker sedimentaire oorsprong vroeger als vaststaand werd aangenomen met gesteenten van eruptieven oorsprong is in vele gevallen geconstateerd en op dit gebied is in Suriname een uiterst belangrijk veld van studie." This statement is substantiated by the alleged fact that eruptiva, frequently diabases, are invariably met with in the vicinity of the crystalline schists. Harrison's view, which advocates the ortho-nature of the schists in British Guiana has largely influenced Middelberg's opinion. If we only consider the schists which were collected by the Government Mining-exploration, ortho-schists indeed appear to predominate by far. Middelberg's opinion, however, may not be generalized for the schists of all Surinam. On the contrary our research has shown that para-schists are more frequent than ortho-schists. There is no reason whatever to assume that the later intrusiva should have caused metamorphism of any importance to igneous rocks. Such metamorphism, brought about by diabases would be quite a novel phenomenon. Microscopical examination shows that contact metamorphism seldom comes into play, and that many of the schists are of sedimentary origin.

Middelberg attached great value to repeated intrusions for the metamorphism of his schists, but he adduced no evidence of this repeated activity.

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1) It is known that where the Suriname river bends, and further downstream, we are in an area of granitodiorites exclusively, so that there cannot be a pronounced connection between a varying composition of the subsoil and a change of the course of the river. The same is applicable to the Saramacca; in the neighbourhood of the place where the river bends (near the Jan Basi Gado mountain) we only know granites. Again almost only granitodiorites have been collected along the Coppename river, above the Raleigh falls and their neighbourhood. The slight exposure in the Courantyne river, at the spot indicated, points to the same again.

About the connection between the gold and the geological nature of the subsoil we want to record the following:

Middelberg rightly points out that gold is not met with in territories of a predominantly granitic composition, it being chiefly confined to the triangle of mixed composition. According to Middelberg it is an established fact that the later intrusions of rocks belonging chiefly to the group of the diabases, are intimately bound up with the occurrence of gold. He adverts to what had been brought forward in favour of this conception by Levat (French Guiana), Martin, Du Bois, Harrison (Br. Guiana) and Morisse (Venezuela). He imagines that contact zones between diabases and the older schists, which have been metamorphosed by these later diabase intrusions, are pre-eminently liable to weathering. Consequently here the conditions for solution of incidental gold-content are most favourable. Secondary concentration may be expected in the vicinity of these contact-areas. In this connection it is not necessary to regard only the later diabases as the rocks from which the gold has been derived. Likewise he does not offer an opinion as to in how far there has been concentration at the contacts during the intrusions. Middelberg particularly emphasizes the favourable weathering conditions at the contacts and the concentration in the creek-beds in the vicinity. This conception is based on the following considerations:

The Mining exploration found that large intrusive masses of basic rocks are not accompanied by alluvial gold, as illustrated by the massif of the De Goeje mountains and the Lely mountains, and possibly also by massifs more in the North of the Colony. They are partly surrounded by epidiorites and hornblende schists. The latter are supposed to have been formed from older, partly weathered diabases when the large intrusions came into action. But even in large areas of these metamorphic rocks no gold occurs. Only near the contact of intrusive- and country rock gold occurs in the creek-beds. There is valid reason to surmise that all rocks, except perhaps the granites, contain some primary gold. Harrison has demonstrated this and also that the gold-content of the basic rocks is little more than that of the acid rocks perhaps with the exception of granites. Levat and Du Bois have only assayed basic rocks collected near alluvial gold, and found a gold-content of 0,2—2 grs. per 1000 kgs. There is strong reason to surmise, therefore, that (with the exception of granites) a primary gold-content occurs in rocks of various composition. Likewise in the metamorphic and later basic rocks. The weathering conditions are supposed by Middelberg to be most favourable at the contacts, so that the primary gold can most easily be removed there; when the conditions of concentration are favourable gold-bearing alluvia may be found in the vicinity. Middelberg assigns greater value to the chemical than to the mechanical transport.

Special significance is attracted to repeated intrusions within a small space. There the conditions for intense weathering whould become more favourable at every following intrusion, unless effusions took place so that the whole area is covered by their products and thus the effect of weathering becomes impossible for the future (Middelberg). These views may account for the fact that the amount of gold is always small in the neighbourhood of simple intrusions of small importance, which fact has been established by the Mining-exploration. Reference is here made to small, hill-shaped amphibolite massifs of an area of some acres in the Lawa basin. They are looked upon as solitary intrusions in the granite-region. The same holds good for later dykes which intruded into the granites and the gneisses and form hill-ridges (obviously diabase ridges are meant here).

In his conclusion Middelberg sets forth that vast areas of granitic composition must be avoided, when looking for gold, as well as large massifs of basic rocks and the spots where intrusions of small extent have taken place. One should give one's attention to hilly grounds of larger-extent and of complex structure. In this connection the high, continuous ridges, which originated from single intrusions of great intensity, should receive less consideration than the marginal fields generally characterized by low, rounded off hills.

The occurence of gold-bearing quartz is dealt with separately. We may pass it by.

The same geological and mining data Middelberg elucidated in a separate publication (1908) [1]).

The knowledge of the mode of distribution of the gold has simplified the operations of the Government Mining exploration. Level areas could be passed by and the first thing to do was to ascertain where the hill-groups were. Similarly the exploration of the tract between the Lawa and the Tapanahony could be brought to an end, while a considerable part of the tract was not explored in detail.

Duyfjes [2]) (1910) tried to find out the relation of gold to geology by petrographical study of the collections of the Mining-exploration. He gives a short review of what was supposed in this respect in Surinam and its surroundings. Then he treats the knowledge of the geology of some gold-bearing tracts (the tract between the N.W. slope of the Lely mountains and the Sara creek; the field of the Cie des mines d'or; about 4 fields in the De Goeje mountains and their environs; the Mindrinetie field and the field of the Saramacca Cy). He gives a short identification of the available rocks from these areas and concludes that the connection between the occurrence of gold and the geology in Surinam is still problematical.

In conclusion we can say that the Governmental Mining exploration has largely contributed to our knowledge of the quantitative distribution of the formations. It was the first systematic exploration of extensive fields. A collection was made of about 1000 numbers. This material was never studied except that examined by Duyfjes. It has furnished important information for the present research.

Meantime fresh contributions to our knowledge of the geology of Surinam came in from another quarter: in 1902 Bergt published a petrographical study [3]). His material consists of sixteen samples from the Coppename river below the

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[1]) E. Middelberg. **67**.
[2]) G. Duyfjes. **77**.
[3]) W. Bergt. **45**.

Raleigh-falls. and some 10 from the Nickerie river. He gives a detailed description of each of these samples. They appear to be granites. a diorite. a few gabbros. gneisses of granitic mineral combination. sillimanite gneisses. crystalline graywackes and contact-rocks.

The contact-rocks from the Coppename are of special interest. There are among them hornfelses. with or without cordierite. andalusite. sillimanite. and contact-metamorphic graywackes. The latter still clearly show the clastic nature of the original material. Clay slates. graywacke-schists. graywackes and clay slate-like phyllites are assumed to be the original material of these contact-rocks. while the granites are considered to have caused the metamorphism.

Bergt's view as to the age of these rocks is unique in the Surinam literature. The gneisses and the sillimanite gneisses are deemed Archeic. Part of the metamorphic sediments and the contact rocks are believed to be Paleozoic. and from this also follows the Paleozoic age of the rocks causing contact. viz. the granites. For the arguments advanced for Paleozoic age we had better quote Bergt's words:

1. Die (kontaktmetamorphen) Sedimentgesteine scheinen unmittelbar an die archäischen krystallinen Schiefer angelagert zu sein. also deren Hangendes zu bilden. und sie sind mit den benachbarten Gliedern der krystallinen Zone (Sillimannitgneiss No. 23) kontaktmetamorph verändert.

2. Die aus den Sedimentgesteinen hervorgegangenen Kontaktprodukte. die Hornfelse und krystallinen Grauwacken entsprechen vollständig den Kontaktgesteinen. die man in zahlreichen genau untersuchten Gebieten der Erde bisher nur aus paläozoischen (von Kambrium bis Kulm) und den unmittelbar benachbarten phyllitischen Schichten kennt.

3. Zahlreiche von Du Bois aufgeführte Gesteine wie phyllitische Thonschiefer. quartzitische Tonschiefer. Diabas in Verbindung mit Schalstein. epidotisirten Schiefern. Epidothornblendeschiefer und Epidotchloritschiefer (schalsteinähnlich). chloritreicher Amphibolit. und Amphibolit in der breiten Zone der krystallinen Grauwacken im Marowynetal seiner geologischen Karte von Surinam. lassen sich auch ohne weitere Beweise an besten als paläozoische Schichtenreihe auffassen. Sie bilden ein weiteres ausgezeichnetes Gegenstück zu zahlreichen europäischen versteinerungsleeren oder -armen paläozoischen Gebieten auf südamerikanischem Boden. in bezug auf den ein förmlicher „horror palaeozoici" zu bestehen scheint" (l.c.p. 109).

Bergt's conclusions concerning the respective ages of schists and granites are interesting. and can only corroborate Martin's and Du Bois's views. However. his arguments for the Paleozoic age of the schists no longer hold good. pre-Paleozoic schists of the same composition. having been discovered in many countries.

The gabbros appear to be hypersthene gabbros. We have discussed their wide distribution in the Nickerie basin in one of our chapters. Bergt has discussed at great length such gabbros from the Northern part of South-America. and from North-America. Finally Bergt speaks of the signs of strong pressure shown by the rocks of divergent composition.

The results obtained by Van Cappelle in the Nickerie basin are interesting. In 1900 the Nickerie river was examined up to the Blanche Marie falls. and a trail was cut out to the divide with the Coppename; this trail starts from the Fallawatra, a side creek of the Nickerie. After the Report of Van Cappelle's journey [1]) (1903) his geological experiences, together with Beekman's petro-

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[1]) H. van Cappelle. 47.

graphical descriptions where published in 1907.[1]). These descriptions also include some material from the Lower Courantyne and Kabalebo, collected by others. Igneous rocks appear to have the largest distribution in the Nickerie basin, especially granites, gabbros and diorites of diverse composition. Aplites, pegmatites, andesites and one boulder of syenite are less important.

By far the most important fact is the identification of a magma differentiation, which comprises gabbros and diorites, all characterized by the presence of hypersthene. From the petrographic relation and the distribution in the field, it is inferred that these rocks are differentiations of the same magma.

Of great interest are also the conjectures regarding the relation between the hypersthene bearing gabbros and diorites on the one hand, and the granites on the other hand. No direct transition was observed between the hypersthene-bearing rocks and the granites, but from their mutual intrusion it was inferred that the granites and the hypersthene-bearing series are of the same age, and also that the two are allied magmatically.

Among the metamorphic schists the sillimanite-, cordierite- and hypersthene-bearing gneisses are interesting. Most of the igneous rocks, and also the gneisses were subject to pressure-action, in such a measure that this phenomenon is perhaps intenser than anywhere in Surinam. Some gabbros have been transformed into "Flasergabbros" or pyroxene gneisses.

It is a pity that the discussions on the genesis of the rocks, especially of the schists, are so short. The difference between para-, and ortho-rocks has not sufficiently been taken into account. In consequence biotite gneisses of igneous origin are classed together with sedimentary schists under an Archeic formation, and are kept apart from the intrusive granites etc. Moreover in the petrographical descriptions the typical gneiss-characteristics, shown by many igneous rocks, are disregarded.

In 1911 Verloop gave a description of the Guyana Gold placer [2]); he also wrote an article on the Surinam Goldfields [3]). Both writings are based on his experiences on the placer mentioned. Besides elaborate technical data we find some informations there on the geology of Surinam. The geological speculation, however, is of little interest.

In 1914—1915 Duyfjes searched for the primary localities of the cinnabar in the vicinity of the Nassau mountains [4]). I have taken over in this writing some of the unpublished results of this research (see p. 455).

For the sake of completeness I shall record here that in 1908 there appeared a monograph on the geology of British Guiana by Harrison [5]). True, this monograph furnishes only little information about Surinam, but it is very valuable with regard to the comparison of the two countries. It is remarkable that Harrison ignores the geology the Courantyne river. The geology along that river has also been omitted on the geological map [6]) of Wilgress Anderson. However, geology is marked along the Courantyne on a later English map [7]). This

1) H. van Cappelle. **62.** and E. H. M. Beekman. **63.**
2) J. H. Verloop. **78.**
3) J. H. Verloop. **75.**
4) G. Duyfjes. **83** and **85.**
5) J. B. Harrison. **68.**
6) C. Wilgress Anderson. **61.**
7) F. Fowler. **82.**

map shows that since Brown new data have been collected along the river. Of late years a geological expedition has also gone up the river as far as the Wonotobo falls. I have not been able to look into the reports of these researches.

I feel urged to accentuate the fact that natural science research has been largely promoted in Surinam by geographical expeditions. Since the year 1900 the "Maatschappij ter bevordering van het Natuurkundig onderzoek der Nederlandsche Koloniën", the "Koninklijk Nederlandsch Aardrijkskundig Genootschap" and the "Vereeniging voor Suriname" have sent out 9 expeditions to map out the interior. All the important rivers have been mapped in this way and triangulation has taken place. The knowledge gained from these expeditions about the distribution of the mountains, is referred to on p. 28. The reports of these expeditions contain a number of data regarding the geomorphology, the habitus of the various formations, etc., which furnish many indications to the geologist, even though these data have been collected by non-geologists. Besides this, samples of rocks have been collected systematically. These collections supply very weighty indications concerning the frequency of the diverse rock-types in the Colony. Important conclusions may be derived from them, e.g. that the granitodiorites show the greatest frequency in Surinam, and that the mountains have been built up chiefly by them. A provisional identification of part of these collections is to be found in the Tijdschrift Koninklijk Nederlandsch Aardrijkskundig Genootschap [1]).

An excellent review of the results of the geological research in the present century up to the first decade inclusive was written by Van Cappelle in the "Encyclopaedie van Nederlandsch West-Indië" (1914—1917) [2]).

After 1910 very little deserving of notice has been published about the structure of the basal complex. We have compiled the opinions about some essential questions considering the basal complex and have added ours to them (see table 34). They will be seen without further remark to differ widely.

The only research of recent date regarding the basal complex is Essed's (1926) [3]).

He discusses the geology of the Coppename from the mouth towards the source as far as the Raleigh falls. Alas, we can only negative the results. Essed's mistake is the very poor identification of his petrographical material. Let it only be mentioned that a considerable number of his rocks do not show any relation whatever to his terminology. To this an exception is formed by the material from localities already referred to by Bergt (l.c.). This is borne out by the material sent up by Essed. It follows that Essed's geological interpretations and his geological sketch-map of the Coppename basin are of little value. We would especially point out the large distribution erroneously assigned to the diabases on this map, etc. Still, Essed's work har enlarged our knowledge by the fact that his material could be worked out in the present writing. At the same time it gave prominence to this region, important from a petrographical point of view, where further research will be necessary.

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1) G. A. F. Molengraaff. **44.** C. Moerman. **54.** A. Thie. **57.** H. N. Duyfjes. **58.** J. A. Grutterink. **73.**

2) H. van Cappelle. **84.**

3) E. Essed. **105.**

	Martin (1888).	Du Bois (1901).	Bergt (1902).	Van Cappelle – Beekman (1907).	Middelberg (1907—1908).	IJzerman (1931).
Geology and age of the intrusive diabases (and related) gabbros.	Dykes traversing the basal complex. Sheets covering the basal complex. Cretaceous age; the possibility of differences in age is emphasized.	Dykes and cupolas traversing the basal complex. Age?	—	—	Repeated intrusions of diabases and related rocks; dykes traversing the basal complex; sheets covering the basal complex. Age?	Diabases, partly in gabbro-facies; related epidiorites are frequent. Dykes traversing the basal complex; some laccolites. The possibility of differences in age is emphasized.
Geology and age of older gabbros and related rocks.	—	—	The first gabbros (pyroxene gneisses) from Surinam are described. Geology unknown.	A differentiation series of gabbros and diorites is found in the Nickerie basin.	—	Gabbros and related diorites are locally differentiations of the granitodiorites of the basal complex and contemporaneous with the latter.
Para- and ortho-schists; age.	All schists are Archeic	Para- and ortho-schists. Archeic.	Archeic para- and ortho-gneisses; Paleozoic para-schists.	Para- and ortho-schists. Archeic.	Ortho-schists only (their metamorphism is ascribed to repeated intrusions of later eruptive rocks chiefly diabases).	Para- and Ortho-schists. pre-Paleozoic.
Geology of the granitodiorites and schists.	Granitodiorites traverse schists and rest on them.	Granitodiorites traverse schists; signs of contact-metamorphism are found in the latter.	Granitodiorites have caused contact-metamorphism in the schists; granitodiorites partly of pre-Paleozoic age.	Granitodiorites are later than Archeic schists.	—	Granitodiorites are later than pre-Paleozoic schists; this relation has not been proved for all schists.
Primary- or secondary genesis of the ortho-gneiss characteristics.	Secondary.	Secondary.	Secondary.	Secondary.	—	Generally primary. Secondary in cataclastic gneisses and in hornblende gneisses which are the equivalents of basic igneous rocks.
Geology of granitodiorites and corresponding ortho-gneisses.	Transitions between both groups are found in the field.	Ortho-gneisses are considered to belong to extensive granite massifs.	Granitodiorites are later than the ortho-gneisses.	Granitodiorites are later than an Archeic-formation which in part consists of ortho-gneisses. Some cataclastic gneisses are derived from granitodiorites.	Granitodiorites and ortho-gneisses are traversed by later granites which build up the mountains.	Granitodiorites, ortho-gneisses and cataclastic ortho-gneisses are facies of the same igneous complex and show transitions.

TABLE 34.

The growth of our knowledge has recently been promoted by the study of the latest deposits, prompted through an interest in Mining, in Agriculture and also in Science. The discussion of a number of older researches in the same domain, especially regarding the laterites, will be added. As early as in 1903 Du Bois published [1]) a study on the Surinam laterites. He speaks of the genesis of laterites in general and of that of lateritic iron ores in particular, while he is the first to ascertain the presence of bauxites. Du Bois's data are of special value, as they were published at a time when our knowledge of laterites was very limited.

Surinam laterites have been also chemically investigated by Van Bemmelen [2]).

Our knowledge of the Surinam laterites was considerably furthered by the interest taken in the bauxite deposits. Du Bois already described bauxites but at the time they had no economical value. In 1915 extensive bauxite-deposits were discovered in Surinam. The exploitations was begun already during the great war, and was afterwards extended to a large industry, now the only Mining of any significance for the Colony.

The article by the engineer Douglas [3]) supplies important geological data. We are however still in expectation of on elaborate study on the genesis of the Surinam bauxites in connection with the original material. Data on the technics of the Bauxite-exploitation are found in the articles by Grutterink [4]), Oudschans-Denz [5]), and Ouwehand [6]). As to the lateritic iron-ores the article by Voit [7]) may be mentioned by the side of the preceding articles in which they are repeatedly discussed. From a technical point of view, however, this article is of little value, as I was informed by experts. Several researches were made regarding the chemical composition of Surinam soils. As early as in 1898 Harrison [8]) at the request of Surinam planters made investigations into Surinam soils suitable for cultivation (especially clays). These analyses were taken over by Van Cappelle (1901) [9]) in a discussion on the Surinam cultures. Also in the articles by Van Bemmelen, quoted before, do we find analyses of soils. Sack [10]) and Miss van Amstel [11]) give analyses of Surinam clays provided with agricultural elucidations. Sack [12]) has made researches regarding the river-water in the lower parts of the rivers, from which an opinion may be formed of the conveying-capacity of the rivers in connection with the succession of the seasons.

Some articles on the latest deposits by Van Cappelle (1919) [13]) we may

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1) G. C. Du Bois. **46**.
2) J. M. van Bemmelen. **48**, **52** and **74**.
3) E. A. Douglas. **96**.
4) J. A. Grutterink. **93**.
5) F. Oudschans Denz. **95**.
6) D. Ouwehand. **109**.
7) F. W. Voit. **101**.
8) J. B. Harrison. **33**.
9) H. van Cappelle. **39**.
10) J. Sack. **60**.
11) J. E. van Amstel. **98**.
12) J. Sack. **70**.
13) H. van Cappelle. **89**, **90** and **91**.

pass in silence, as they repeat what was recorded in his previous publications and in those by Martin. In 1920 Martin has discussed the possibility of young uplifts of the Surinam coastland [1]).

To the domain of the latest deposits belong also the researches for oil made these last few years. The occasion and the first results of these researches are to be found in De Munnick-Van Dijk's [2]) report (1928). Van Hettinga Tromp [3]) gives interesting speculations on the genesis of the indications of oil. The geological results of the first deep-boring in Surinam have been described by me.

The most recent contribution to the knowledge of the latest deposits are the reports of Dr. Jenny Weijerman (1929) [4]) in connection with the laying-on of water-works for the town of Paramaribo. The geological profiles, in as far as they were drawn, are by Mr. Weijerman himself. An identification of his boring-samples has been added by me; a study of the samples is published in the present writing. The borings in connection with the said water-works have considerably increased our knowledge of the latest deposits. The same also holds good for the deep-boring at Nickerie.

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1) K. Martin. **99**.
2) O. M. de Munnik and J. W. van Dijk. **110**.
3) H. van Hettinga Tromp. **111**.
4) J. W. Jenny Weijerman. **113**.

THE GEOLOGY OF SURINAM, AS A PART OF THE GUIANA HIGHLANDS, COMPARED WITH THAT OF THE NEIGHBOURING COUNTRIES.

The comparison between Surinam and the neighbouring countries will be chiefly based on the data mentioned in the literature. I have moreover been in a position to study some petrographical material from several countries.

The comparison concerns first the countries known as "the Guiana Highlands". Afterwards we shall discuss the relationship with other South American countries.

THE GUIANA HIGHLANDS.

The Guiana Highlands comprise besides Surinam, British Guiana, Venezuelan Guiana (South of the Orinoco), the Northern border of the Amazon basin, so far as the basal complex has been exposed (the Brazilian States Para and Amazonas), and French Guiana.

In these states we know the following formations arranged chronologically:

1. The crystalline, pre-Paleozoic basal complex.
2. A series of ferruginous quartzites, in the border-mountains of Venezuelan and British Guiana, the "Imataca series".
3. The Roraima formation.
4. Intrusive basic igneous rocks, which traverse the preceding formations.
5. The latest deposits.

For the Roraima formation and the Latest Deposits I refer to p. 85—89 and p. 60—62 of this book.

The basal complex.

We can say that the basal complex has the largest distribution in the Guiana Highlands. It is exposed in the rivers and the mountains of the Northern part of the Amazon basin and in French, Dutch, British and Venezuelan Guiana. In the last two countries it is superposed by the Roraima formation in extensive areas. On the South side it is bordered by the Paleozoic and also by the Tertiary sediments of the Amazon basin, in the West, North-West and North by the "llanos"-deposits in Venezuela, on the North-East by the latest deposits of the Orinoco-delta and those of the coastal plain of the countries along the Atlantic Ocean.

A. *British Guiana.*

The basal-complex in British Guiana is known best. Brown and Sawkins [1])

[1]) C. B. Brown. **10.**

have made a geological survey of the whole Colony. For many years Harrison has been doing geological and petrographical work. His results have been published in many reports, and in his excellent monograph. [2]) in which the former reports have been embodied. New results are found in two reports concerning the Diamond mining in British Guiana [3]). Conolly's report is of special importance, as it gives an interpretation of the structure of the basal complex, different from that of Harrison. Wilgress Anderson has published a geological map (1906) [4]); geological data have also been marked on a topographical map (1913) [5]).

The basal complex in British Guiana shows many points similar to that of Surinam, especially with regard to the igneous rocks, the granitodiorites and the ortho-gneisses. This is much less the case with regard to the crystalline schists. The interpretations of the basal complex given by Brown, Harrison, Conolly and myself differ considerably.

The following summary shows the points of similarity of the basement rocks in both countries.

In both countries we only know members of the calcalkali series.

Of the Surinam ortho-gneisses we find the following types in British Guiana:

Biotite gneisses. They are as in Surinam rich in microcline and "vermicular" microperthite (according to Harrison; apparently quartz plagioclase myrmekite is meant, which is of very frequent occurrence in Surinam). This gneiss type is very common in British Guiana.

Hornblende granite-gneiss. Just as in Surinam this gneiss is less common. Primary epidote, so characteristic of Surinam igneous rocks, occurs in these gneisses.

Epidote granite-gneiss. It strikes us that primary epidote occurs in such an amount that it typifies a special gneiss. As has been said above, the same epidote may in Surinam belong to the chief components.

Diorite-gneisses. These gneisses appear as bands in granitite-gneiss. They are fine-grained, dark rocks. Some of them contain potash feldspar. The types without potash feldspar, rich in hornblende, and in waterclear plagioclase, and poor in quartz, and with more or less distinct parallel texture, resemble the banded hornblende gneisses on the Suriname river. Harrison's microphoto (l.c. Plate II fig. II) presents a similar type to ours.

Of the normal igneous rocks we know in both countries:

Biotite granite. This granite is in part decidedly the petrographical equivalent of the Surinam granites. It is a relatively coarse grained rock, locally with large porphyritic crystals of potash feldspar, sometimes also of plagioclase. As a rule it contains microcline. The biotite is green, dark olive green, or brownish, and forms ragged-edged plates, as in Surinam.

Biotite hornblende granite (hornblende granitite). Like the preceding type, but it contains, moreover, green hornblende in greater or less abundance, principally present in aggregates with biotite, some granular epidote and not infrequently with crystals of titanite. Sometimes this granite also appears in porphyritic facies (described by Conolly), just as in Surinam.

Pink to red granite. This type is an acid variety of the preceding type, poor in dark minerals. This granite may be the equivalent of the types we found so abundantly in the Wilhelmina mountains in Surinam.

Granite. (bi-mica granite). This granite is again described as containing microcline. It may be the equivalent of our bi-mica granites.

Muscovite granite. This granite contains primary muscovite and very acid plagioclase (albite) and microcline. Among the different facies of the Gran-rio granite massif we have discussed this granite type.

Gabbros, norites and mica norites. These basic igneous rocks are described by Harrison. Although they might resemble some types of the basic igneous rocks of the De Goeje mountains and the Nickerie region of Surinam, the descriptions do not absolutely justify the conclusion that the rocks from both countries are petrographically equivalent.

Syenites are rare in both countries.

Quartz porphyries and allied rocks. Harrison describes a series of quartz porphyries with

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[2]) J. B. Harrison. **68.**

[3]) H. J. C. Conolly. **104,** and S. Bracewell. **108.**

[4]) C. Wilgress Anderson. **61.**

[5]) F. Fowler. 82.

various structure types, also known in Surinam, though the nomenclature adopted by us is different. The equivalent of our augite porphyrites have been discussed by Harrison together with the quartz porphyries and allied rocks.

Para-schists. It is remarkable, that the equivalents of the para-schists in Surinam are sparsely known in British Guiana. The intensely metamorphic schists, the sillimanite, cordierite, garnet, and staurolite-bearing schists are not recorded, except the occurrence here and there of garnet-holding forms, mentioned by Brown, and by Conolly (l.c. p. 28). Harrison found nowhere schists in which clastic components could be recognized. His publications give the impression that of the quartz, chlorite, sericite, chloritoid, calcite, and albite-schists of Surinam but few representatives are found in British Guiana. In this connection it is of interest that Conolly describes schists of clastic origin. He mentions fine-grained sandstones and shales, modified through dynamometamorphism and contactmetamorphism (the latter through intrusion of dolerites and gabbros). Although these rocks are almost certainly of sedimentary origin, they offer little or no evidence of original bedding planes (l.c. p. 44—46).

Of undoubted sedimentary origin are also the schists that contain waterworn pebbles of quartz (l.c. p. 30). These schists must be the petrographic equivalent of our conglomerate-schists and conglomerates of the crystalline graywacke formation. Conolly also records a schist series of partly massive, partly well-foliated schists, shales, slates, mudstones and tuffs, which form a part of the so-called "Volcanic series". According to him this series is partly of sedimentary, partly of pyroclastic origin, while also metamorphosed effusiva occur. The ortho-, and para-schists are according to him difficult to discriminate. Although he does not enter into a detailed description, yet it is clear that this series comprises many para-schists, that can be compared with the terrigenous and detritic schists in Surinam.

Beside the points of resemblance there are also some of difference.

The equivalent of the quartz mica-, and quartz mica hornblende diorite-gneisses so common in Surinam are almost entirely unknown in British Guiana. In this connection it should be observed, however, that very often in the rocks of British Guiana the occurrence of sericite in potash feldspar is mentioned (Harrison) while in the Surinam rocks sericitization is restricted to plagioclase and does not occur in the potash feldspar. The probability, therefore, is that in Br. Guiana indistinctly twinned and sericitized plagioclase has been mistaken for potash feldspar and that consequently a number of rocks have been named granites that are in reality quartz-rich diorites.

The remarkable intermediate series from acid rocks to basic gabbros and corresponding gneisses, as we know them locally in Surinam, are not encountered in the literature on British Guiana.

It is startling that besides microcline orthoclase is also often mentioned in the rocks of British Guiana, while microcline predominates far and away in Surinam.

Among the metamorphic schists formed from igneous rocks special mention is made for British Guiana of epidiorites, amphibolites and hornblende schists. But we miss the garnet and pyroxene-containing amphibolites and the hornblende gneisses, types known locally in Surinam.

When looking at the geological maps of British Guiana alluded to above, and at our Sketchmap (Map I), we shall see that the frequency and the distribution of the several rocks of the basal complex show points of difference in the two countries. The acid igneous rocks, especially granites are much more frequent in Surinam. The extensive areas of granite, such as the Granrio-massif, are not known in British Guiana. Harrison speaks only of granite areas of relatively small compass (l.c. p. 25). Likewise the granite areas of the Mazaruni basin discussed by Conolly are comparatively small. Ortho-gneisses have a much larger distribution in British Guiana than in Surinam. In this respect the Upper Courantyne basin in Surinam bears a resemblance to British Guiana. Metamorphosed basic rocks are more largely distributed in British Guiana than with us. They occupy vast areas and in Surinam they are known only locally. A remarkable difference is that the equivalent of the schist formation of Surinam is not marked on the maps of British Guiana. As, however, according to Conolly, it appears that many schist complexes, formerly classed as belonging to the base of the Roraima formation (Brown, Harrison) are unconformable with the Roraima formation and belong to the basal complex, we suspect the schists of the basal complex to have a larger distribution than is known now.

Now let us consider the different opinions regarding the geological connection of the components in the basal complex of British Guiana.

Brown assumes that granites are the oldest rocks. Subsequent to granites are gneisses and schists. He does not say anything about the origin of the different rocks, in connection with the views of his time. But he states that gneisses and granites are united by intermediate types. The quartz porphyries underly, according to Brown, the gneisses and therefore must be older than the latter; they occupy extensive areas over the surface of the granite.

Harrison thinks that the oldest parts of the basal complex are gneisses formed from igneous rocks through dynamometamorphism: they are mostly the equivalents of acid rocks, but in part also of basic rocks. The latter rocks, however, are relatively later than the acid gneisses. Later than these rocks are the quartz-porphyries and porphyrites of various composition; they have partly been metamorphosed to ortho-schists. According to Harrison para-schists are of little consequence or are lacking altogether. The granites are of later age than the gneisses, quartz porphyries and allied rocks and schists.

Conolly's scheme is different again. Like Harrison he assumes that the oldest members of the basal complex are gneisses formed from granitodiorites through dynamometamorphism. Granites have intruded into the gneisses and together they form the "gneiss-granite complex" (l.c. p. 24). The granites may have undergone dynamometamorphism (e.g. cataclasm). Locally the gneiss-granite complex appears in basic modification as diorites, syenites and gabbros and metamorphic rocks, epidiorites, amphibolites, etc. The "Volcanic series" is later than the granite-gneiss complex. The rocks of the Volcanic Series have resulted from a prolonged period of intrusion and extrusion of igneous material which was contemporaneously or subsequently transported and bedded with epiclastic material, and afterwards metamorphosed to a schist complex, in which it is difficult to discriminate ortho-, and para-rocks. Among the Volcanic Series we find basic members, epidiorites, amphibolites, and hornblende schists. Tectonically these schists have been affected: they form a system of intensely compressed folds. The area of the Volcanic Series has been intruded again by granites, so a distinction is made between older and later granites. It should be observed, however, that the complicated conceptions of Conolly are speculative and that in his report we miss essential observations of contact phenomena.

It is evident from the foregoing that the interpretation of the genesis of the basal complex in British Guiana deviates considerably from the scheme adopted by us for Surinam. Some facts, however, point to a similar structure in both regions. Brown's statement that the granites pass into gneisses, and the reverse, points to the geological connection and equal age. Similarly Conolly has tentatively included granite-gneisses with granites (namely with the latest granite intrusion in the Buck Canister area, l.c. p. 27). Harrison, however, seems to distinguish sharply between older gneisses and later granites. In his monograph there are a number of examples of granite- and diorite-dykes traversing gneisses. The question rises, however, whether this dyke-shape has been positively established. From Harrison's monograph it appears that he is perfectly convinced. This, then, would constitute a significant geological difference with Surinam, as we suppose that by far the greatest part of the Surinam ortho-gneisses are united by intermediate types with the granitodiorites, and, therefore, cannot differ much as to their age. Moreover, we have stated that by the side of gneisses formed from granitodiorites through cataclasm, there is an abundance of gneisses whose structure and texture are primary. In British Guiana, however, it is assumed that besides cataclastic ortho-gneisses there are only gneisses whose structure and texture result from recrystallization (Harrison, Conolly).

As we have seen, Harrison thinks that in British Guiana only ortho-gneisses occur, and Conolly has pointed to the sedimentary origin of some of the schists. In consequence of Conolly's observations Harrison has afterwards changed his opinion in favour of the para-schists (cf. Conolly l.c. p. 31). The tectonics of these para-schists are similar to those in Surinam.

B. *Venezuelan Guiana.*

Now let us look at the basal complex of Venezuelan Guiana, saying a few words at the same time about the contiguous part of the Province of Amazonas.

The following explorers have published geological data concerning these regions. Schomburgk gives a review of his expedition to Mt. Roraima along the rivers Uraricuera, Casiquiari, and Rio Negro (1841) [1]). Tate discusses a profile from the Orinoco to the Yuruari river (1869) [2]). Attwood has given a better description of the same profile (1879) [3]). Sievers discusses Venezuelan Guiana in his report of his second Venezuela excursion (1896) [4]). Passarge has made a geographical journey in Venezuelan Guiana (1903) [5]). Bendrat (1911) [6]) publishes geologic and petrographic notes on the region about Caicara (Orinoco). Starting from the Amazon basin Koch-Grünberg has made an expedition along the Rio Branco, Uraricuera and Ventuari rivers to the Orinoco basin (1917) [7]). Von Bauer has furnished data about the region S.W. of San Fernando de Atabapo in the South-West of Venezuela (1919) [8]). Duparc has written about the geology of the Mining district of El Callao (1922) [9]). Jahn has written a memoir on the geology of Venezuela (1921) [10]). An important publication on the geology of Venezuela has been written by Liddle (1927) [11]).

These authors are the most prominent contributors to our knowledge. Their petrographical information bears chiefly on the outward habitus of the rocks. They give hardly any results of microscopical examination. Attwood describes gabbro and diabase; Bonney a few other rocks, collected by Attwood (l.c.). Bergt has studied but not described the rocks collected by Sievers. Sievers (l.c.) incidentally alludes to results of Bergt's determinations. Bergt himself refers to some of his determinations when he compares rocks from Surinam and Venezuela [12]). Bendrat (l.c.) gives descriptions of a few types of rocks. Koch-Grünberg's rocks have been determined by Deecke (Koch-Grünberg l.c. p. 36). With Prof. Deecke's kind assistance I have been able to study these rocks again. Duparc has given us an extensive description of his petrographical material, from El Callao (l.c.) and from Ciudad Bolivar [13]).

All explorers agree that the basal complex is predominantly made up of granitodiorites, gneisses and schists. Basic igneous rocks are rare, apart from the later basic intrusions. The gneisses are mostly ortho-gneisses: beyond these there are also para-gneisses and para-schists of various compositions. On closer examination we observe some resemblance to the rocks of the areas above-discussed.

Among the granitodiorites there is a pronounced predominance of the acid members. Biotite and biotite hornblende are very frequent; bi-mica granites and aplitic granites occur less frequently. These granites are exposed in a number of localities in the Orinoco from the delta upwards to above San Fernando de Atabapo, and locally in the tributary rivers, the Caroni and the Caura. The same can be observed in the sources of Rio Ventuari, the Upper Orinoco,

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1) R. H. Schomburgk. **2.**
2) R. Tate. **9.**
3) G. Attwood. **14.**
4) W. Sievers. **32.**
5) S. Passarge. **50.**
6) A. T. Bendrat. **79.**
7) Th. Koch-Grünberg. **86.**
8) P. P. von Bauer. **87.**
9) L. Duparc. **100.**
10) Alfredo Jahn. **97.**
11) R. A. Liddle. **107.**
12) W. Bergt. **45.**
13) L. Duparc et L. Cuisinier. **102.**

and in the confluents of the Amazon, namely in the Aracasa, the Uraricuera, and the rivers flowing from the Roraima plateau to the Rio Branco, and also in the Casiquiari. The potash feldspar of these granites appears to be developed as microcline, and to contain microperthite. Anyhow this holds for the rocks from the rivers Ventuari, Aracasa, Uraricuera, and the Upper Orinoco, examined by myself. The occurrence of microcline is recorded in the granite from Ciudad Bolivar (Duparc. 1922. l.c. p. 8; ibid. 1923. pp. 19, 20), and that near Caicara (Bendrat. 1911. l.c.). According to Bendrat also the ortho-gneisses near Caicara are characterized by the presence of microcline (l.c. p. 450). It is remarkable that porphyritic granites with coarse microcline phenocrysts, which are often twinned according to the Carlsbad-law, are frequent. They were collected in Rio Hacha (an affluent of Rio Ventuari), in the Wodintade rapids (Rio Ventuari), from the Macaba rocks (Rio Negro), in the Rio Casiquiari (Durutamoni rapids) and near San Fernando de Atabapo, along the upper course of the Rio Negro as far as the affluent the Isana (according to Koch-Grünberg), in the neighbourhood of Caicara (Bendrat l.c. p. 448); according to Liddle porphyritic granites occur frequently in Venezuelan Guiana (l.c.).

In so far as I have been able to examine these granites their habitus is quite the same as in Surinam; they might just as well have been collected there.

In some parts of V. Guiana the granites seem to assume an acid dioritic facies, just as in Surinam, judging from a quartz mica diorite from the Aracasa (a tributary of the Uraricuera) of the type of that of Surinam (coll. Koch-Grünberg).

As said, basic igneous rocks have seldom been met with in the basal complex. The pyroxene-bearing rocks, which, according to Sievers, have been exposed locally along the Orinoco between Ciudad Bolivar and the embouchure of the Caroni, are remarkable. Sievers considered them to be pyroxene granulite, but Bergt determined them as hornblende and pyroxene-bearing gabbro. Bergt has already pointed to their likeness to rocks known locally in the Coppename- and the Nickerie basin in Surinam. The rocks of the latter localities we have termed basic pyroxene gneisses, in compliance with the parallel texture (see p. 272). The same texture is mentioned by Sievers for the pyroxene-bearing rocks of Venezuela.

Granite-gneisses, gneissose granites, etc. have been recorded from a number of places in the literature. It seems, however, that granites are far predominant along the rivers Ventuari, Casiquiari and the tributaries of the Rio Branco, as ortho-gneisses were not sent me for examination. When glancing at the geological map of Alfredo Jahn the same relation between granites and ortho-gneisses appears to exist along the Orinoco, along the Upper Orinoco, and along the Casiquiari and the Rio Negro. Anyhow, in so far as the exposures along these rivers have been examined, especially granites have been marked down. However, the literature records along the trails, which penetrate into Venezuelan Guiana from the Orinoco, also many ortho-gneisses beside granites (Liddle, Duparc), while Bendrat reports that in the vicinity of Caicara granites are in the minority (l.c. p. 443 and 445), so that there the relation seems to be the reverse.

Quartz porphyries and allied porphyrites are mentioned here and there in the literature. The quartz porphyries collected by Koch-Grünberg from the Serra Aruana, and from the Rio Surumu (between Rio Branco and Mt. Roraima) and from the source of the Merewari river, show microscopically quite the same habitus as the types prevailing in Surinam, by microgranitic groundmass and phenocrysts of quartz and acid plagioclase, and above all by the unmistakable microcline structure presented by the potash feldspar phenocrysts.

It is difficult to say if besides ortho-gneisses also para-gneisses are well examplified. The muscovite- and biotite-rich gneisses we find in Venezuelan Guiana, are probably para-gneisses. The same can be said no doubt for the garnet-containing gneisses mentioned by Sievers from the Lower Orinoco (l.c. p. 305), and described more minutely by Duparc [1]). According to Duparc they are gneisses without parallel texture. They are composed of quartz, basic plagioclase, biotite, garnet and magnetite. There may be present a cordierite-like mineral. There is a remarkable type that contains hypersthene besides garnet. From the description it appears that we have to do here with a series of gneisses, closely allied to the garnet-, cordierite-, hypersthene- (and sillimanite-) bearing para-gneisses of Surinam (Nickerie-basin discussed by us. Duparc (l.c. p. 21) suspects that the recrystallization was caused by contact-metamorphism. For our rocks we have also demonstrated that the metamorphism must be closely related to contact-metamorphism.

Para-schists occur in the Rio Uraricuera, where they are exposed over a distance of some tens of kilometers (in accordance with data published by Koch-Grünberg and his material). In the same region occur phyllitic mica schist, graphite-bearing graywacke-sandstone, and phyllitic mica schist, all from the same river.

In connection with the comparison with Surinam the schists from El Callao, described by Duparc (l.c.), are of special interest. There a series of rocks is known that, judging from the outward appearance have been called "Roches Vertes" and that on microscopical examination appear to be basic and metamorphic basic igneous rocks, and also quartz chlorite schists, sericite chlorite schists, rich in calcite. It is evident from Duparc's description that

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[1]) L. Duparc et L. Cuisinier. **102**.

petrographically these schists are altogether the equivalent of the schists described by us from the eastern part of Surinam.

Most explorers do not say anything about the geological relation of the components of the basal complex. In some places, however, we are told that granites pass into gneissose granites and into gneisses. From this we deem it probable that the two groups are of the same age (inter alia Sievers l.c. p. 306); Bendrat supposes geological connection between the two groups because of their petrographical relation (l.c. p. 451). Contrariwise Liddle states that gneisses as well as granites may be traversed by later intrusive granites. Liddle supposes, that the shapes of the granite mountains fairly correspond to the original shape of the igneous masses (l.c. p 6).

From the far South-West of Venezuelan Guiana, in the Barima-, and the Cuyuni-district Harrison records the occurrence of granitodiorite-dykes in gneisses. This is quite in harmony with what the same worker has stated for the adjoining British Guiana.

The gneiss-characteristics are considered by the explorers as being secondary.

Duparc's speculation on the geological relations between the granitodiorites and the para-schists is the only one worth mentioning. According to him the schists from El Callao are "presumably" later than the gneisses exposed in the savannahs on the trail to Cuidad Bolivar. Porphyrites and aplites are still later; but which of the two is the younger we cannot possibly say. There is no evidence to prove that the granites are younger than the "roches vertes". The only indication in this direction is perhaps given by the aplites, which may be considered as granite-apophyses.

The intensely metamorphic para-gneisses from the vicinity of Callao form according to Duparc a zone in the granites and presumably have been metamorphosed by the latter.

In conclusion we can say that, what we know of the basal complex in Venezuelan Guiana, suggests a composition similar to that of the same complex in Surinam. Among the rocks accurately studied we find again the petrographic equivalent in Surinam. This applies to granites, quartz porphyries, a basic gneiss and a few typical para-schists and para-gneisses. There seems to be no essential difference between the frequency of the various rock types and those in Surinam. But we know very little about the geological relation of the components.

C. *French Guiana.*

We must be brief about the basal complex in French Guiana, as there is only little information at hand. Vélain has endeavoured to give a general view of the geology of the country after the results obtained by the explorer Crevaux [1]). Some geological data are found in the publications of Levat [2]) and of Viala [3]). Fieux's results concern the exposures along the Approuage [4]).

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1) M. Ch. Vélain. **22.**
2) M. E. D. Levat. **34.**
3) L. F. Viala. **24.**
4) G. Fieux. **20.**

Some geological data can also be gathered from the reports of Coudreau's explorations [1]), and Brousseau's general description of the country [2]).

These writings go to prove that the basal complex is formed by granitodiorites and ortho-gneisses, some para-gneisses, and in large measure also by para-schists. Granites have built up the unimportant mountains. The gneisses and schists seem to be restricted to the hilly country and to the little undulating territory. Many ridges and cupolas are formed by basic intrusiva (diabases).

Vélain's publications furnish the only source from which we can draw for a detailed petrographical comparison with Surinam. He describes granitodiorites, ortho-gneisses, very few basic igneous rocks, and some para-gneisses and para-schists. The biotite granites, biotite hornblende granites, bi-mica granites ("granulites"), "gneiss-granitoides", and granite-gneisses do not differ essentially from the types discussed for Surinam, and are characterized by the frequency of microcline and, as it seems, also by myrmekite. Beside microcline also orthoclase is often mentioned as potash feldspar. It is very likely that here untwinned plagioclase has been mistaken for orthoclase, just as Vélain mistook untwinned zonary plagioclase for potash feldspar. The typical porphyritic granites of Surinam are not recorded among Vélain's material. Quartz diorites may be very well the equivalent of the Surinam rocks. It seems that the syenites, which are frequently mentioned, contain too much quartz to be true syenites. The origin of the amphibole gneisses is doubtful (l.c. p. 485—490). Para-schists can be identified in the descriptions of the garnet-rich gneisses from the Oyapok (l.c. p. 482), in the bi-mica schists (l.c. p. 456, 458, 484), in the sericite schists (l.c. p. 456, 492) in the "schistes ferrugineux" and the quartzites (l.c. p. 460, 461). The frequency of para-schists appears from the terms "quartzites schisteux", "schistes ardoisiers", "schistes argileux micacés" etc. which we often come across in the literature. These terms justify the plausibility that the schist formation existing in Surinam continues into French Guiana although we do not know anything about the distribution there.

An exact examination of the geological relation of the components has never been undertaken. We will pass over Brousseau's complicate system (l.c. p. 231) as it is valueless without extensive argumentation. Vélain rightly assumes on the basis of contactmetamorphism in the schists (chiastolite schists), that the granitodiorites are later than the schists. For his conception of the stratigraphical connection of the schists, however, evidence is entirely lacking. For the remarkable age-differences and the mutual intrusion of granitodiorites we refer to p. 459—460 of this writing.

D. *The State of Para in Brazil.*

Katzer has furnished a synopsis of the facts known about the basal complex in Para (1903) [3]); since then nothing appeared worth mentioning. The components of the basal complex are granites, bi-mica granites, quartz diorites, and corresponding ortho-gneisses and less frequent syenites and quartz porphyries, while also para-schists are known. No reliable petrographical descriptions of these components are at our disposal. Katzer has adopted Vélain's descriptions [4]).

We can establish the following points of similarity to the igneous rocks of Surinam: the corresponding rock-types, the frequency of microcline, of microperthite, and it would seem also of myrmekite. It strikes us that Vélain mentions epidote in "amphibolite" (probably hornblende gneiss is meant here); this epidote is characterized by idiomorphism: "Parmi ces amphibolites il en est une remarquable qui présente cette particularité intéressante de compter l'épidote parmi ses éléments anciens" (Vélain, 1885, p. 491). So we see, that it is just as in many Surinam igneous rocks.

The garnet-rich mica schists from the Upper Parou, described by Vélain, can be considered as para-schists. Perhaps the banded biotite gneisses (from the Coanany river) also can be referred to the para-schists, on account of their heterogeneous texture of biotite-rich bands alternating with bands rich in quartz and orthoclase. Katzer's statement that limestones occur

[1]) H. A. Coudreau. **21.**
[2]) G. Brousseau. **42.**
[3]) F. Katzer. **49.**
[4]) M. Ch. Vélain. **13, 22.**

to a limited extent in the basal complex (l.c. p. 225) I have not found confirmed anywhere.
It is a familiar fact that the divide between North and South, namely the Tumuchumac mountains and the Acarai mountains, consists of granites. In the tributaries of the Amazon chiefly granitodiorites and ortho-gneisses and some crystalline schists are exposed.

Little is known for certain about the connection between the components. Vélain states that on either side of the divide the same stratigraphic succession of gneisses and schists appears (vide a.i. Vélain, 1885, p. 463). Since the distribution of the rocks given by Vélain appears to be incorrect for Surinam, no value can be attached to his statements regarding the stratigraphy in the State of Para.

The basal complex dips below Paleozoic sediments in southern direction. These sediments have been little interfered with tectonically and form a flat syncline, through which the Amazon is flowing. The oldest sediments of which the age has been established, are Upper Silurian, and have marine facies. According to Katzer a series of schists exists at the base of these sediments. Petrographically they resemble members of the basal complex, but they are looked upon as being Paleozoic because they are conformable to the Silurian. They are mica and chlorite-bearing quartzitic schists, and in part graphite- and bitumen-bearing sandstones. There is, however, contradiction between Katzer's statements, which on the one hand accentuate the conformity with the little disturbed Paleozoic sediments, and on the other lay stress upon the intensely folded texture of the schists which show "gewaltige dynamische Einwirkungen" (l.c. p. 226).

"The Imataca Series."

The series occurs in the boundary area between British Guiana and Venezuelan Guiana, and extends towards the West into the latter country as far as the Orinoco. Liddle (l.c.) is the only author who dwells at large upon it. They are ferruginous quartzites that form prominent hills through their resistance. According to Liddle they are definitely later than the basal gneissoid complex, for in the north-eastern part of the Guiana Highlands these quartzites are faulted into gneissoid rock. The quartzites have, however, never been found directly overlying the gneiss; the contacts are obscured by alluvial material and complicated by faulting (l.c. p. 64). The exact age is unknown. Liddle supposes, however, that the quartzites must be referred to the early Paleozoic (l.c. p. 65). He supposes these rocks to form a normal succession with the Roraima formation (l.c. p. 65).

Do the quartzites dip steeply, or are they lying approximately horizontal? In the first case the quartzites could very well belong to the basal complex, in the second, however, they must be considered to be of later age.

The Intrusive Diabases and Gabbros.

Diabases and gabbros are known to have been collected in all the countries belonging to the Guiana Highlands. They have intruded into the granitodiorites, ortho-gneisses and schists; they are in consequence of later age and do not belong to the basal complex proper. They have partly altered into epidiorites.

Petrographically the diabases from British Guiana have been studied minutely. Data from other regions bear almost exclusively on the outward habitus of the rocks.

The diabases from Omai in Br. Guiana [1]), examined by myself, are quartz diabases with granophyre of quartz and potash feldspar, as we know it in Surinam.

Harrison calls all the rocks diabases in spite of the variability in structures. He mentions, however, that coarse-grained rock-masses of large dimensions show gabbro-structure with a tendency for ophitic structure just as in Surinam (cf. Harrison Pl. X fig. II and our Pl. 26 fig. 1). Besides ordinary diabases also quartz diabases are found, whereas olivine diabases are rare; in stead of orthoclase microcline may have a share in the formation of granophyre (l.c. p. 89 and 91); in the olivine-bearing diabases quartz may occur (as granophyre).

In sum we can say that the intrusive diabase-gabbros of Br. Guiana are completely the petrographic equivalent of the Surinam rocks.

Tate (l.c.) has described a somewhat altered diabase-gabbro from Venezuelan Guiana of an indifferent type. Bonney (l.c.) discusses some highly altered rocks, which may have been diabases.

Katzer (l.c.) records diabases, diabase-porphyrites, melaphyres, spilites, and proterobases from the State of Para. Of these a diabase porphyrite has been more closely examined (l.c. p. 187).

Petrographical descriptions of diabases from French Guiana are lacking.

The rocks of the diabase group occur as dykes and masses. They are said to have partly extruded over the basal complex and over the later sedimentary formations; others have intruded into the latter. The literature records many instances of dykes and masses; this also refers to French Guiana, where the diabases have been called "diorites".

What is known about the relative age follows here: The diabases are later than the basal complex. In Venezuelan Guiana is has been observed that they traverse the Imataca series. In Br. Guiana they traverse the Roraima formation, overlie the remnants of this formation, and are observed to intrude into them. Contact phenomena have been observed in this formation [2]), so that the diabases are no doubt younger, at least some of them. It is still a moot point, however, whether in the latter countries part of the diabases are post-basal complex and pre-Roraima. In this connection it is striking that boulders of basic igneous rocks have never been met with in the conglomerates of the Roraima formation. This renders it probable that all diabases are later there. Observations in the Amazon-basin, on the border of the region discussed at present, imply that diabases are of various ages. It has been established that part of the diabases, accompanied by tuffs ("Schalsteine") are of Devonian age (Katzer l.c. pp. 122, 187, 216). In many places it has been stated that diabases and the allied rocks traverse the Devonian sediments (l.c. pp. 128,

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[1]) Present in the Collection at Delft: V. 241, 254, 269.

[2]) S. Bracewell. **108.** p. 19.

203, 208, 209) and have caused contact-metamorphism (l.c. p. 210). Diabases, diabase-porphyrites, spilites and melaphyres, break through Carbonian sediments and cover them (l.c. pp. 178, 181, 187, 188, 189, 190). Here then we have indications of Devonian to post-Carbonian age. It deserves notice that it is possible that here diabases and dykes of trapp cut through old-Tertiary deposits; Katzer, however, has his doubts about it (l.c. p. 124 and 174).

SUMMARY OF THE COMPARISON BETWEEN SURINAM AND THE OTHER COUNTRIES OF THE GUIANA HIGHLANDS.

It becomes evident from the above that the countries belonging to the Guiana Highlands evince so many points of similarity, that they can be conceived to constitute a geological whole. The geological formations are identic.

Truly, the latest deposits are in the coastal area of a great thickness, but we have no conclusive evidence that the deeper parts go down into the Tertiary. To the North, West, and locally to the South the Guiana Highlands are bordered by continental deposits of Neogene and partly also of Paleogene age.

The Roraima formation superposes over a large distance the basal complex in the Central and Northern part of the Guiana Highlands.

The Imataca series, which possibly also covers the basal complex unconformably, is only known locally; it is supposed to be of early Paleozoic age.

The quartz porphyries and the allied rocks occupy an uncertain-place in the geological system, as it is not sure whether they belong to the basal complex proper, or whether they are of later age, in part perhaps. The latter supposition is justified by the occurrence of porphyry tuffs in the Roraima formation.

In all the countries there are many members of the diabase-gabbro group. They are later than the basal complex, later than the Imataca series and often also later than the Roraima formation. That the rocks, anyhow those in the Southern part of the region, are of divergent age, we have already alluded to. Petrographically the members of the intrusive diabase-gabbro group in Br. Guiana and Surinam are no doubt completely equivalent: as for the other countries this is still uncertain, as data are lacking.

We distinguish petrographically two groups in the basal complex: first igneous rocks, secondly para-schists. Among the igneous rocks the acid members, i.e. granites, quartz-rich diorites and equivalent ortho-gneisses predominate far and away over the basic members, examplified by gabbros and allied rocks, in part epidioritized, and by hornblende gneisses etc. The literature seems to warrant the conclusion that ortho-gneisses are about as frequent as granito-diorites. In Surinam, however, we have encountered a predominance of granitic rocks and the question rises, in how far this will also be the case elsewhere on further investigation.

Various arguments can be advanced for the fact that the acid members of the igneous rocks have crystallized under the same physico-chemical conditions, namely 1° the fact that potash feldspar has chiefly developed into primary microcline, 2° the frequency of microperthite and myrmekite, 3° the frequency of primary epidote in a part of the region, and 4° of a typical porphyritic facies of the granites. The corresponding habitus, and the corresponding combinations of the rock-types in the countries under discussion demonstrate that the rocks of the whole territory belong to the same magmatic province. For Surinam we have brought forward the frequency of cerium epidote (orthite) and of monazite as an argument for magma-relationship. In the other countries these minerals have not been met with, but the data are too incomplete and such minerals are too easily overlooked for affording a negative argument. I have moreover found orthite in porphyritic biotite granite from the Rio Hacha (tributary of the Rio Ventuari spring of the Orinoco).

The para-schists differ greatly as to the degree of recrystallization. They vary from the rare cordierite-, and sillimanite-, and staurolite gneisses etc. to clay slates. The original material of these schists is terrigenous-detritic, while locally we have also found schists of pyroclastic origin. This composition implies that the oldest developmental period of the basal complex was characterized by sedimentation under continental conditions; chemical sediments are lacking [1]).

It is certain that quantitatively the para-schists are inferior to the igneous rocks and the ortho-gneisses. Para-schists are frequent in the East of Surinam and in French Guiana. From the literature we gather that they occur only locally in the other territories, although it has appeared of late years, that they are more frequent than it had been supposed, especially in Br. Guiana.

There is so vast a difference in the opinions about the geological correlation and the genesis of the components of the basal complex, that they cannot be summarized. For Surinam we have pointed out that all or nearly all the para-schists are older than the granitodiorites. The reverse is adduced for Br. Guiana; for Venezuela Duparc leaves the question undecided.

We have distinguished three groups among the Surinam ortho-gneisses: 1° gneisses with primary gneiss-features; 2° cataclastic ortho-gneisses; 3° recrystallized gneisses. The gneiss-features of the last two groups are conceived to be secondary in contradistinction to those of the first. The first two groups comprise the equivalent of the predominating acid to medium-acid granitodiorites, the last one the equivalent of basic igneous rocks. Wherever the genesis of the ortho-gneisses of the other countries is discussed, secondary genesis is assumed for all gneisses. It should be brought forward that the petrographic examination of these gneisses has been very limited, so that no opinion can be formed concerning their genesis.

It is generally admitted that there may be considerable age differences between granitodiorites and ortho-gneisses, a relatively later age being mostly adopted for the granitodiorites. In Surinam, however, leaving the metamorphic basic ortho-gneisses out of consideration, there is often direct connection between granitodiorites and ortho-gneisses. This, together with the petrographical examination implies that geologically the two groups are inseparable. On the

[1]) L. F. Viala. **24.** (p. 38—39) gives a communication on crystalline limestones in French Guiana. But is seems to be unreliable, and this dictum is certainly applicable to the Devonian age assigned to these limestones.

preceding pages we have alluded to some indications which point to the same relation in the other countries, locally at least.

It still rests with us to bestow a few words upon the question whether some regular systeme can be observed in the tectonic maindirection of the schists. In all the writings attention is called to the steep dip of the schists. Generally strongly compressed folds come into play. The main trend seems to be East-West to S.E.—N.W.

Katzer records that the strike in the Northwestern part of Para runs N.W.—S.E., in the Northern part East-West [1]). Levat mentions East-West for French Guiana, without entering into particulars [2]). Vélain, however, gives a N.N.E.-strike [3]). In Dutch Guiana the schist-complex on the Marowyne shows N.-W. to N. trend, that on the Suriname river East-West. In British Guiana we have accurate observations in the Mazaruni basin [4]), the trend is N.W. to W., with some local changes. The observations in the Eastern part of Venezuelan Guiana point to a change in the main trend. Tate reports that the schists between Las Tablas on the Orinoco and the Rio Yuruari trend in general East-West, and dip steeply Northward. The same he mentions from near Ciudad Bolivar [5]). Of the same region Attwood mentions East-West strike [6]), and S.-E. strike [7]) while the schists dip towards the South and S.W. or stand vertical. Siever's data accord with the preceding ones as regards the strike, but according to him the schists dip steeply towards the South, along the Orinoco [8]). Duparc reports for the El Callao tract East-West trend and steep dip [9]).

It should be observed that the above trends bear partly on the para-, and partly on the ortho-schists, and apparently on the former most. The scanty data on the trend and the dip in the granitodiorite-gneisses point out that in the latter the trend varies locally more than in the para-schists. This appears from my own data on the Suriname river (see p. 240) and on the Upper Courantyne (see p. 301). Brown found the same in the Courantyne basin [10]). In some areas the trend may be constant also in these rocks viz. on the Curuni between the New river embouchure and Point right about.

Efforts to detect a system in the tectonic main trend are not new. Katzer gives the same course as I of the main trend (without mentioning sources) [11]), Evans again the same for the southern part of the Guiana Highlands.

NOTES ON THE ROCKS OF THE BRAZILIAN SHIELD.

It has been propounded repeatedly that the basal complex of the Guiana Highlands is connected with that of Eastern and Central South America. In other words that the sediments in the Amazon basin are only an superficial interruption.

The basal complex has been exposed in all the Eastern States of Brazil, and southward as far as Argentina. Exposures seem to be little frequent in the Central States of Brazil, in the Brazilian Highlands and in the rivers flowing

1) F. Katzer. **49.** p. 240.
2) M. E. D. Levat. **34.** p. 24—25.
3) M. Ch. Vélain. **22.**
4) H. J. C. Conolly. **104.** p. 32—33.
5) R. Tate. **9.** p. 344—346.
6) G. Attwood. **14.** p. 585.
7) G. Attwood. **14.** p. 584.
8) W. Sievers. **32.** p. 306—307.
9) L. Duparc. **100.**
10) C. B. Brown. **10.** p. 224—229.
11) F. Katzer. **49.** p. 240.

northward: the Madeira, Tapajos, Xingu and Tocantins. It has been established that in a number of places the basal complex is overlain by Silurian and Devonian sediments, so that very probably pre-Paleozoic age may be assumed.

The components are the same that we have observed in the Guiana Highlands. The data are too scanty and also too little detailed, however, to furnish material for an extensive comparison of this immense territory with Surinam. Only the rocks from some areas have been examined microscopically. Evans, Derby, Graeff, Gorciex, Hunter, Hovey, Hussak, Iddings, Machado, Pöhlmann, Rosenbusch, von Saksen Coburg, Schuster, Washington, Williams and Wright have been working petrographically. We quote from their works only that which points to analogies to the Surinam Highlands.

Petrographical details on the rocks exposed in the southern tributaries of the Amazon are to be found only in a writing by Evans on the upper course of Rio Madeira [1]). Many rocks have a granulitic composition, and are of a type unknown in the Guiana Highlands. With reference to Surinam a porphyritic biotite granite, with microcline phenocrysts, twinned after the Carlsbad-law, is of interest. This granite contains orthite (l.c. p. 114) and seems to be altogether of the type of Gran-rio granite from Surinam.

Schuster gives elaborate descriptions of rocks from the Sierra Paranapiacaba [2]). It is striking that there the granites are characterized by microcline, microperthite, and myrmekite, as in Surinam. Schuster calls attention to the occurrence of these components. "Die beiden beschriebenen Vorkommen haben eine gewisse Familien-ähnlichkeit mit solchen Graniten die in Verbindung mit kristallinen Schiefern aufzutreten pflegen. Bemerkenswert ist namentlich der Gehalt an Mikroklin, das Auftreten von Myrmekit, die Spuren von Kataklase" (l.c. p. 1180). Porphyritic biotite hornblende granite containing microcline phenocrysts from Parahyba are described by him (l.c. 1171). The granite-gneisses of these tracts are again characterized by frequency of microcline, microperthite and myrmekite. It strikes us that a granite-gneiss from the Eastern Sierra Paranapiacaba contains isotropic orthite-remnants, encircled by a rim of iron-rich epidote, as in Surinam. The structure of these gneisses is conceived to be secondary by Schuster.

Some granites and ortho-gneisses from Brazil, examined by me, might as well have been collected in Surinam. This holds good for biotite granite rich in microcline from the Sierra de Tingua, for microcline- and microperthite-bearing ortho-gneisses from the same tract, for some garnet and myrmekite-bearing granite-gneisses from Rio de Janeiro (town), for biotite-rich granite-gneiss from the same locality and for muscovite-bearing biotite granite from Estrella del Sul (N.N.W. of Araguary in Minas Geraes). The samples from the last two localities I was in a position to examine through the valued assistance of Prof. Molengraaff of Delft.

Pöhlmann [3]) describes biotite gneiss from Paraguay, which contains besides microcline an abundance of primary epidote, and is consequently quite comparable with some granite-gneisses from Surinam and British Guiana.

The frequency of monazite as accessory mineral in acid igneous rocks from Bahia, Minas Geraes, Sao Paulo, Rio de Janeiro and Argentina (Cordoba) which we know from the writings of Derby [4]) affords an argument for the relation with the Surinam rocks.

The small number of available data imply that in the tracts we mentioned, there occur rocks which are altogether of the types discussed for the Guiana Highlands and especially for Surinam.

It is remarkable that the granites of Central Argentina of which Romberg gives an elaborate description are also closely related to those of Guiana [5]).

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[1]) J. W. Evans. The rocks of the Cataracts of the River Madeira and the adjoining portions of the Beni Mamoré. Quart. Journ. Geol. Soc. LXII. 1906. p. 88.

[2]) K. Schuster. Petrographische Ergebnisse der brasilianischen Expedition 1901 der Kaiserl. Akademie der Wissenschaften. Sitzungsber. Kaiserl. Akad. Wissensch. Wien. CXVI. 1907. Abt. I. p. 1111—1203.

[3]) R. Pöhlmann. Gesteine aus Paraguay. Neues Jahrb. Mineral. 1886. I. p. 245.

[4]) O. A. Derby. On the occurrence of Monazite as an accessory Element in Rocks. Amer. Journ. Science. (III). XXXVII. 1889. p. 109; do. Notes on Monazite. (IV). X. 1900. p. 217.

[5]) J. Romberg. Petrographische Untersuchungen on argentinischen Graniten, mit besonderer Berücksichtigung ihrer Structur und der Entstehung derselben. Neues Jahrb. 1893. Beil. Bd. VIII. 275.

This applies to Archeic granites of Central Argentina, but just as well to those given as Paleozoic. The age of the latter group seems, however, often to be uncertain (l.c. p. 291).

The granites are characterized by microcline, often with microperthite, while also the other minerals show many points of secondary importance, which we observe again in the Surinam rocks. It is striking that the mineral orthite is not lacking (l.c. p. 334); it may be provided with a rim of epidote. Although in most rocks epidote is secondary, in several rocks the primary character of this mineral is not doubtful according to Romberg's description (l.c. p. 333). The epidote namely shows distinct idiomorphism towards biotite and occurs enclosed in the latter, while the rock does not show secondary changes (l.c. Table XVII, fig. 65). Here the habitus is quite the same as the one we have described for the Surinam rocks.

A dissimilarity between the granites of both regions is the occurrence of distinctly zonary structure of the plagioclases (l.c. p. 286). Another difference is the great frequency of muscovite granites, which, however, are often hypo-abyssic rocks.

These data suffice to show that rocks with a habitus that is typical of the Guiana Highlands are not lacking in the basal complex of the Brazilian Shield, and farther to the South. This lends support to the view *that the rocks from both regions belong to the same magmatic province.*

An important difference between the two regions is shown by the alkali rocks from the Southern States of Brazil and from Paraguay, described by Derby, Pöhlmann, Graeff, Rosenbusch, Hunter, Washington and others. We do not know alkali rocks from the Guiana Highlands.The question rises whether these alkali rocks are only local differentiations of the calc-alkali series. If the latter is the case, they would not be an argument against the magma-province. Moreover is still problematic in how far these alkali rocks belong to the basal complex proper of whether they are of later age, as has been fixed by Derby for the alkali rocks of S. Eastern Brazil.

I may be allowed to add a single remark considering the later intrusiva. The basal complex, and to some degree also the overlying sediments, are traversed in a number of places by intrusive diabases, diabase porphyrites, porphyrites, and trapp. Of the many occurrences only few have been examined microscopically.The rocks from Rio de Janeiro described by Hovey [1]), and the rocks from Sao Paulo, described by Schuster [2]) furnish points of similarity to types from the Guiana Highlands. The diabases of these two areas contain namely granophyre. The quartz diabases described by Schuster contain granophyre of quartz and potash feldspar; the latter mineral may also occur independently. Just as in the Surinam rocks quartz and potash feldspar decrease quantitatively according as the pyroxenes are increasing.

NOTES ON ROCKS FROM THE AREA OF ANDEAN FOLDING.

The rocks, thus far concerned in the comparison, belong to the same geological unit, viz. to the pre-Paleozoic crystalline core of the South-American Continent. We shall now compare the Surinam rocks with rocks from the area

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1) E. O. Hovey. Ueber Gangdiabase der Gegend von Rio de Janeiro und Salit von Sala in Schweden. Tscherm. Miner. Petrogr. Mitt. XIII. 1892. p. 211.

2) K. Schuster. l.c. p. 1151 and 1153.

of the Andine folding, to the West, Northwest and North of the Guiana Highlands.

The Guiana Highland and the Brazilian Shield seem to have been stable from early Paleozoic time. The Western and the Northern borders of the continent, however, have been subject to strong tectonic disturbances in Paleozoic, Mesozoic, Tertiary and more recent times. Everywhere the Guiana Highlands are separated from this region by Neogenic and Quaternary deposits.

Igneous rocks, especially the acid igneous rocks, from Venezuela, Columbia, Ecuador, Peru, and some of the islands before the Venezuelan coast, will now be drawn into the comparison. Among the basic rocks of these countries andesites, porphyrites, diabases and related rocks are frequent. These rocks, however, are either of a habitus different from those of the Guiana Highlands, or they belong to indifferent types, unfit for a comparison (especially diabases and porphyrites). Among the diabases recorded in the literature, however, I never encountered the equivalent of our quartz diabases.

In most cases we do not know whether the acid rocks and the attending, highly metamorphic schists are parts of an older, metamorphic subsoil, which has been involved in the Andean plications, or whether the later foldings should be made answerable for the metamorphism of the schists. This question is important, for in the first case the rocks might be the continuation and the outcrops of the same basal complex that is exposed in the Guiana Highlands. According to informations given by the Caribbean Petroleum Company Cretaceous deposits are traversed by granite dykes, north of Tocuyo, State of Lara, Venezuela. The authors Karsten (1862) [1], Sievers (1882, 1896) [2], Dalton (1912) [3], and Liddle (1926) [4] do not report any conclusive data concerning the age of the granites of northern and western Venezuela. Most often, however, Archeic and for some of the rocks Paleozoic age has been supposed. The same is reported for Columbia (Sierra de Santa Marta) in Bergt's publication (1899) [5]. Stutzer (1927) [6] has demonstrated that the granites in the Central Cordillere are posterior to the schists which are believed to be Paleozoic. Stille (1907) [7] mentions that granites of Cretaceous age occur where the Sierra de Perija unites with the Cordillera of Columbia. In Ecuador Syenite of Tertiary(?) age is known (Sheppard 1930) [8]. It is a fact that the granites in the Andes of Peru are partly of Tertiary age and partly much older; the latter are probably pre-Paleozoic and if so, they are to be referred to parts of the basal

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[1]) H. Karsten. Die Geognostische Beschaffenheit der Gebirge der Provinz Caracas. Zeitschr. Deutsche Geol. Gesellsch. 1862, XIV. p. 282.

[2]) W. Sievers. Die Cordillere von Merida. Geogr. Abhandl. A. Penk. III. 1. 1888. p. 238. Do. Zweite Reise in Venezuela in den Jahren 1892—1893. Mitt. Geogr. Gesellsch. Hamburg. XII. 1896. p. 1.

[3]) L. V. Dalton. On the geology of Venezuela. Geol. Mag. (V). IX. 1912. p. 203.

[4]) R. A. Liddle. The Geology of Venezuela and Trinidad. Texas. 1927.

[5]) W. Bergt. Die älteren Massengesteinen, Kristallinen Schiefer und Sedimente. Vide W. Reiss & A. Stübel. Reisen in Süd-Amerika. Berlin. 1899. II. 2.

[6]) O. Stutzer. Geologische Beobachtungen und Gedanken bei einer zweimahligen Durchquerung der Kolumbianischen Mittelcordillere. Neues Jahrb. 1927. Beil. Bd. 56 B. p. 135.

[7]) H. Stille. Studien im Gebiete der Rio Magdalena. Von Koenen's Festschrift. 1907. p. 277.

[8]) G. Sheppard. The igneous rocks of Southwest Ecuador. Journ. of Geology. XXXVII. 1930. p. 318.

complex that have been involved in the younger tectonic disturbances (Douglas 1920. 1921) [1]). Alkali syenites in South-eastern Peru seem to be of Paleozoic age (Douglas l.c.).

It appears then that the granitodiorites of the Andean folding area are of diverging age.

The following data have been derived from the petrographical descriptions to be found in the literature. and have been extended by the results of an examination of material procured chiefly by the „Bataafsche Petroleum Mij" at the Hague. We start with the East of the Andean folding areas and then proceed Westward and Southwestward.

The granites from the Caribbean range and the Andes in Venezuela are generally gray, biotite hornblende granites locally with feldspar phenocrysts. that can assume considerable dimensions according to Liddle. From the Valencia-Puerto Cabello road (Coast range). near Trincheras I have some material available for comparison. They are normal- and coarse-grained biotite granites with phenocrysts of microcline and with microperthite. They are rich in quartz. The plagioclase is distinctly idiomorphic. In another set of samples from the vicinity of Puerto Cabello. again coarse- to normal grained and with a perfectly massive texture. the potash feldspar is developed as orthoclase. or presents very slight traces of microcline structure. Albite occurs again as perthite.

To the South of the Caribbean range in the Llanos-region. near El Baul. schists and igneous rocks are exposed. Samples from two localities in this region appear to be biotite granite. containing orthoclase. microperthite. and idiomorphic plagioclase.

We have some material from granite-dykes which traverse Cretaceous deposits North of Tocuyo. state of Lara. These granites contain microperthite-bearing orthoclase and show defective idiomorphism of very acid plagioclases.

In the Venezuelan Andes the greatest areal extent of granites in Venezuela occurs as an irregularly exposed mass. forming the core of the Venezuelan Andes. chiefly in the Cordillera de Trujillo and the Sierra Nevada de Merida (Liddle l.c.). From the granite on the N.-West margin of the range. along the road from Valera to Timotes we have several samples at our disposal which were collected at a distance of several miles from each other. They are non-porphyritic bi-mica granites with typical brown biotite partly intergrown with primary muscovite. In the potash feldspar we observe some vague microcline structure. or we have to do with orthoclase. Here and there myrmekite is associated with the plagioclase. which has a tendency to idiomorphism. From the same region (Rio Momboy) there is a quartz mica diorite with greenish brown biotite and rather distinct crystallization sequence between plagioclase and quartz.

From the central part of the Sierra de Merida we have igneous rocks from West of Mucuchies. It is biotite granite. muscovite-bearing. Plagioclase shows distinct idiomorphism towards quartz and microcline. the latter showing no distinct sequence mutually. Twinning of the microcline is vague. Some microperthite and myrmekite are present. A quartz mica diorite from the same locality shows distinctly idiomorphic plagioclase (oligoclase-andesine) and biotite with distinctly developed base. It is interesting that in a section of this rock an orthite-twin occurs. olive green. distinctly pleochroitic and surrounded by differently tinged marginal zone.

Stutzer has published a few details on the igneous rocks of the peninsula of Goajira [2]): the granites are developed into biotite granites with orthoclase.

For the Northern part of the Sierra de Perija we have hardly any petrographic details on the older igneous rocks. Liddle mentions biotite hornblende granites judging from boulders (l.c. p. 90). Also granitodiorites are present. We have a quartz mica diorite from Rio Palmar characterized by distinct idiomorphism of plagioclase; the latter mineral shows tendency to zonal structure.

More detailed data are at hand on the Sierra Nevada de Santa Marta in Columbia. Bergt describes a biotite granite. and a similar ortho-gneiss (l.c. p. 14—15). Potash feldspar seems to have developed as orthoclase. The structure and the texture of the gneiss are considered to be primary. A sample of biotite granite from Rio Tucurina. now available for comparison. is rich in beautifully twinned microcline. which is sometimes twinned according to the Baveno-law. and contains microperthite. The plagioclase evinces a tendency for idiomorphism and is sometimes accompanied by myrmekite.

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[1]) J. A. Douglas. Geological Sections through the Andes of Peru and Bolivia. II and III. Quart. Journ. Geol. Soc. LXXVI. 1920 and LXXVII. 1921.

[2]) O. Stutzer. Streifzüge eines Geologen im Gebiete der Goajira-Indianer. Berlin. 1927.

From the Southern part of the Sierra de Perija, to the North of the area where this highland joins the Venezuelan Andes, many samples are available for comparison. To the East of Tamalameque between Angustora and Hatillo we have biotite granite, rich in acid plagioclase and orthoclase, in part intergrown with quartz to granophyre. From Santander del Norte we have at the highroad from Pedro Alonzo to Rio Sardinata normal grained biotite granites with microcline, which according to the Baveno-law may be twinned, and which contain some perthite. The plagioclase shows distinct idiomorphism. From the Rio Sardinata, just inside the Columbian province, we have normal-, to coarse grained biotite granites, containing pink microcline phenocrysts, and may enclose plagioclase crystals and particles of biotite. The plagioclase behaves idiomorphic towards quartz.

From much farther towards the West, on the Magdalena river, about 10 km. to the South of El Banco we have normal grained biotite hornblende granites. The hornblende has intergrown with some diopside. Potash feldspar has developed as orthoclase. Ore, apatite, and brownish titanite are the accessoria. We possess a series of granite samples from the border region, where the Columbian and the Venezuelan mountains meet (from Rio Umuquera and Rio Cocuy, State of Tachira, Venezuela). They are normal grained biotite granites. The phenocrysts have developed into microcline; this mineral appears also in the groundmass. A small amount of microperthite and myrmekite occurs. The plagioclase shows a tendency to idiomorphism. Ore, apatite and some titanite are the accessoria. From the same region we also have bi-mica granite and a quartz mica diorite; the latter contains brownish titanite of irregular shape which encloses ore and apatite.

Bergt has described some acid biotite granites from Santa Anna, the east side of the Central Cordillere of Columbia (l.c. p. 37). They contain orthoclase. The same granite has also been collected more to the South (near Las Piedras) (l.c. p. 69). He also makes mention of biotite granite both with orthoclase and microcline from the region of the Upper Magdalena (l.c. p. 79). In the same latitude on the West slope of the Central Cordillere (near Termales) orthoclase-containing biotite granite with zonary plagioclase has been collected (l.c. p. 103). On the same side of the range, a little more Southward (Quilichao), boulders of orthoclase-bearing diorites, with typical crystallization sequence, have been collected (l.c. p. 105). In the extreme South of the Central Cordillere dynamometamorphic biotite granite with orthoclase has been found (l.c. p. 123). Still farther southward biotite and biotite gneiss with microcline have been recorded from the East Cordillere (from La Cocha l.c. p. 195 and 197).

In the petrographical publications on the Equatorial East- and West Cordillere by Esch, Young, Herz, Belowsky, and Klautszch, which treat of the representatives of the young volcanic group, a single orthoclase-bearing granite is mentioned, that is referred to the older rocks (Belowsky. p. 81) [1]).

From Ecuador no data are available for comparison. As said, the granitodiorites in the Andes of Peru are of a widely differing age. The Tertiary granites and granitodiorites contain orthoclase as potash feldspar according to the descriptions of Douglas (l.c.). They are normal granites. But in the same tract also alkali granites occur, which are supposed to be the equivalent of the basal complex of Brazil and to be involved in the Andean folding. These alkali granites contain microcline.

From the Dutch isle of Aruba I have a series of granitodiorites at my disposal for comparison. They are quartz bearing hornblende diorites; they pass into quartz mica diorites by increase of mica and quartz, and into granodiorites and biotite granites by the appearance of potash feldspar. All are normal- or fine-grained and of quite massive texture. The plagioclase shows tendency to idiomorphism and distinct zonally structure in most rocks. The granites contain some microperthite and potash feldspar may be developed into microcline; the biotite is alway a greenish-brown type. The rocks alltogether form a transitional series from medium basic to acid rocks, which show no points of resemblance with those in the Guiana Highlands.

A biotite granite from the isle of Blanquilla shows again distinct idiomorphism of plagioclase; orthoclase is accompanied by some myrmekite.

A quartz hornblende diorite from the isle of Los Testigos is closely related to those of Aruba.

From these notes it appears that the acid granitodiorites of the Andine folding area reveal less constant features than those of the old core of South America. Their habitus varies according as microcline structure in the potash feldspar, microperthite, and myrmekite are present or absent. It varies according to the distinctness of the crystallization sequence of the colourless main components. On the one hand the rocks are characterized by greater variabilities, on the other hand many types cannot be differentiated from those belonging to the

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[1]) Vide W. Reiss and A. Stübel: Reisen in Süd-Amerika. Das Hochgebirge der Republik Ecuador. I. 1. 1.

old core of the continent. It is a fact of more significance that the typical orthite and the primary epidote we met with in many countries of the old core, seem to be absent in the Andine folding area. Neither in the literature, nor in the samples I have been able to examine, have these minerals been discovered, except orthite in a quartz mica diorite from the Sierra de Merida (Mucuchies). These facts seem to imply that most granitodiorites from the Andean folding area, are not related magmatically to those of the basal complex alluded to. It should be observed, however, that this conclusion requires to be corroborated by more facts. The guide minerals may have been overlooked in the Andean area.

DESIDERATA.

In conclusion we will call attention to a few subjects that require further investigation. The following remarks bear only on areas that are comparatively easy of access.

Let us begin with the latest deposits. It would be interesting to know how far the distribution of the fluvio-marine deposits accords with the scheme given in the previous chapters. From an agricultural point of view the knowledge of the distribution could be more or less significant, because the fluvio-marine deposits are very fertile, which cannot be asserted for the continental deposits.

Those who are in a position to undertake a research near the embouchure of the Marowyne river should not omit ascertaining whether more inland fluvio-marine deposits are found. We do not know this for certain.

How little we know of the distribution of the fluvio-marine is illustrated by what follows. As early as seventy-five years ago Voltz has pointed out the occurrence of shell-reefs to the South of Paramaribo, at the junction-canal between Para creek and the Suriname river ("Para-doorsteek"). Although this place is only at 20 km. distance from the capital and can be reached daily the occurrence of these shell-reefs has never been affirmed.

There is a fit opportunity nowadays to increase our knowledge of the vertical distribution of the fluvio-marine. Borings are now being performed in the low land in connection with the water-supply. It is to be hoped, that in Surinam data will be noted down concerning the composition of the profiles and material will be preserved. Should a deep-boring ever be performed again in the littoral, then it will be of prime interest to collect samples systematically and to send them up to Holland in order to ascertain whether the Tertiary is represented in the deepest deposits.

Surinam is pre-eminently the land for a study of laterite formation. We are not sure, however, from which rocks the Surinam bauxites have been derived. As stated above, the heavy accessoria spread in the bauxites, afford some indication. If possible entire profiles must be studied down to the bedrock. It is certain that many interesting data will come to light, which will most likely augment considerably our knowledge of laterite formation.

We must devote a few words to the Roraima formation. The formation in the interior can be left out of consideration. The exposures in the Courantyne river, between the Kabalebo river, and the Governor falls, and in the Kabalebo river itself, near to the Avanavero falls are easily accessible from Nickerie. It would be interesting to know whether the rocks belong indeed to the Roraima formation and how far they extend inland. It seems doubtful whether we have to do here with the Roraima formation, considering the important tectonic disturbances in these deposits (Brown). Brown stated, moreover, that granite dykes traverse these sandstones. I its evident, that these exposures can be studied in the rivers only in the dry season.

Now let us look at the basal complex. In the previous chapters we have dwelt at large on the many doubtful points in our geological knowledge of the basal complex. Many rock-types have been studied but the knowledge of the geological correlation is deficient. In this connection we call attention to some areas that promise a satisfactory exposure and are also comparatively easy of access. They are the exposures in the Lower Coppename, the Tibiti, and possibly also the Nickerie river. It appears from the writings of Essed and Bergt that in the Lower Coppename basin most of the components occur that are found in the basal complex. There we encounter granitodiorites, gabbros, ortho-gneisses, crystalline schists, among which above all graywackes, many types of contact-rocks, etc. Dykes of diorite, diabase, and lamprophyre traverse the basal complex. Pseudo-tachylytes have also been observed. It is probable that contacts are met with here grounding an insight into the interrelation.

We are ignorant of the geology of the Tibiti river. It does not seem improbable, however, that there are exposures in this river of crystalline schists, belonging to the moderately or little metamorphic schists that are classed among the groups V—IX of the scheme discussed on page 360. The Tibiti rises near the Jan Basi Gado mountain and flows through the area which we suppose to be rich in schists (Vide Map I). Contacts may be met with in the upper course between the schists mentioned and the granitodiorites of the basal complex, from which it appears which of the two groups is older than the other. As we have stated before, the age-relation between the little metamorphic schists and the granitodiorites forms a great gap in our knowledge. In the Suriname river, where these schists have been largely studied by Martin, contacts seem to be wanting. The exposure at the same height in the Saramacca river seems to be scanty, and this also refers probably to the upper course of the Tempati creek, which also falls within the schist area. For the age-question the Lower Marowyne requires no consideration, because there chiefly the graywacke formation is represented, whose age with respect to the granitodiorites has already been established.

Information regarding the navigability of the Upper Tibiti can no doubt be received at Paramaribo, as this river was mapped out only a short time ago.

True, the Nickerie basin has been explored elaborately by Van Cappelle, but new data concerning the relation of the basic and acid igneous rocks would be welcome, now that we possess knowledge of the petrographical composition of the formations in that region. It would be recommendable to go up the Nickerie river as far as the Blanche Marie falls. This trip is probably the most difficult one of the three.

These trips are not what we call expeditions. They can be undertaken by one single excursionist accompanied by about 5 men as rowers, and a cook. Only one boat is wanted. It will be expedient, however, to bring a small "korjaal" for reconnoitring in the Upper-Tibiti and the Upper-Nickerie-rivers in order to pass rapids and fallen trees. For a trip of six weeks the expenditure for each trip will be about £ 100. For the equipment we refer to pp. 11—12.

As stated in the preceding chapters our knowledge of the distribution of the formations in the interior proper is in part based on the samples collected by topographical expeditions. I cannot omit emphazising the value of such data, even though they have been collected by non-geologists, and also even though others doubt whether this system yields a true image of the geological composition. Our expedition induced me to visit several areas where collections had been made before by topographical expeditions. These visits prove me that their material gives a true image, especially of the areas whose geology is little variable, which is the case in many granitodiorite-areas of Central Surinam. These facts should be emphasized with a view to the project of settling the boundaries between Surinam and Brazil, which is in course of preparation. Should money be lacking for the superaddition of a geologist to the border-expeditions, it would yet be advisable to collect rock-samples systematically.

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INDICATIONS FOR THE USE OF THE REGISTERS.

With the aid of the place-name register it is possible to ascertain what is known about the geology of a certain locality, river, mountain, etc. The register also mentions those pages on which the locality is only discussed in a few words. In case only a single mineral of a rock is discussed, the findspot of this rock has not been inserted in the register. References to the chapters "A short Outline" (pp. 13—22), "The Development of our Geological Knowledge" (pp. 457—474), and "The Geology of Surinam, as a part of the Guiana Highlands" have been omitted.

The register of the rock-numbers has been drawn up in order to make it possible in using the collections to find out where a special rock is discussed. For the way in which the rocks of the different collections are indicated cf. pp. 4—5.

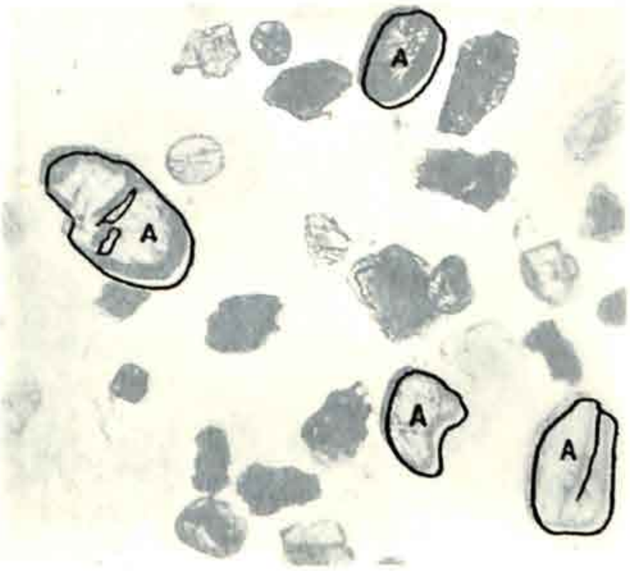
An index of subjects treated has not been drawn up, as one can find all the information required when consulting the detailed general index.

INDEX OF PLACE-NAMES.

REGISTER OF ROCK-NUMBERS QUOTED.

"V" vide p. 510; "Y" vide p. 517; "C" vide p. 519; "Vtz." vide p. 519; "G" vide p. 519; "B" vide p. 519; "P" vide p. 519.

Plate 23.



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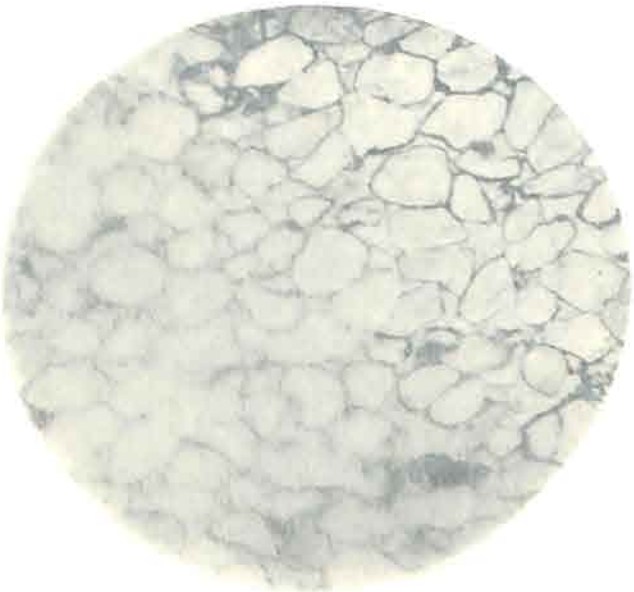

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Plate 23.

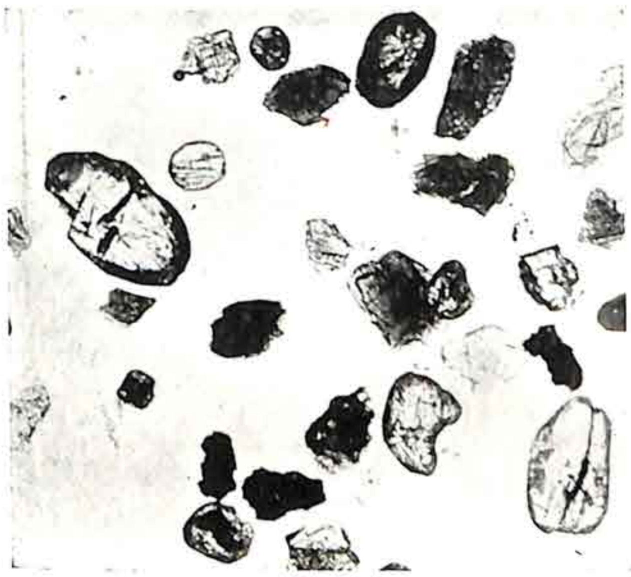


Fig. 1. Grains of tinstone (a) among heavy minerals from weathered bedrock; Onverwacht boring, Colonial railway. × 30.

Fig. 2. Quartzitic sandstone of the Roraima formation showing distinctly rounded-off quartz-grains. Table mountain. × 22. (Y. 261).

Fig. 3. The same as fig. 2. Crossed Nicols. × 18.

Fig. 4. Quartz-grains in quartzitic sandstone, surrounded by equally polarizing recrystallization fields. Table mountain. Crossed Nicols. × 30. (Y. 259).

Plate 24.

Fig. 1. Monoclinic pyroxenes showing bent prism-cleavage. Olivine diabase. Crossed Nicols. × 51. (Y. 206).

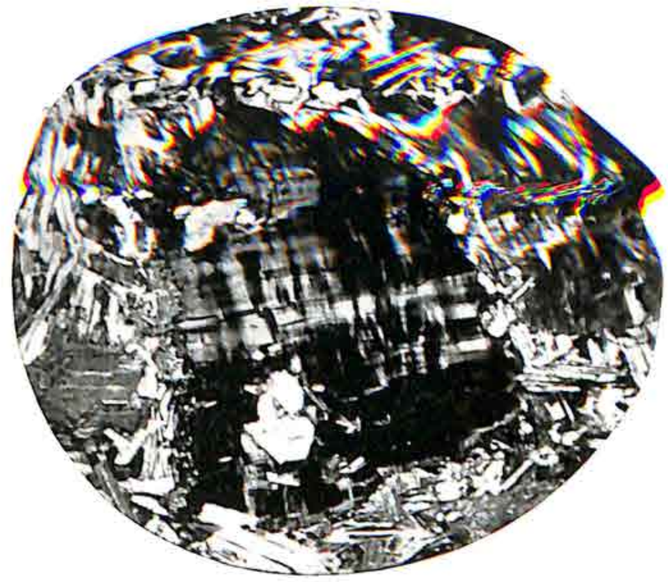


Fig. 2. Pseudo-microcline structure of orthorhombic pyroxene. Quartz gabbro. Crossed Nicols. × 18. (Y. 245).

Fig. 3. The same as fig. 2; besides the orthorhombic pyroxene is intergrown at the edges with monoclinic one. × 32.

Fig. 4. Olivine replaced by biotite (initial stage). Olivine diabase. × 48. (V. 1702).

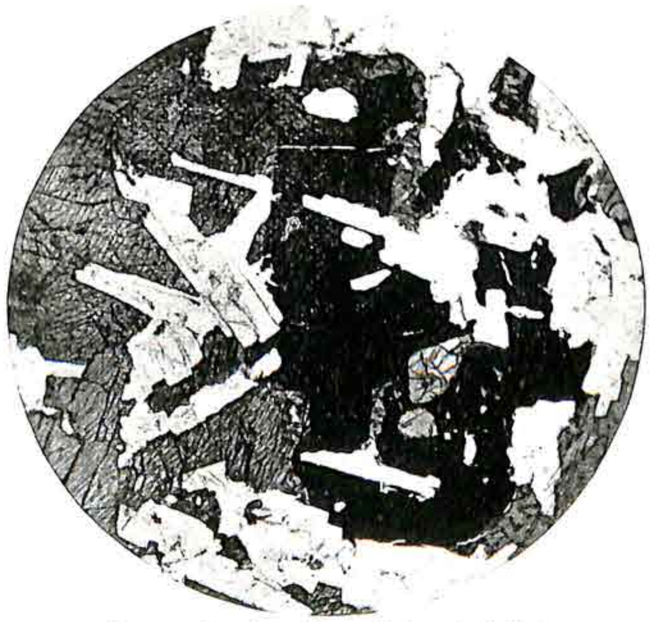


Fig. 5. Ilmenite dissected by plagioclase. Quartz gabbro. × 22. (Y. 246).

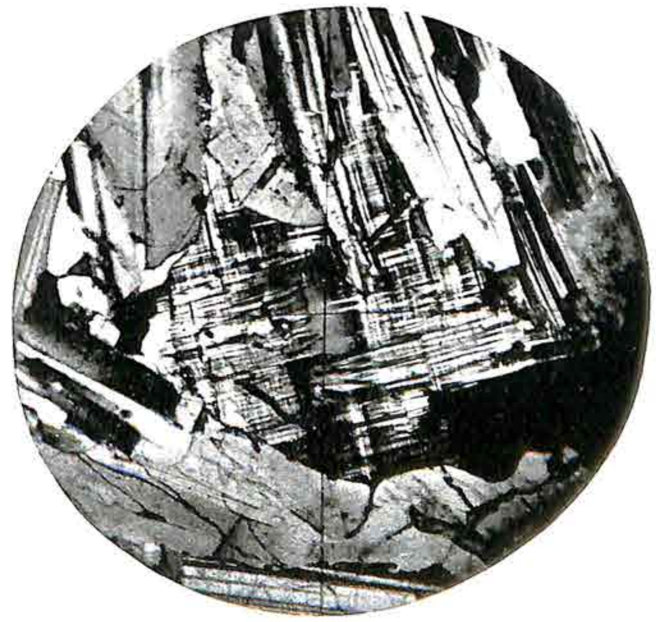


Fig. 6. Microcline in quartz diabase. Crossed Nicols abt. × 100. (V. 1894).

Plate 25.

Fig. 1. Granophyre of quartz and potash feldspar in quartz diabase. Crossed Nicols. × 105. (V. 241).

Fig. 2. Quartz diabase rich in granophyre. Crossed Nicols. × 33. (V. 241).

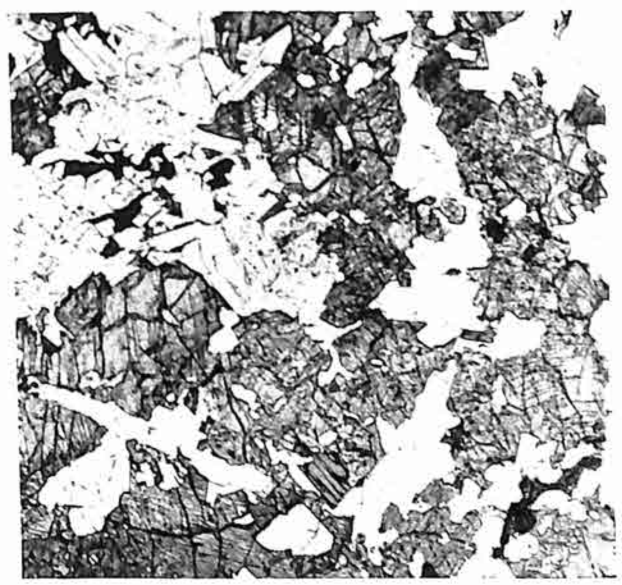


Fig. 3. Quartz gabbro showing tendency towards ophitic structure. Crossed Nicols. × 38. (V. 3632).

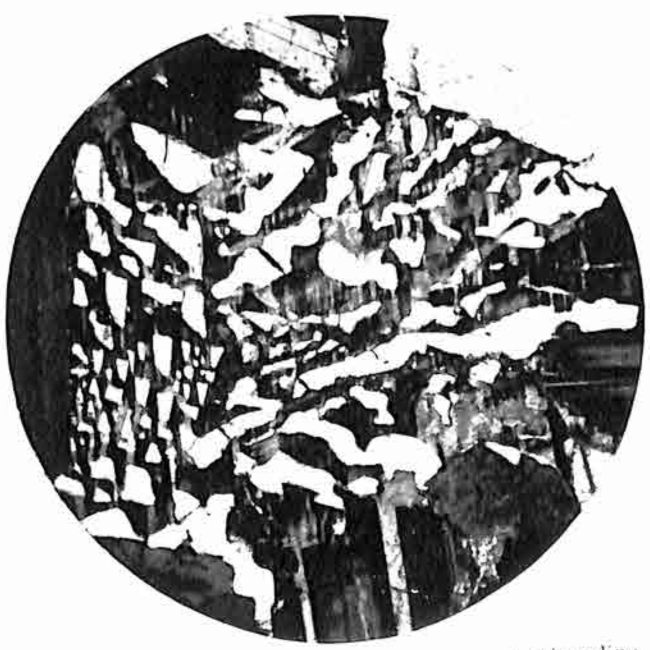


Fig. 4. Granophyre of quartz and microcline (The grating-structure of the latter may be recognized between the clear quartz). Crossed Nicols. × 11. (V. 1371).

Fig. 5. Ophitic structure. Quartz diabase. × [illegible] (V. 290).

Plate 26.

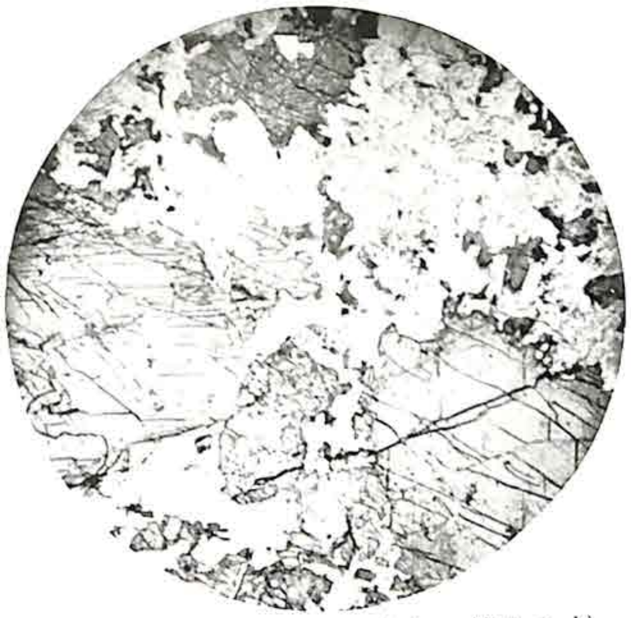


Fig. 1. Coarse pyroxene crystals in gabbro. × 16. (Y. 230).

Fig. 2. Groundmass in hypersthene diabase showing split plagioclases. Crossed Nicols. × 25. (Y. 70).

Fig. 3. Uralite-pseudomorphs showing time-glass structure in epidiorite. × 93. (Y. 184).

Fig. 4. Ore-skeleton in epidiorite. × 18. (Y. 912).

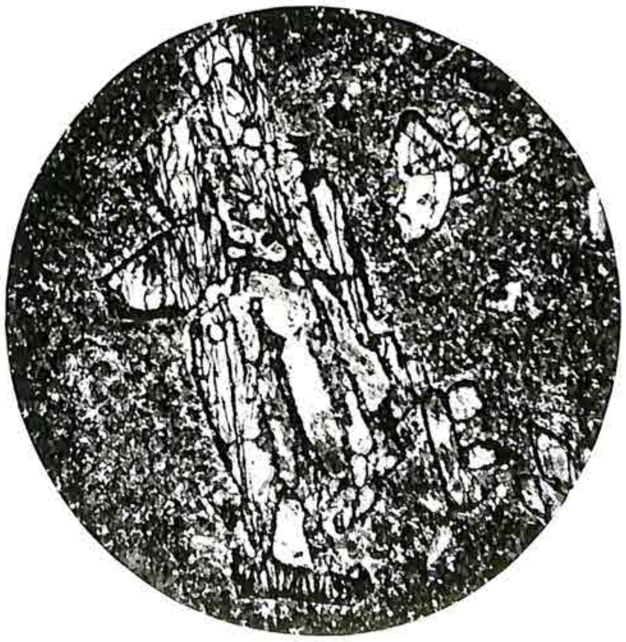


Fig. 5. Olivine skeleton in uralite diabase. × 13. (Y. 78).

Fig. 6. Uralite with fibrous prolongations in epidiorite × 54. (Y. 1651).

Plate 27.

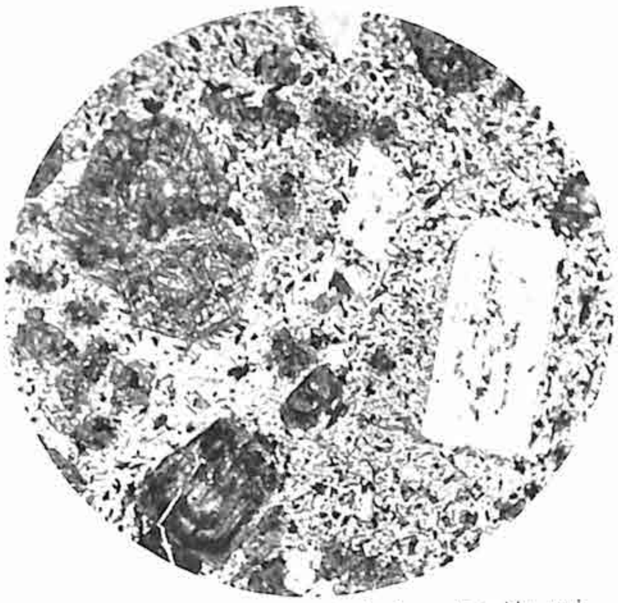


Fig. 1. Phenocrysts of plagioclase, diopside and hypersthene in diopside porphyrite. × 26. (Y. 286).

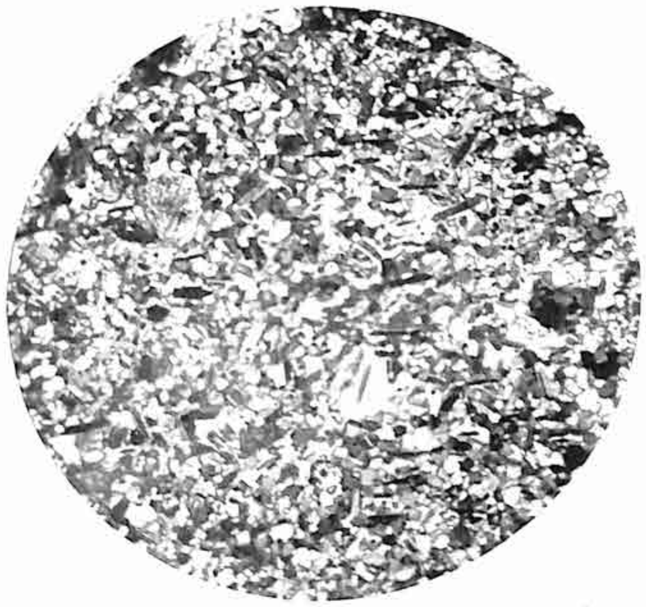


Fig. 2. Groundmass of the same as fig. 1 showing granular structure and lathshaped biotite. Crossed Nicols. × 51.

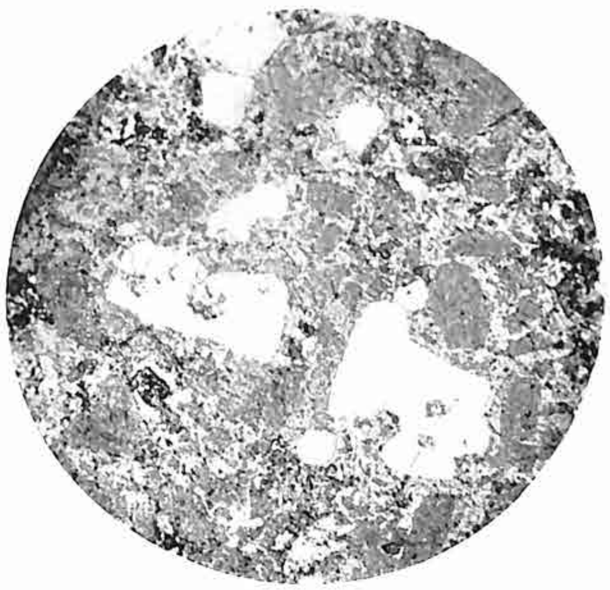


Fig. 3. Corroded quartz phenocrysts in quartz porphyry. × 11. (Y. 1257).

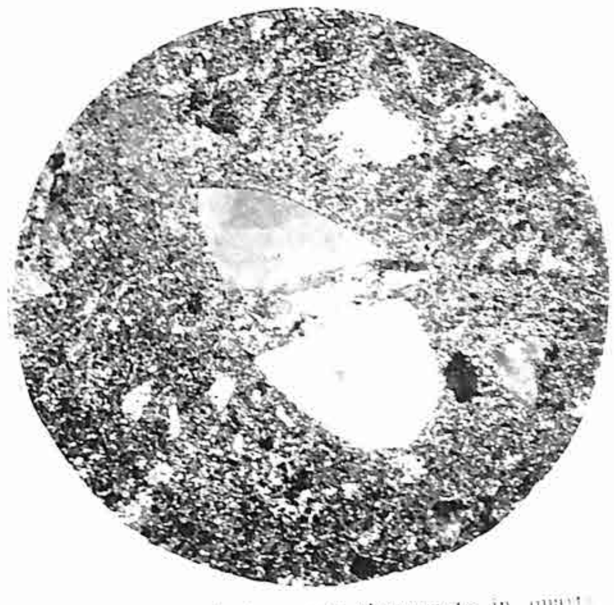


Fig. 4. Protoclastic quartz-phenocrysts in quartz porphyry. Crossed Nicols. × 15. (Y. [illegible]).

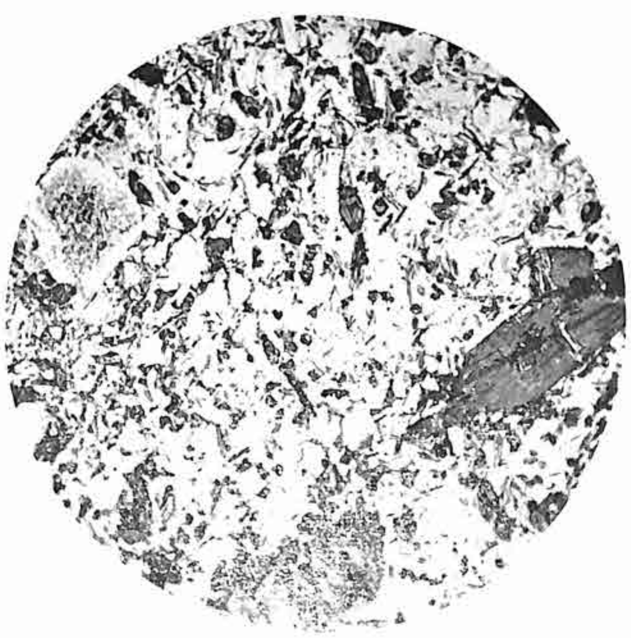


Fig. 5. Biotite hornblende kersantite containing phenocrysts of hornblende and plagioclase × 21. (Y. 58).

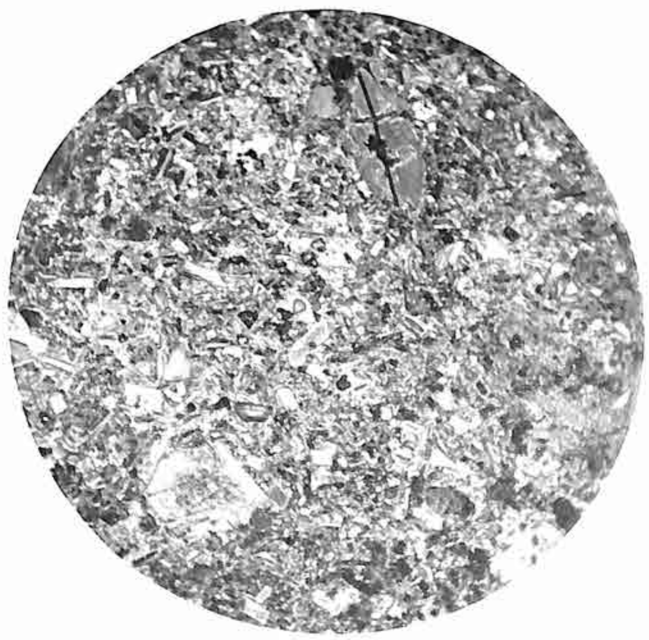


Fig. 6. The same as fig. 5. Crossed Nicols. × [illegible]

Plate 28.

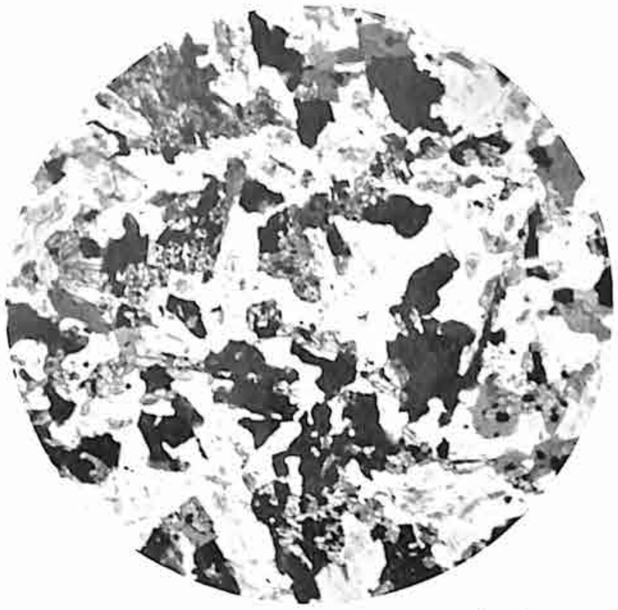


Fig. 1. Biotite pyroxene kersantite showing plagioclase, biotite and diopside. × 16. (Y. 332).

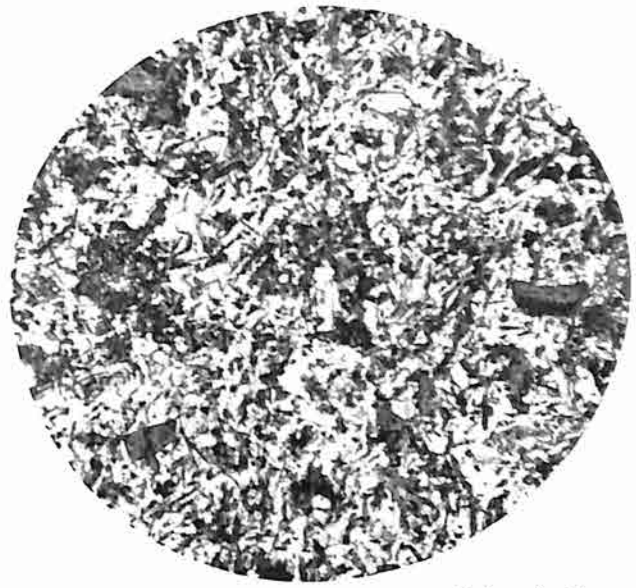


Fig. 2. Needle-shaped hornblende in odinite. × 21. (Y. 65).

Fig. 3. Idiomorphic topaz and chlorite (dark) in albitite (?). × 33. (Y. 1065).

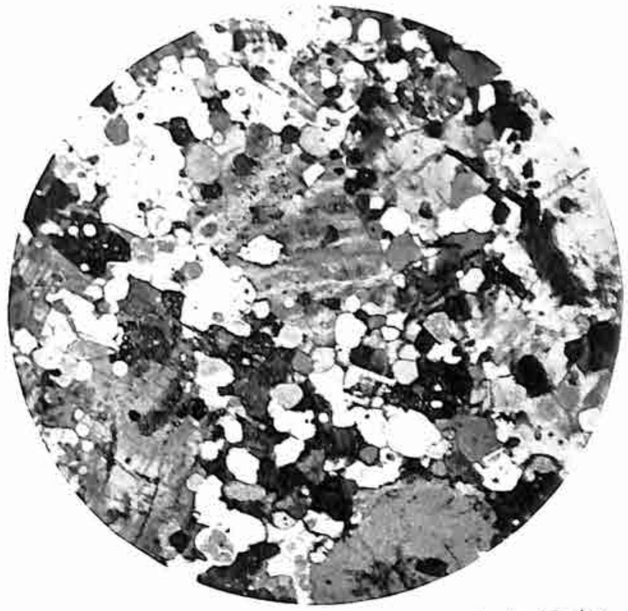


Fig. 4. Small idiomorphic quartz crystals in biotite hornblende granite. Crossed Nicols. × 26. (Y. 145).

Fig. 5. Idiomorphic potash feldspar in biotite granite. Crossed Nicols. × 15. (Y. 203).

Fig. 6. Baveno-twin of microcline cut abt. perpendicular to P/M. Crossed Nicols. × 25. (Y. 658).

Plate 29.

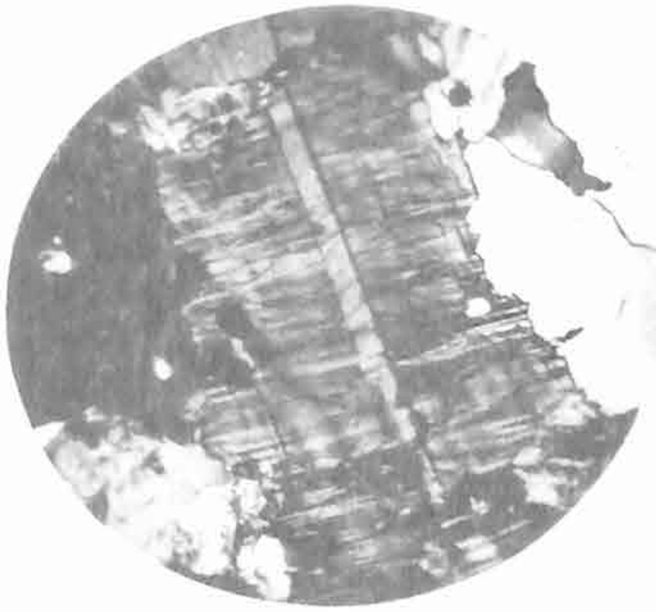


Fig. 2. Multiplet of microcline according to Baveno-law. Crossed Nicols. × 28. (V. 658.)

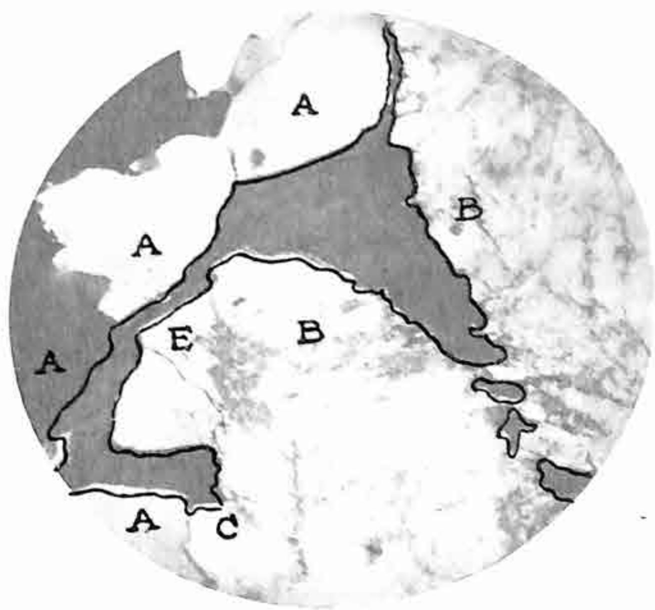


Fig. 4. Corroded biotite crystal in biotite granite. × 22. (V. 52.)

Plate 29.

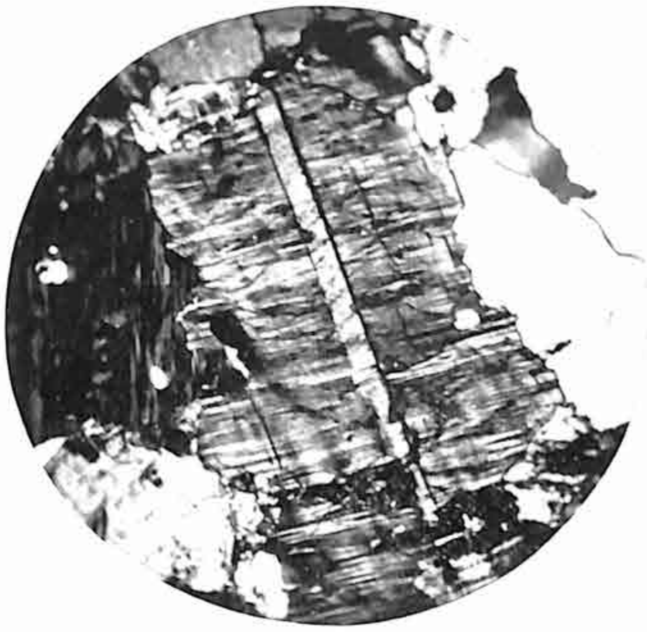


Fig. 1. Triplet of microcline according to Bavenoslaw. Crossed Nicols. × 25. (Y. 658.)

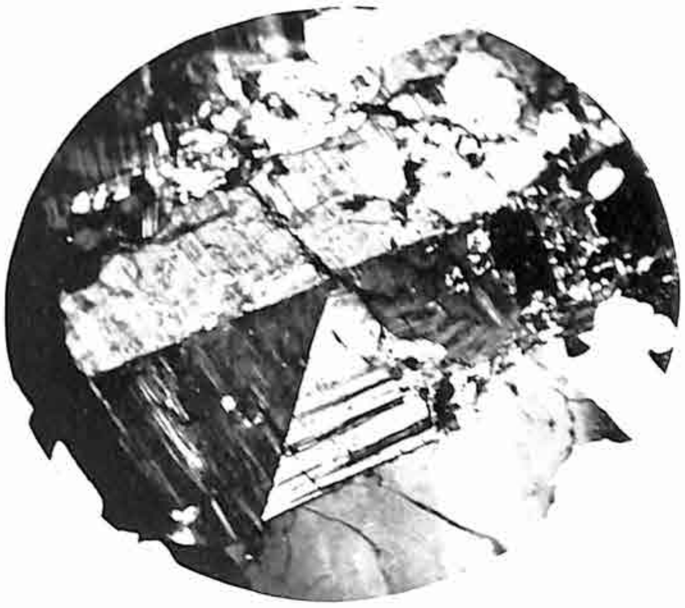


Fig. 2. Multiplet of microcline according to Bavenoslaw. Crossed Nicols. × 28. (Y. 658.)

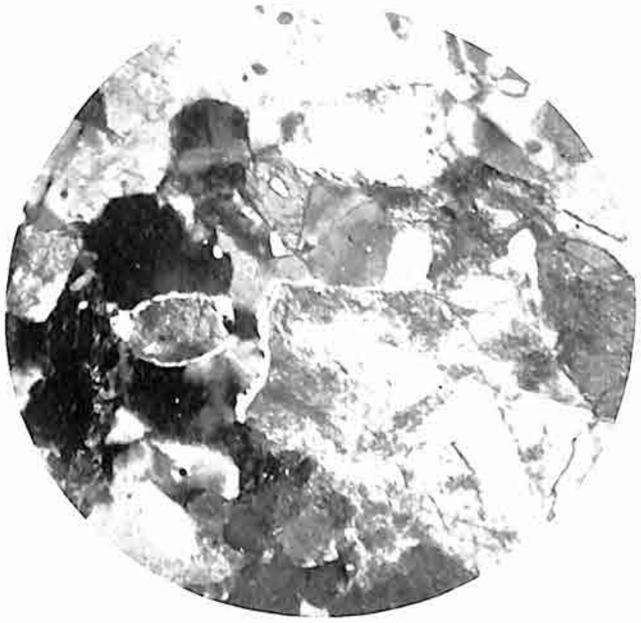


Fig. 3. Rims of quartz around plagioclases. Crossed Nicols. × 38. (Y. 10.)

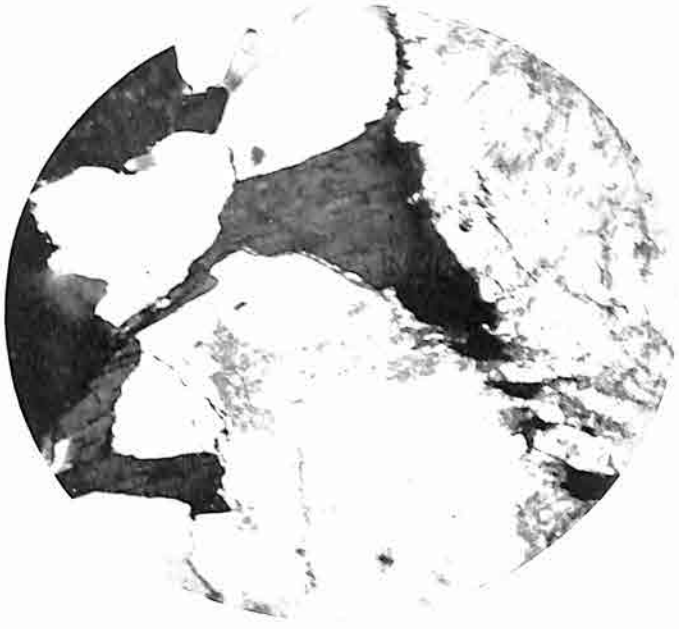


Fig. 4. Corroded (?) biotite crystal in biotite granite. × 22. (Y. 52.)

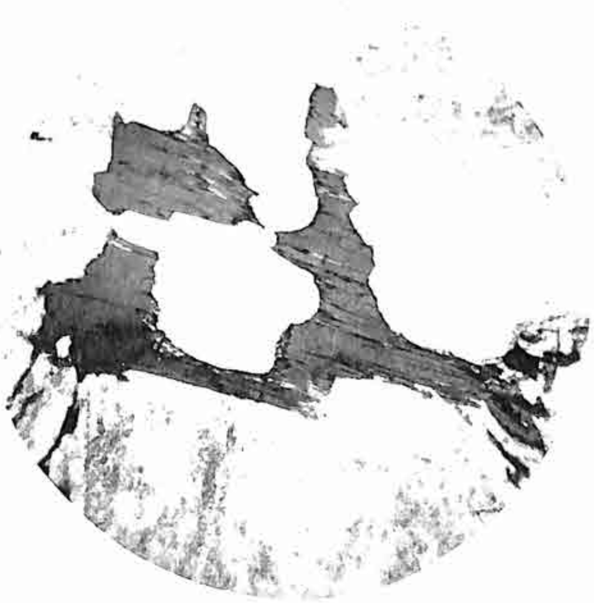
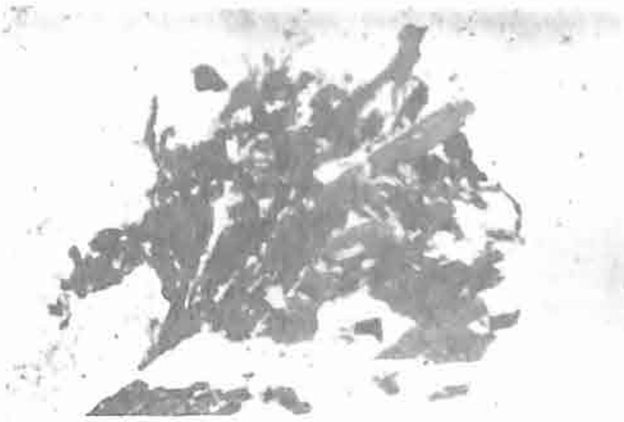
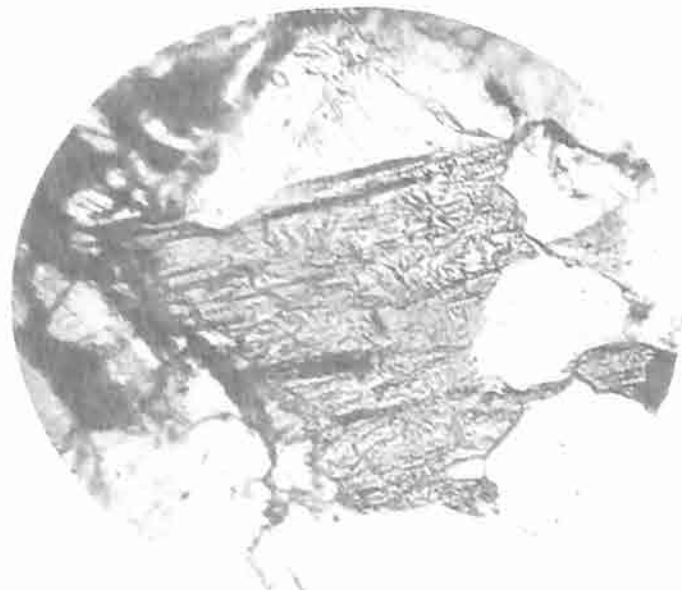


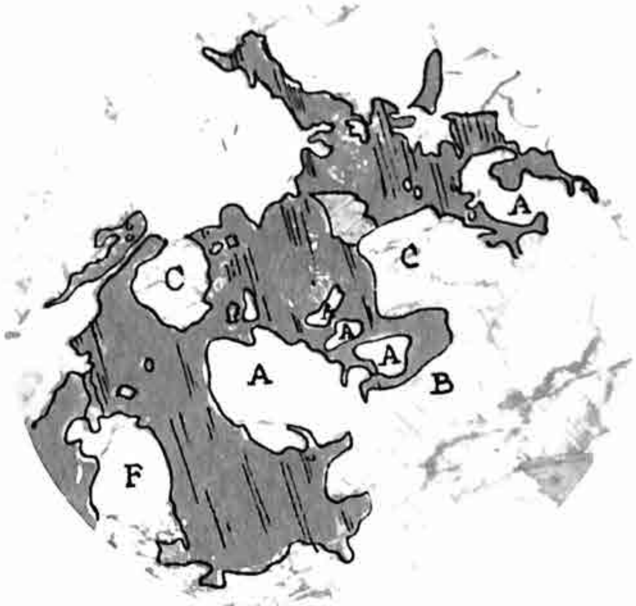
Fig. 5. Corroded (?) biotite crystal in biotite granite. × 11. (Y. 50.)

Fig. 6. Corroded [illegible]

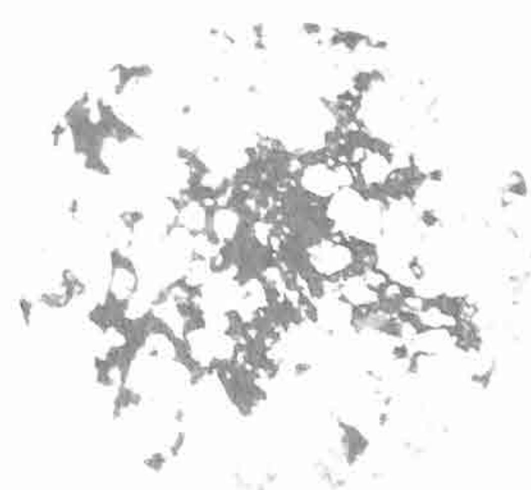
Plate 30.







Hornblende skeleton in biotite hornblende granite



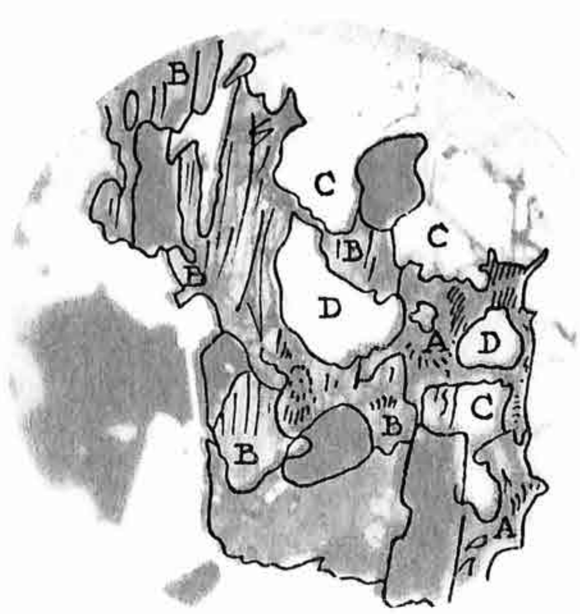


Plate 30.

Fig. 1. Group of corroded (?) biotite crystals in quartz mica diorite. × 21. (Y. 17).

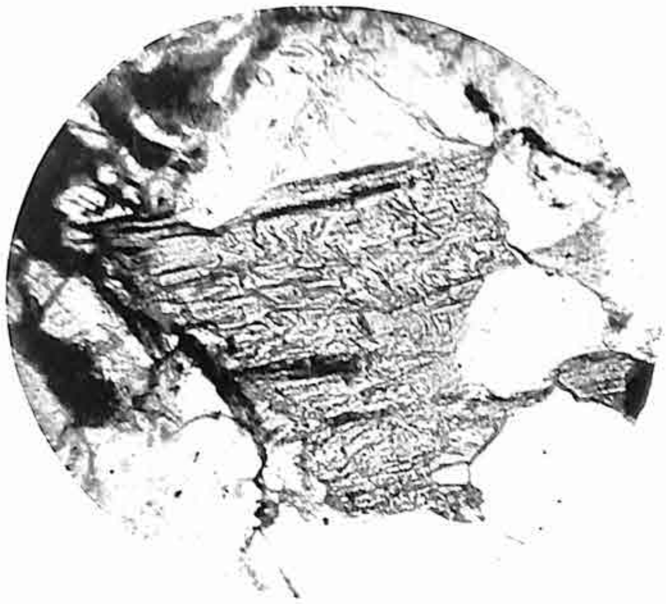


Fig. 2. Perforated muscovite crystal in bi-mica granite. × 100. (Y. 284).

Fig. 3. Hornblende skeleton in biotite hornblende granite. × 9. (Y. 53).

Fig. 4. Hornblende skeleton in biotite hornblende granite. × 16. (Y. 96).

Fig. 5. Corroded monoclinic pyroxene (left) and orthorhombic pyroxene (right) in biotite granite. × 30. (Y. 107 B).

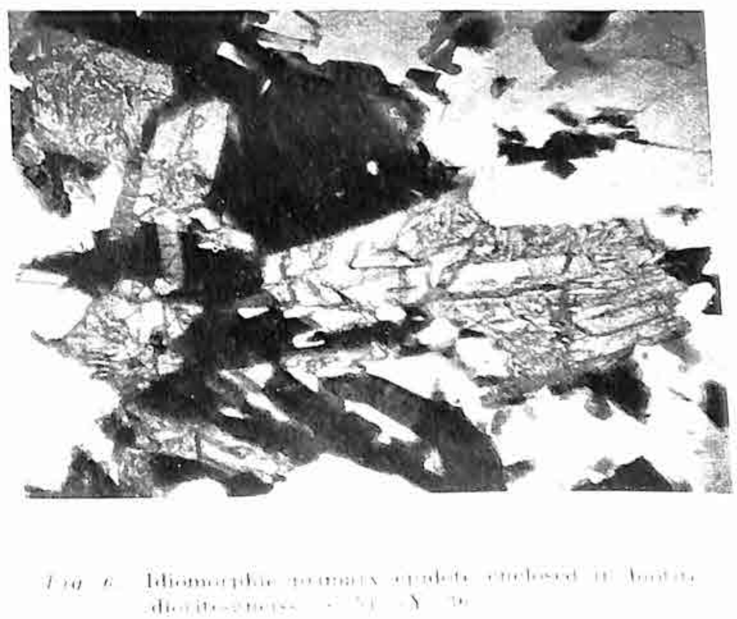


Fig. 6. Idiomorphic primary epidote enclosed in biotite diorite-gneiss. × [illegible]. (Y. [illegible]).

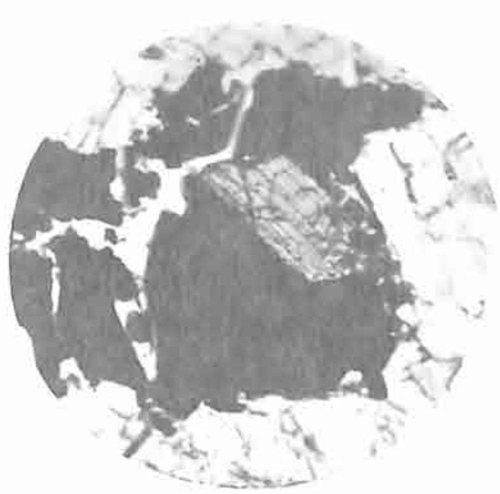


Fig. 1. Idiomorphic primary epidote enclosed in biotite, in quartz mica diorite; abt. × 70, (Y. 1317).

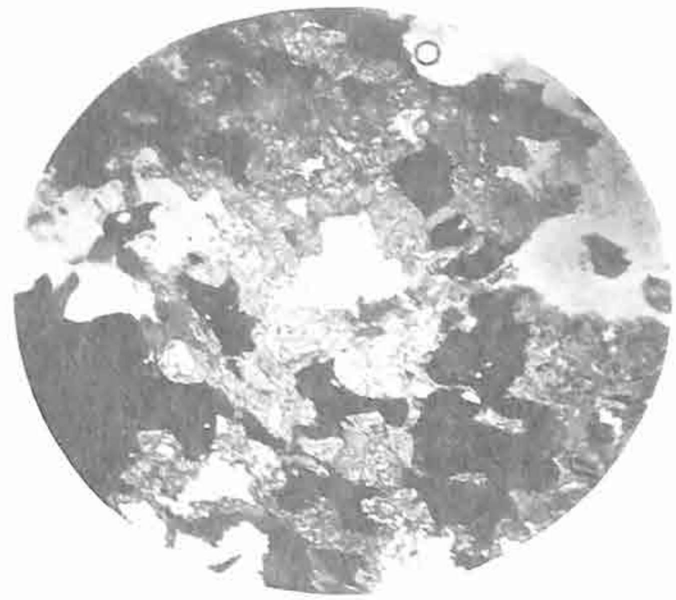
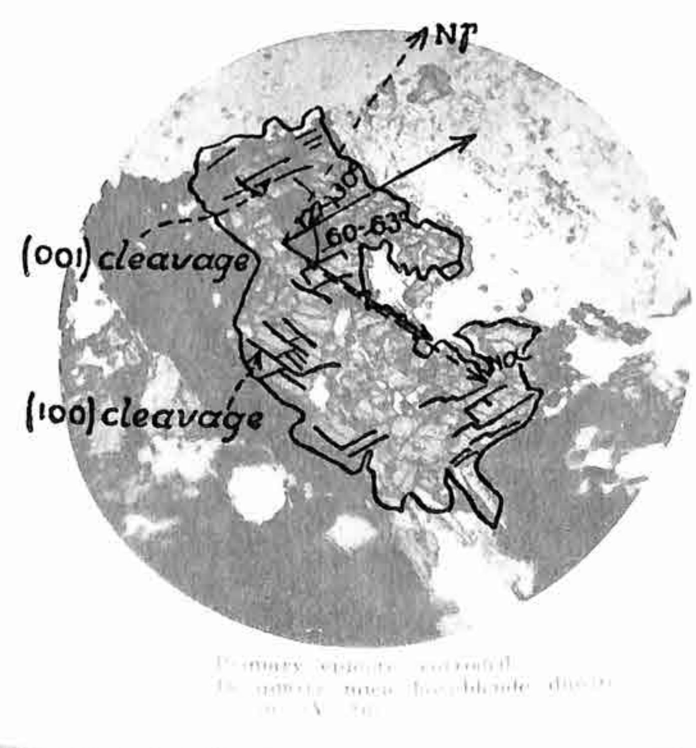


Fig. 2. Epidote showing spongelike structure in diorite-gneiss, × 16, (Y. 32).

Fig. 3. Group of corroded hornblende, biotite and primary epidote in gneissic diorite, × 30, (Y. 14)



Primary epidote corroded [illegible] quartz mica hornblende diorite [illegible]

Plate 31.

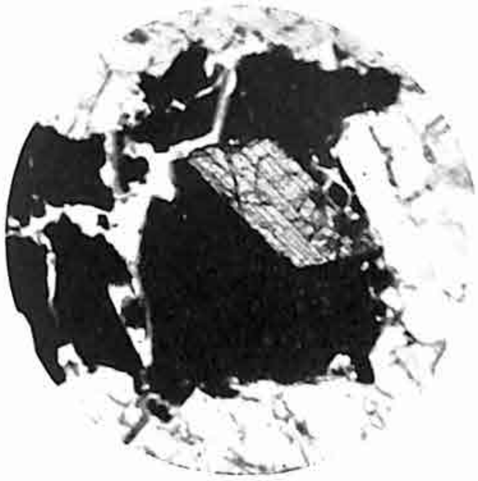


Fig. 1. Idiomorphic primary epidote enclosed in biotite: in quartz mica diorite, abt. × 70. (Y. 1417).

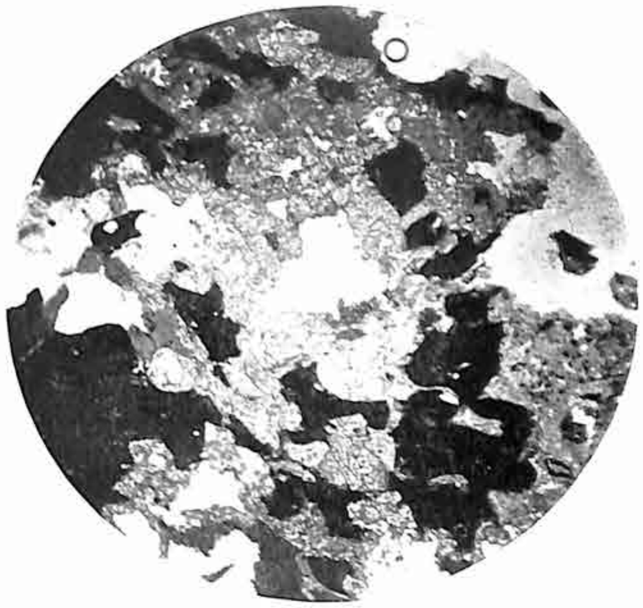


Fig. 2. Epidote showing sponge-like structure in diorite-gneiss. × 16. (Y. 32).

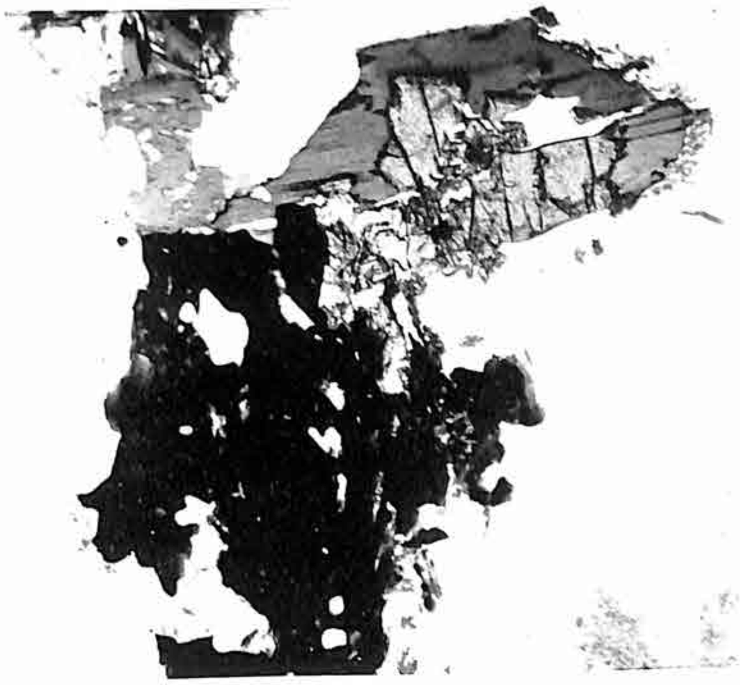


Fig. 3. Group of corroded hornblende, biotite and primary epidote in gneissic diorite. × 30. (Y. 14)

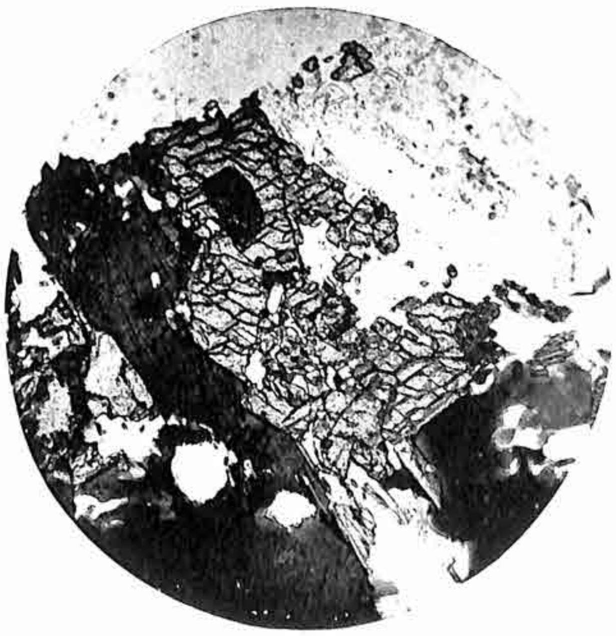


Fig. 5. Primary epidote, corroded. In quartz mica hornblende diorite × 50. (Y. 16).

Fig. 4. Primary epidote corroded [illegible] colourless minerals [illegible] (Y. [illegible])

Plate 32.

Fig. 1. Spongelike epidote in dioritegneiss, × 31. (V. 32).

Fig. 2. Orthite crystal in biotite granite, × 56. (V. 1785).

Fig. 3. Isotropic orthite-remnant in part surrounded by epidote, biotite and radiating cracks. Biotite granite, × 49. (V. 961).

Fig. 4. Ilmenite in biotite granite

Plate 32.

Fig. 1. Sponge-like epidote in dioritegneiss. × 31. (Y. 32).

Fig. 2. Orthite crystal in biotite granite. × 56. (V. 1285).

Fig. 3. Isotropic orthite-remnant in part surrounded by epidote, biotite and radiating cracks. Biotite granite. × 40. (V. 961).

Fig. 4. Ilmenite in biotite granite. × 41. (Y. 72).

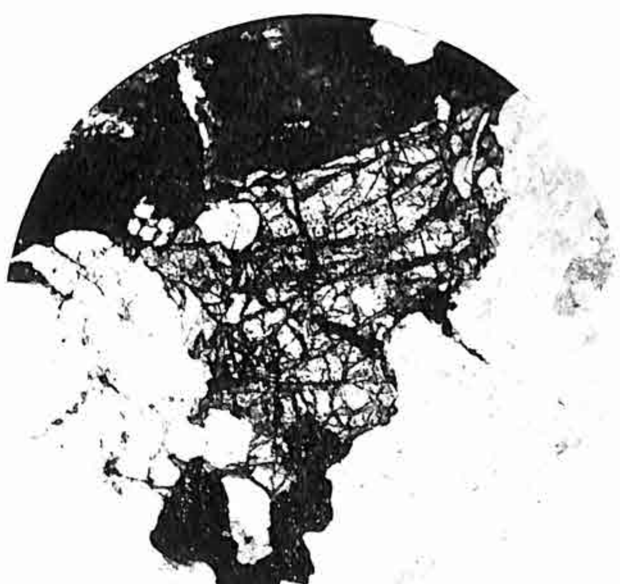


Fig. 5. Irregular-shaped titanite crystal in biotite granite. × 21. (Y. 73 B).

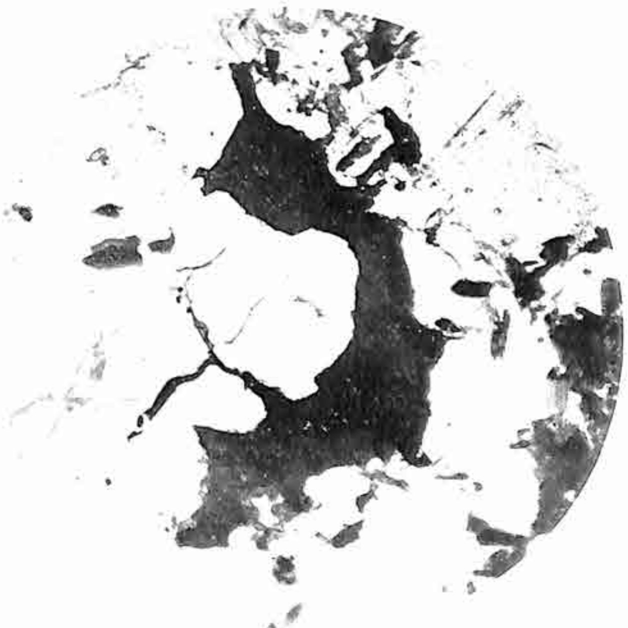


Fig. 6. Ilmenite in diorite [illegible] (Y. [illegible]

Plate 33.

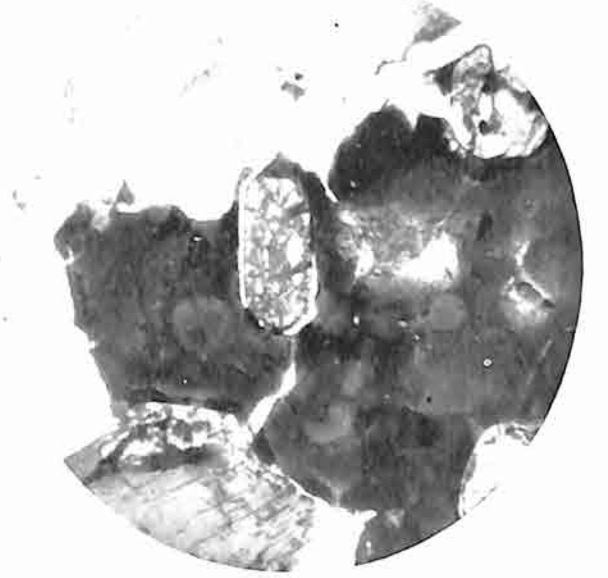


Fig. 1. Zircon showing zonal structure. Biotite granite. abt. × 50. (V. 1184).

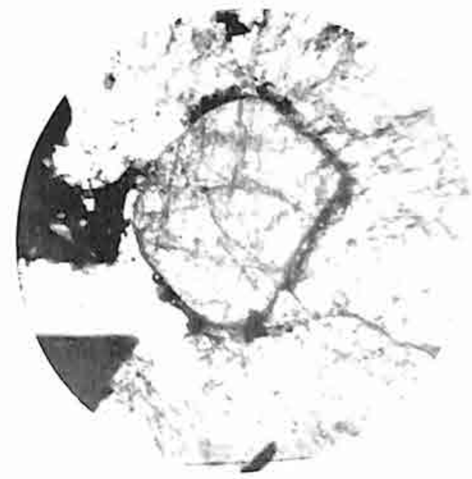


Fig. 2. Monazite crystal in biotite granite. × 71. (V. 1195).

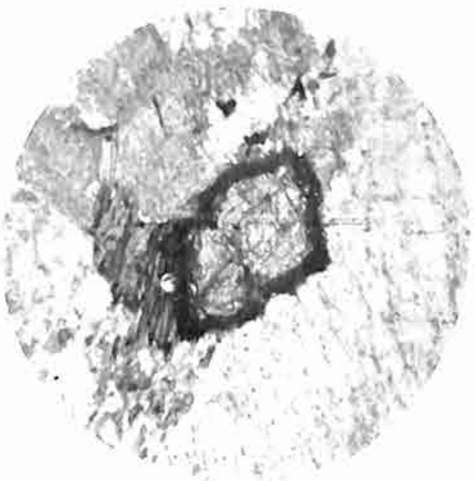


Fig. 3. Monazite showing dark transformation-rim; in biotite granite. × 140. (V. 1200).

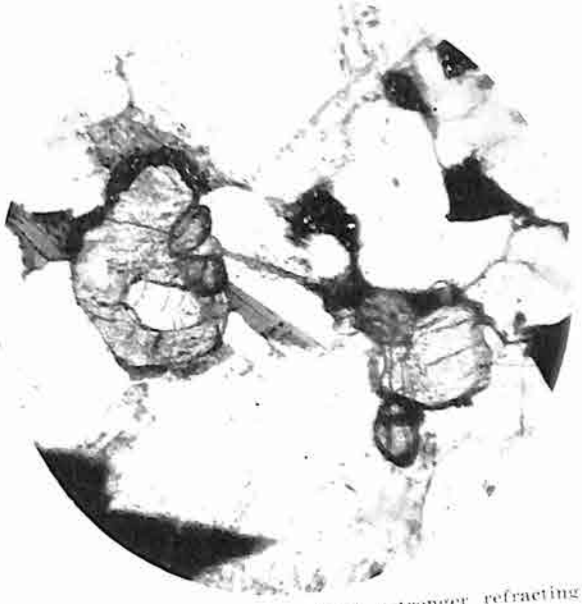


Fig. 4. Monazite enclosing zircon (stronger refracting) and apatite (clear); in biotite granite. × 70. (V. 1195).

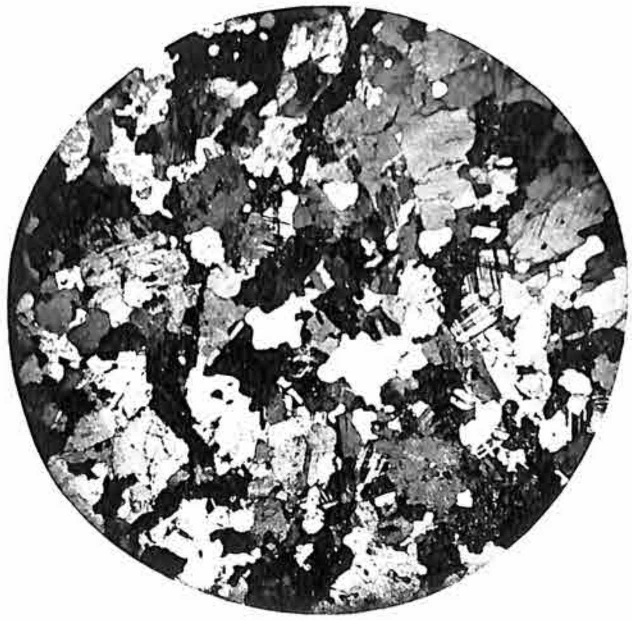


Fig. 5. Granite-gneiss. Crossed Nicols. × 9. (V. 115).

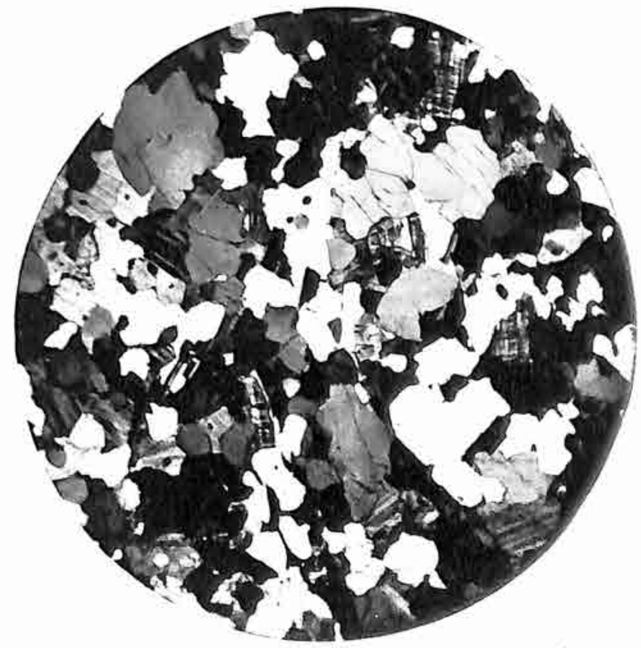


Fig. 6. Granite-gneiss. Crossed Nicols. × 13. (V. 1196).

Plate 34.

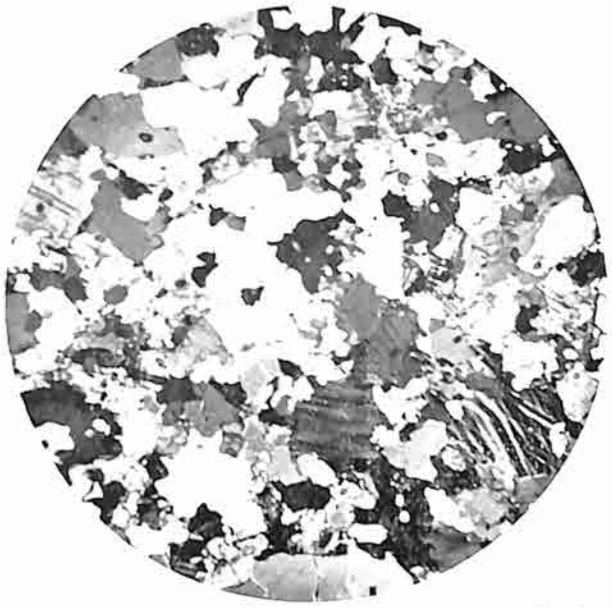


Fig. 1. Granite-gneiss. Crossed Nicols. × 10. (Y. 35).

Fig. 2. Granite-gneiss showing indistinct parallel texture. (Y. 35).

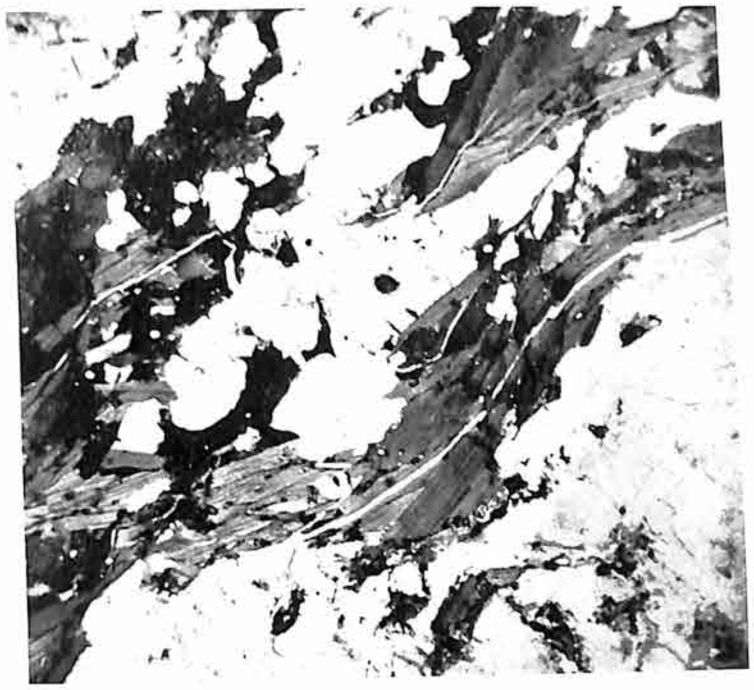


Fig. 3. Streaky arrangement of biotite in diorite-gneiss. × 16. (Y. 125).

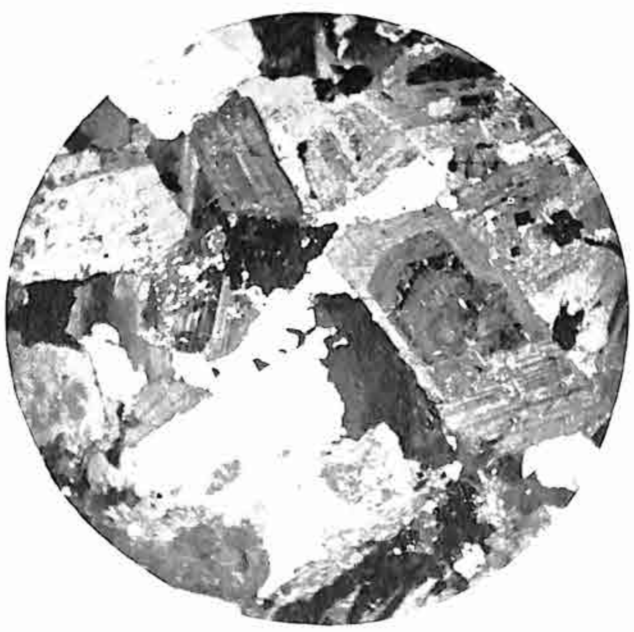


Fig. 4. Distinct idiomorphism of plagioclases in quartz mica diorite. Crossed Nicols. × 9. (Y. 166).

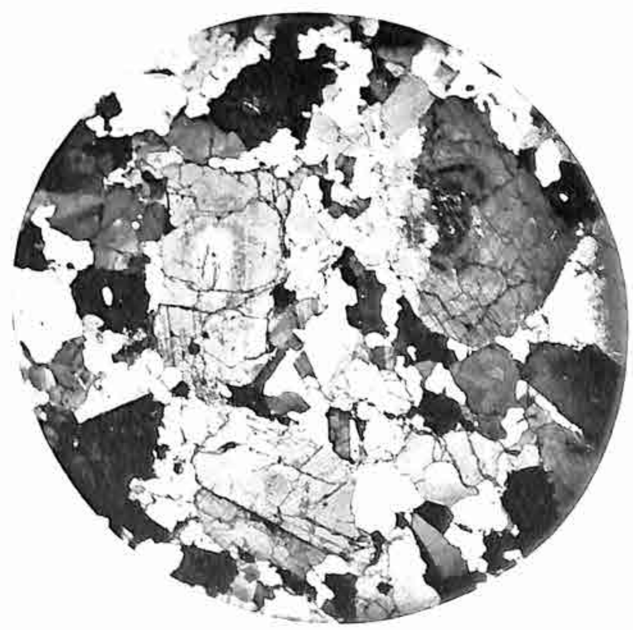


Fig. [illegible] Subidiomorphic plagioclases [illegible] mica diorite. Crossed Nicols. × 8. (Y. 1112).

Plate 35.

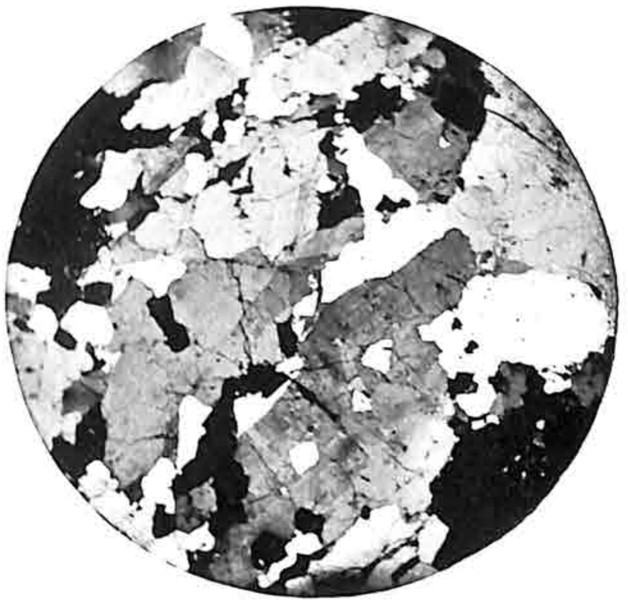


Fig. 1. Plagioclases irregular in shape, in gneissose diorite. Crossed Nicols. abt. × 10. (V. 1674).

Fig. 2. Quartz mica diorite-gneiss, "irregular" structure-type. Crossed Nicols. × 17. (V. 483).

Fig. 3. Quartz mica hornblende diorite-gneiss. "irregular" structure-type. Crossed Nicols. × 12. (Y. 21).

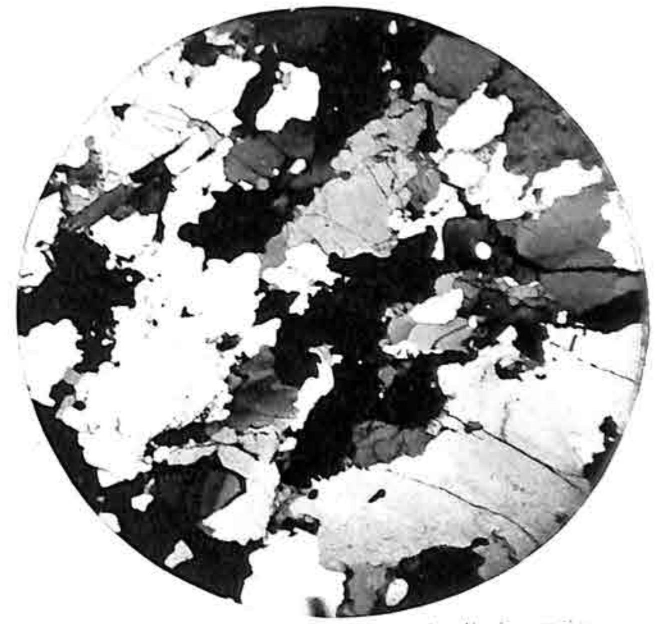


Fig. 4. Quartz mica hornblende diorite-gneiss. "undulating" structure-type. Crossed Nicols. × 10. (Y. 30 B).

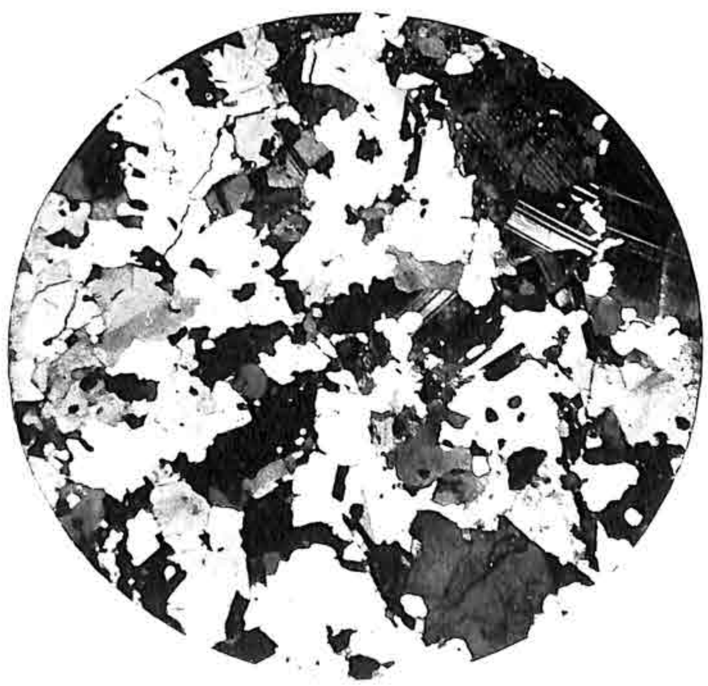


Fig. 5. Quartz mica hornblende diorite-gneiss. Crossed Nicols. × 18. (Y. 35).

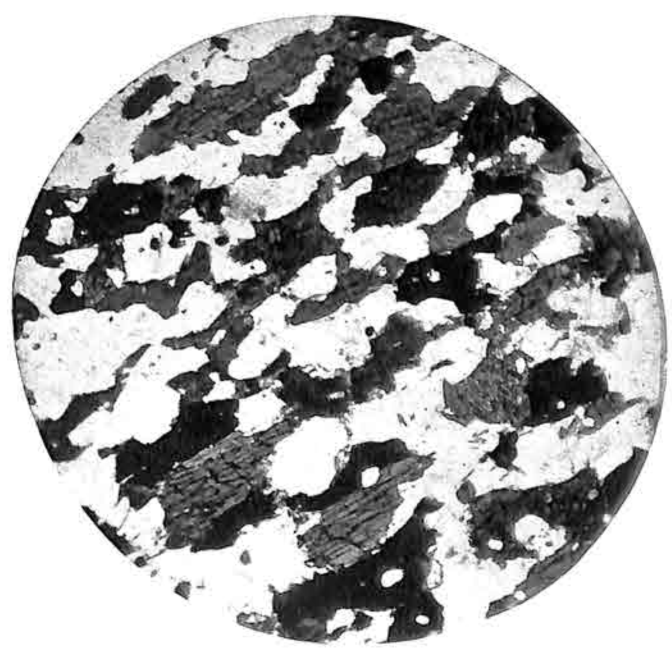


Fig. 6. Hornblende diorite-gneiss. × 18. (Y. [illegible]).

Plate 36.

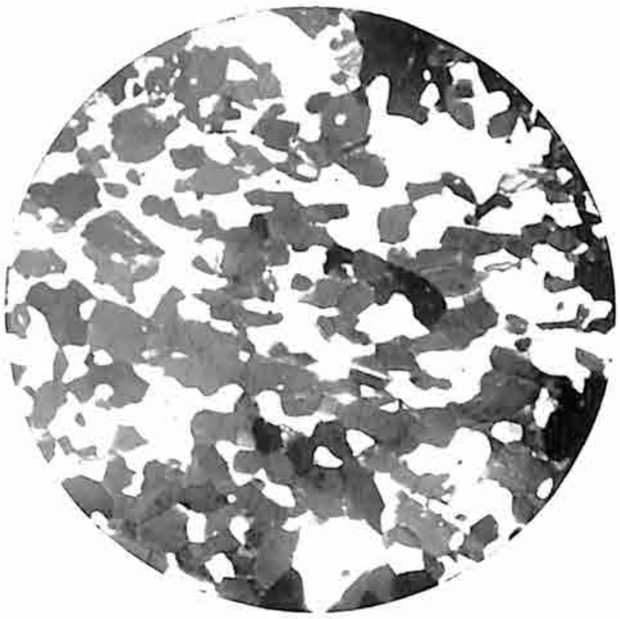


Fig. 1. Hornblende gneiss. × 27. (Y. 46).

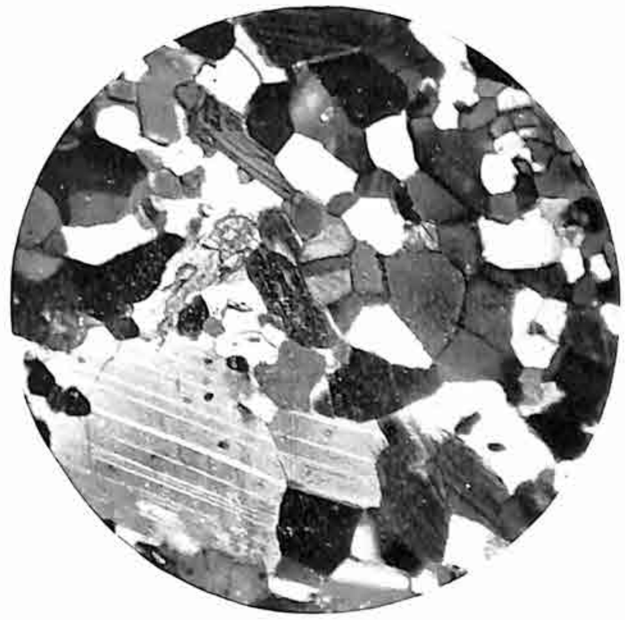


Fig. 2. Detail of fig. 1. Crossed Nicols. × 53.

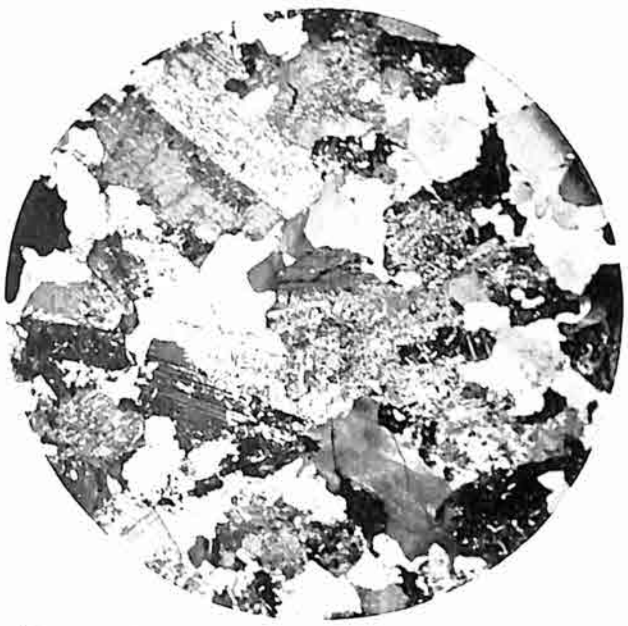


Fig. 3. Sub-idiomorphic plagioclases in part containing sericite scales, in aplitic diorite. Crossed Nicols. × 11. (V. 1113).

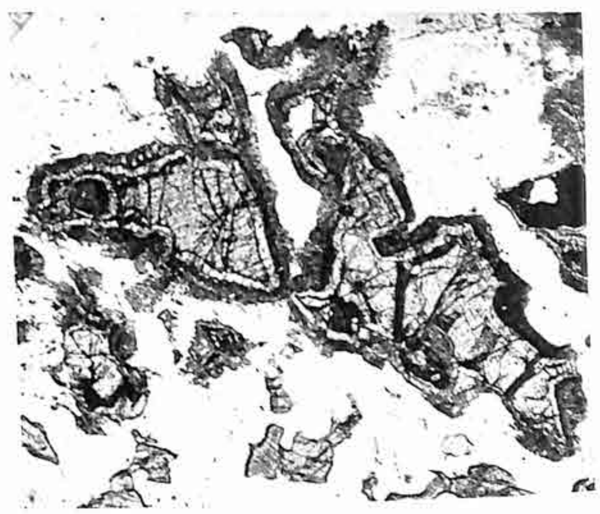


Fig. 4. Dubble kelyphitic zones around olivine in gabbro. × 20. (V. 512).

Fig. 5. Polysynthetic hornblende in quartz-bearing diorite. Crossed Nicols. × 55. (V. 645).

Fig. 6. Hornblende with enclosed idiomorphic plagioclases in quartz mica hornblende diorite. × 33. (V. 664).

Plate 37.

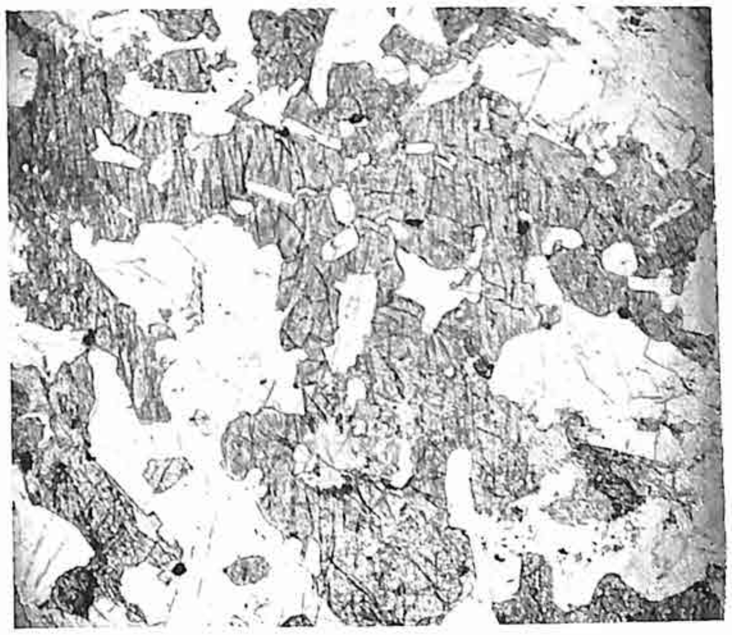


Fig. 1. Norite with large orthorhombic pyroxenes of irregular shape. × 16. (V. 516).

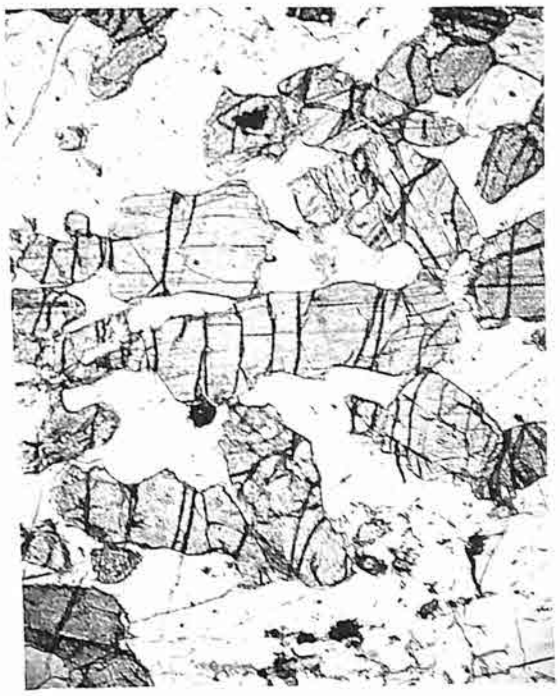


Fig. 2. Oblong orthorhombic pyroxenes in norite. × 20. (V. 695).

Fig. 3. Pyroxenes of irregular shape in gabbro. × 13. (V. 512).

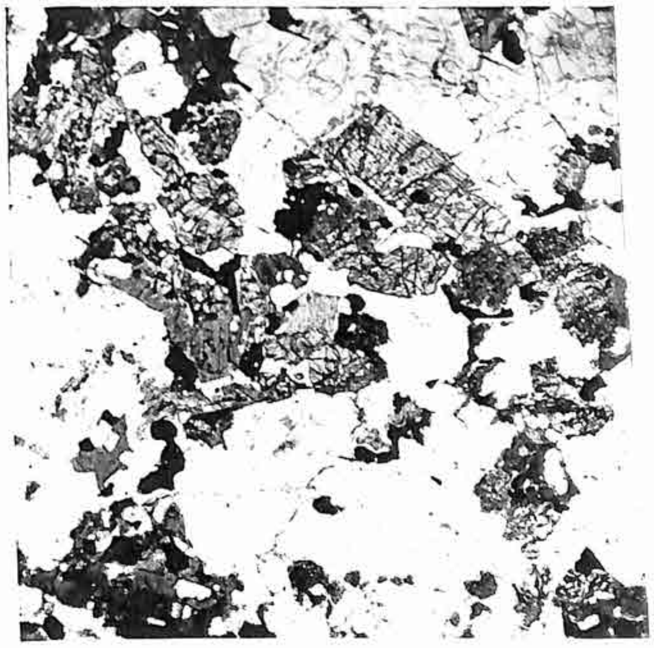


Fig. 4. Quartz-bearing hypersthene hornblende diorite. × 12. (V. 615).

Plate 38.

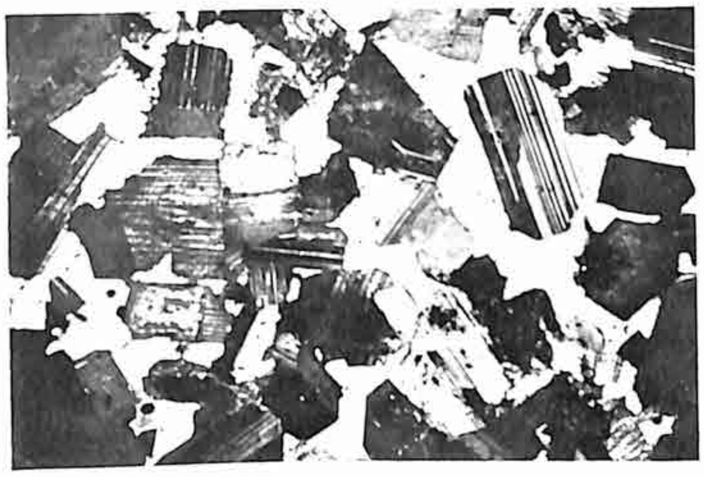


Fig. 1. Idiomorphic plagioclases in quartz mica hornblende diorite. Crossed Nicols. × 16. (V. 630).

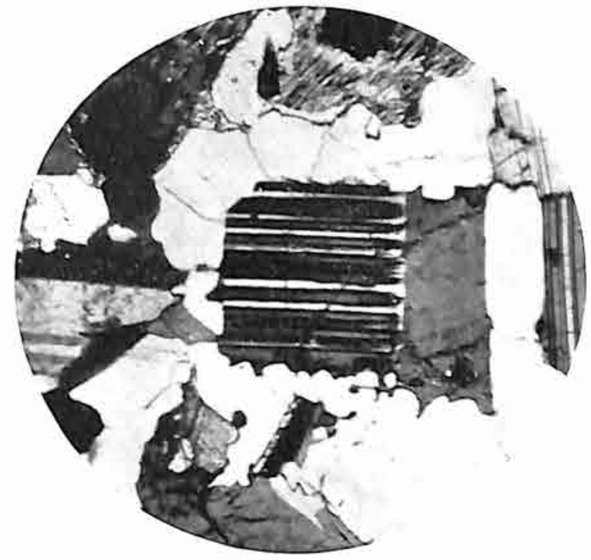


Fig. 2. Plagioclase-crystal with "sutured" border-lines. The same rock as fig. 1. Crossed Nicols. × [illegible].

Fig. 3. Reaction-rim of garnet around ore; in gabbro. × 20. (V. 2082).

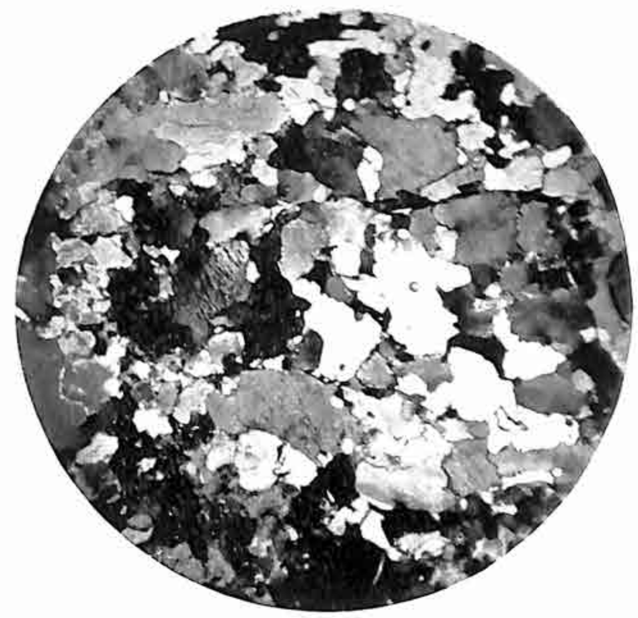


Fig. 4. Quartz hypersthene gneiss. Crossed Nicols. × 15. (V. 2035).

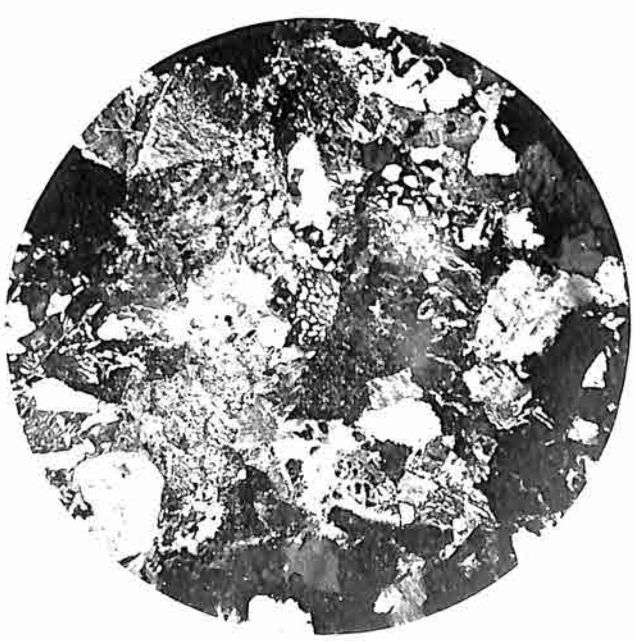


Fig. 5. Granophyre in aplitic granite. Crossed Nicols. × 16. (V. 216).

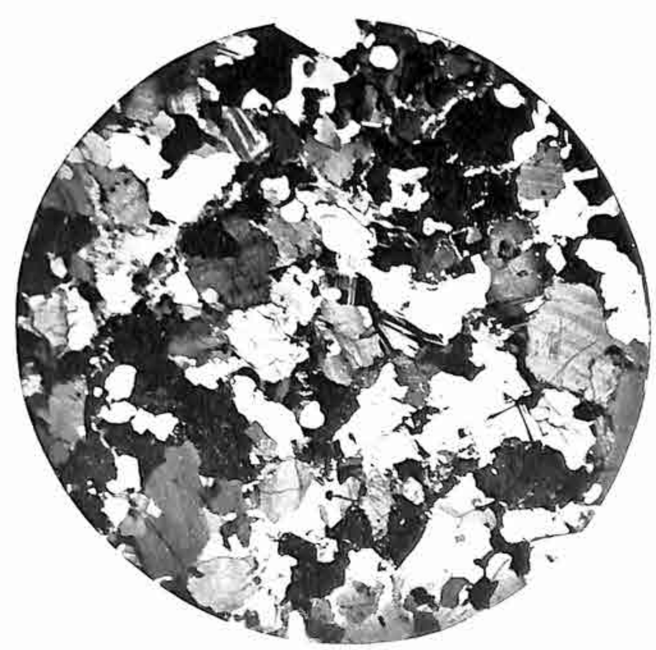


Fig. 6. Granite-gneiss. Crossed Nicols. abt. × 8. (V. [illegible]).

Plate 39.

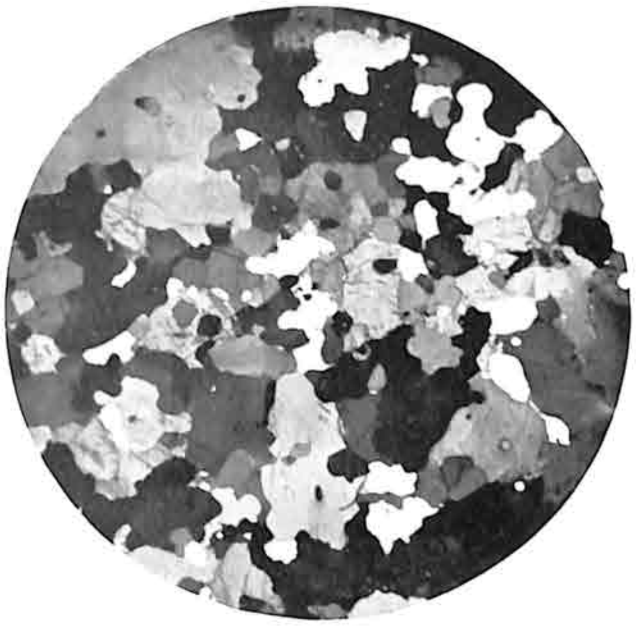


Fig. 1. Granite-gneiss. Crossed Nicols. × 9. (V. 1076).

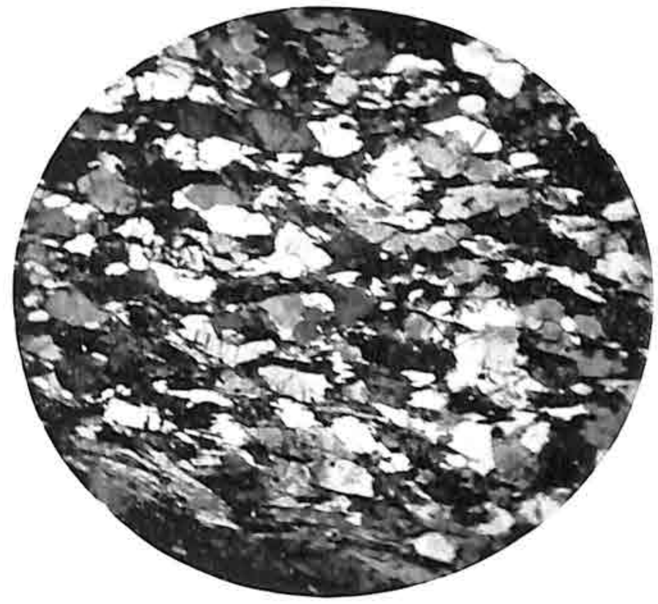


Fig. 2. Granitegneiss. Crossed Nicols. × 16. (V. 285 B.).

Fig. 3. Eyegneiss (granitegneiss). Crossed Nicols. × 10. (V. 2356).

Fig. 4. Hornblende granitegneiss. Crossed Nicols. × 15. (V. 1086).

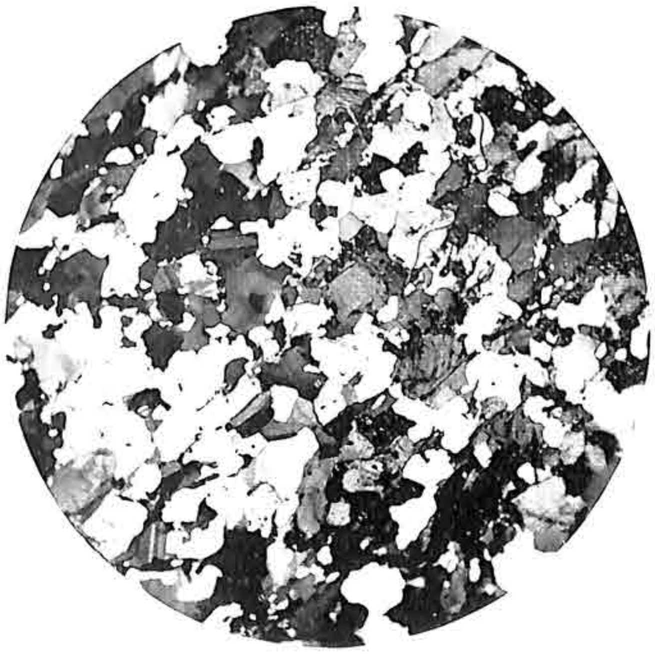


Fig. 5. Quartz mica dioritegneiss. Crossed Nicols. × 13. (V. 1159).

Fig. 6. Quartz mica dioritegneiss. Crossed Nicols. × 16. (V. 208).

Plate 40.

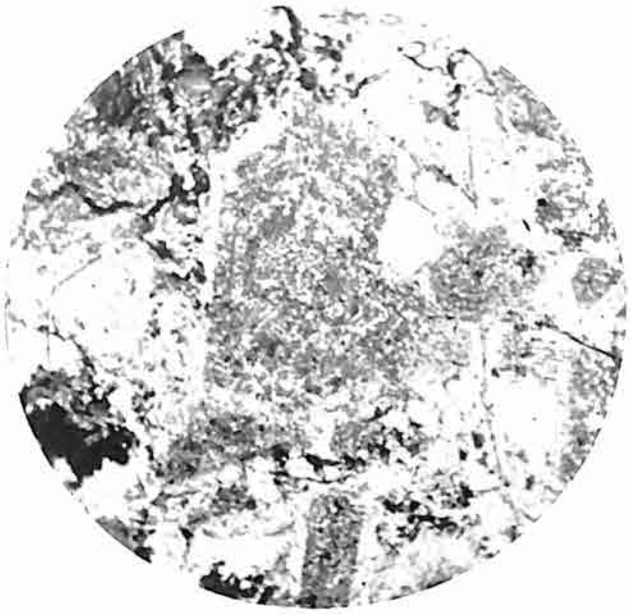


Fig. 1. Plagioclases replaced by epidote-grains in quartz mica diorite. × 20. (V. 1568).

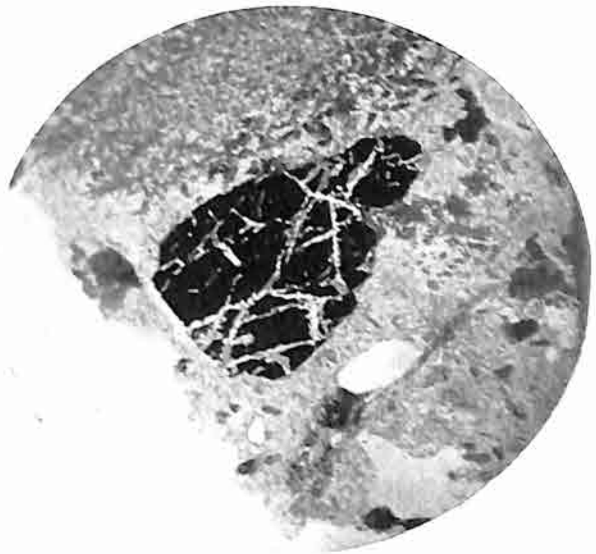


Fig. 2. Ore intersected by channels filled with sericite; in granite. × 31. (Y. 42).

Fig. 3. Epidioritised gabbro showing secondary hornblende. × 19. (V. 509).

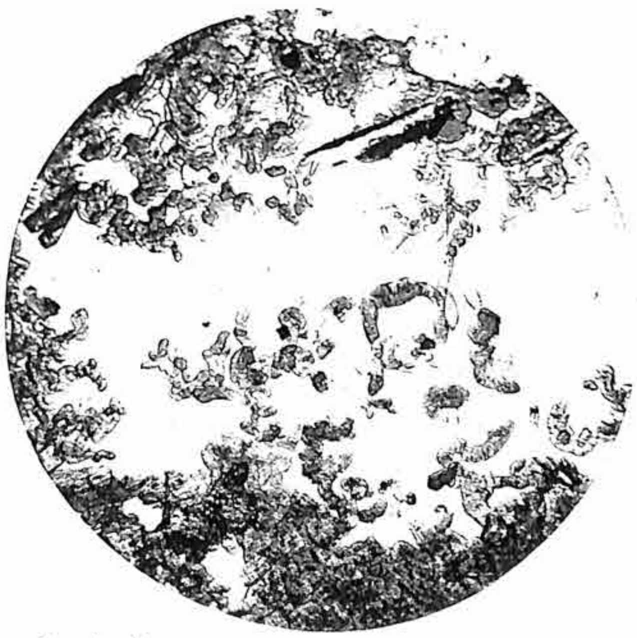


Fig. 4. Quartz containing curved chlorite aggregates. × 72. (Y. 60).

Fig. 5. Undulose quartz, in part crushed; in granite. Crossed Nicols. × 25. (Y. 116).

Plate 41.

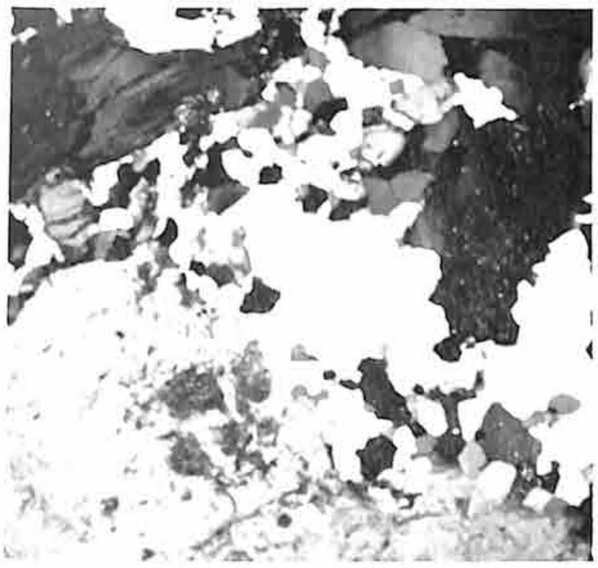


Fig. 1. Crushed quartz [illegible] granite. Crossed Nicols. × [illegible] (Y. [illegible]).

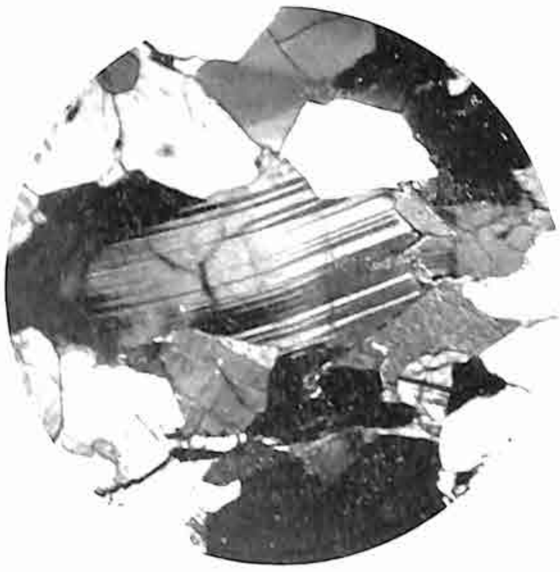


Fig. 2. Warped twinning structure of plagioclase in diorite-gneiss. Crossed Nicols. × 44. (Y. 288).

Fig. 3. Cataclastic quartz mica diorite-gneiss showing undulating streaks of biotite. × 11. (Y. 287).

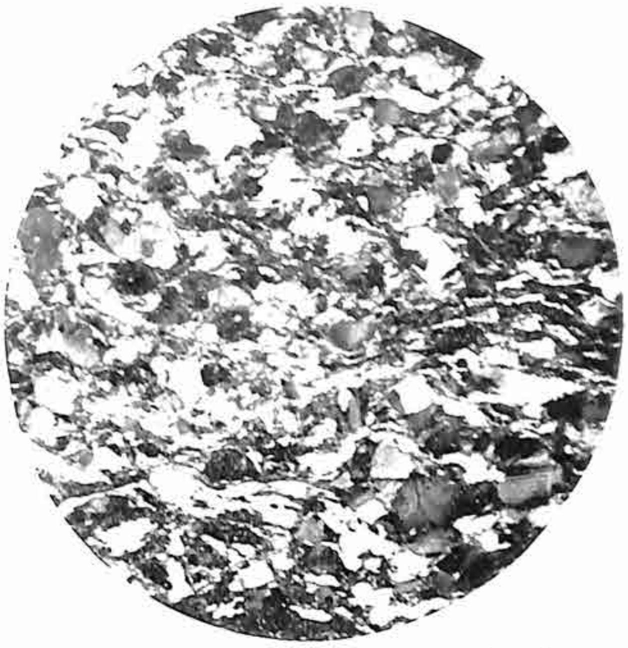


Fig. 4. The same as fig. 3. Crossed Nicols. × 10. (Y. 287).

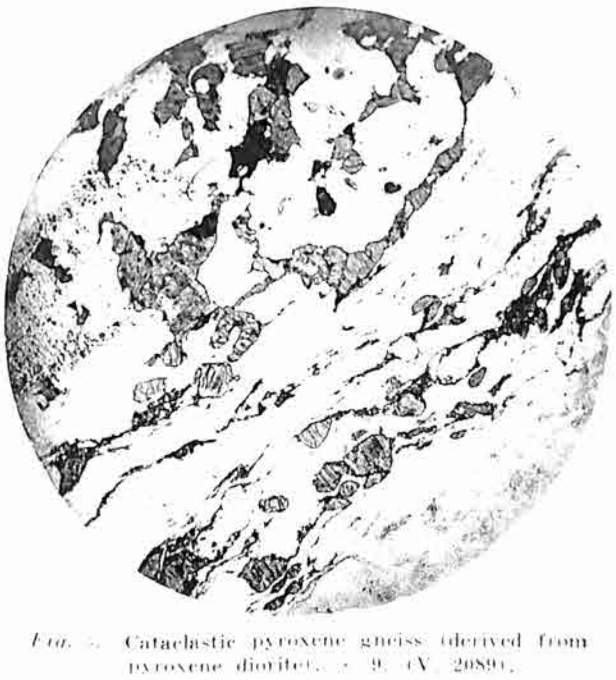


Fig. 5. Cataclastic pyroxene gneiss (derived from pyroxene diorite). × 9. (Y. 2089).

Fig. 6. The same as fig. 5, detail. Crossed Nicols. × 25.

Plate 42.

Fig. 1. Mylonized part of cataclastic granite-gneiss, showing pseudo-fluidal texture. × 20. (Y. 324).

Fig. 2. Mylonized granite. Crossed Nicols. × 18. (Y. 76).

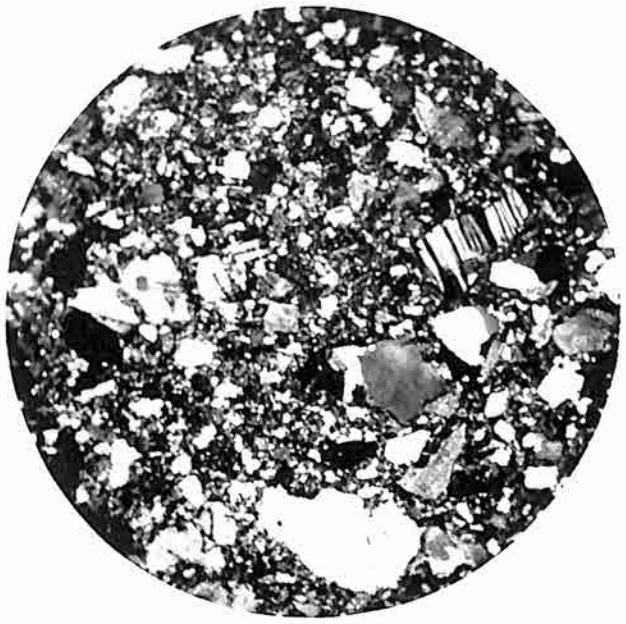


Fig. 3. Mylonized granite. Crossed Nicols. × 20. (V. 1059).

Fig. 4. Fragments of crushed feldspar and quartz enclosed in pseudo-tachylyte. × 31. (Y. 324 B.).

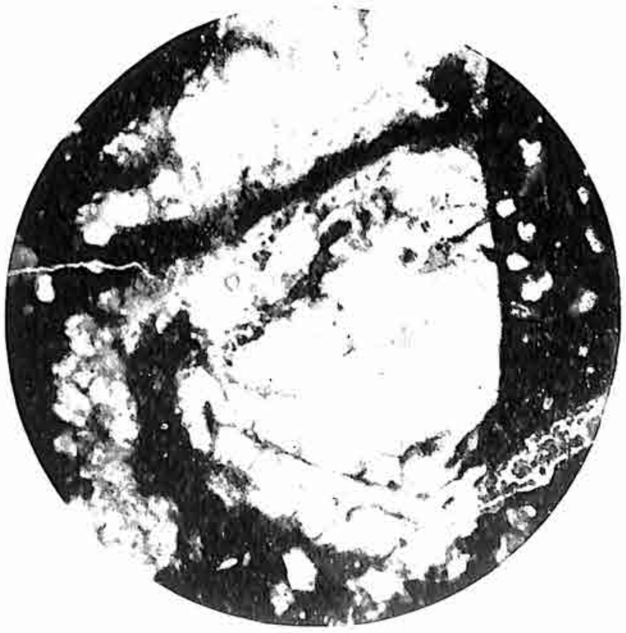


Fig. 5. Detail of fig. 4. × 61.

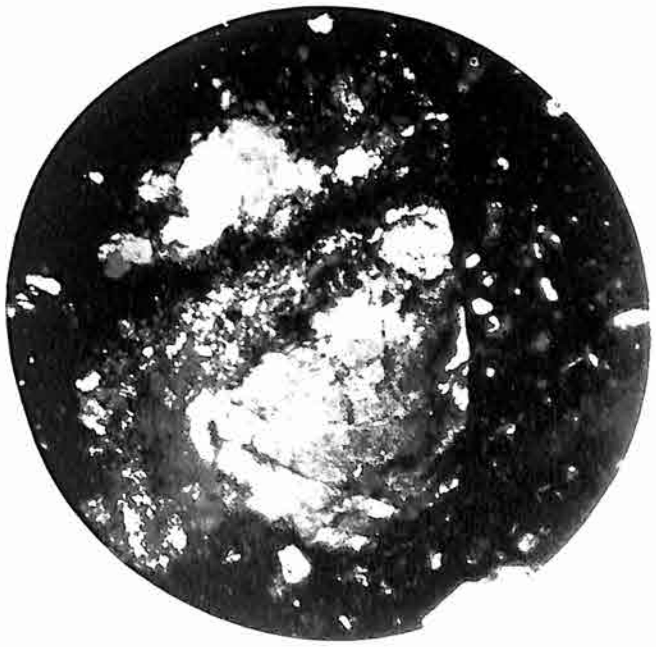


Fig. 6. The same as fig. 5. Crossed Nicols. [illegible]

Plate 43.

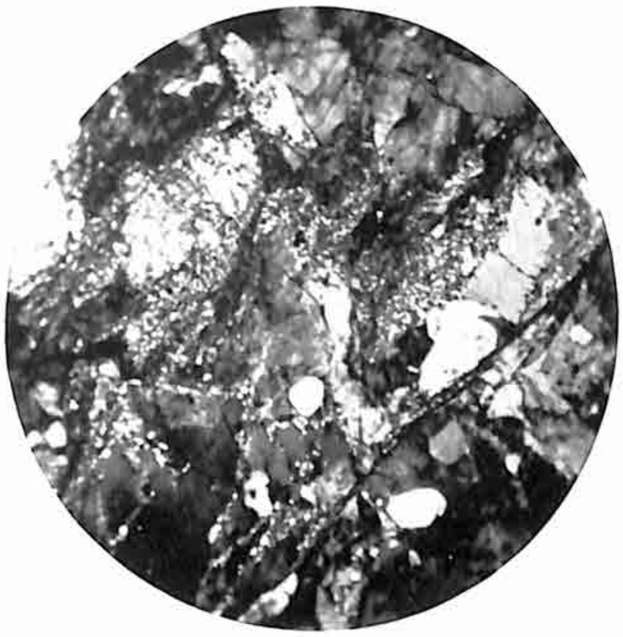


Fig. 1. Intensely crushed granite-gneiss (this gneiss adjoins to pseudo-tachylyte). Crossed Nicols. abt. × 25. (V. 2342).

Fig. 2. Large sillimanite-needles with cross-factures and enclosed dust; in sillimanite-hypersthene gneiss. × 11. (V. 2064).

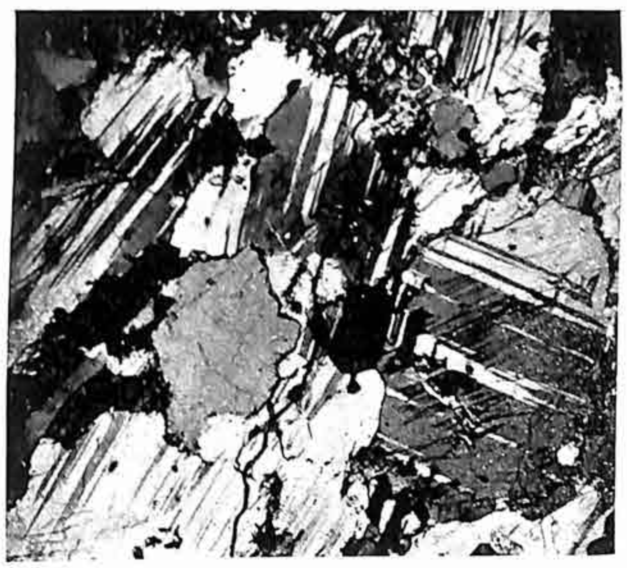


Fig. 3. Fields of cordierite showing polysynthetic twinning, in sillimanite cordierite gneiss. Crossed Nicols. × 31. (V. 1905).

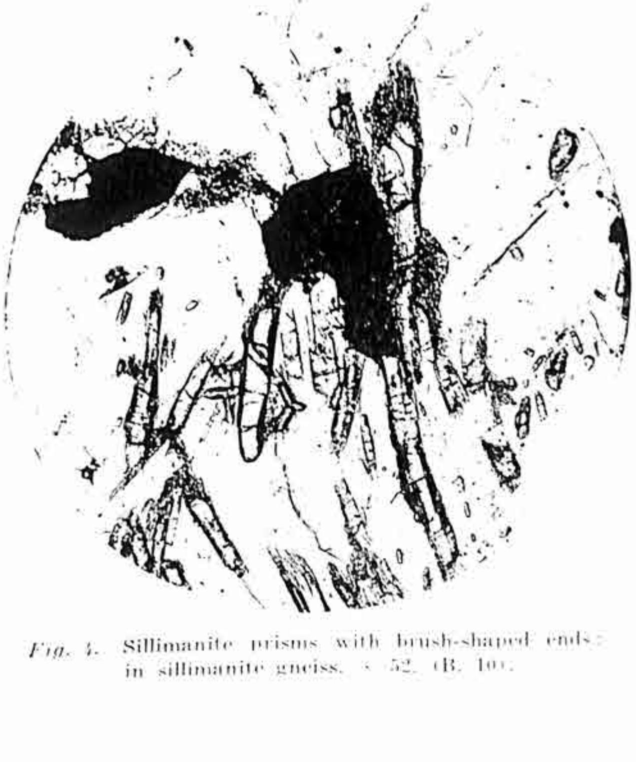


Fig. 4. Sillimanite prisms with brush-shaped ends; in sillimanite gneiss. × 52. (B. 10).

Fig. 5. Sillimanite crystal with brush-shaped edge; in sillimanite gneiss. × 31. (V. 2065).

Plate 44.

Fig. 1. Ore surrounded by sillimanite-fibres, in sillimanite gneiss. × 17. (B. 10).

Fig. 2. Sillimanite cordierite gneiss showing numerous sillimanite needles and ore-grains. × 17. (Y. 95).

Fig. 3. Porphyroblasts of garnet and skeleton of staurolite (at right), in garnet staurolite gneiss. × 18. (V. 61).

Fig. 4. Skeleton-like porphyroblast of staurolite, and garnets, in garnet staurolite gneiss. × 8. (U1. 1902 [illegible]).

Plate 45.

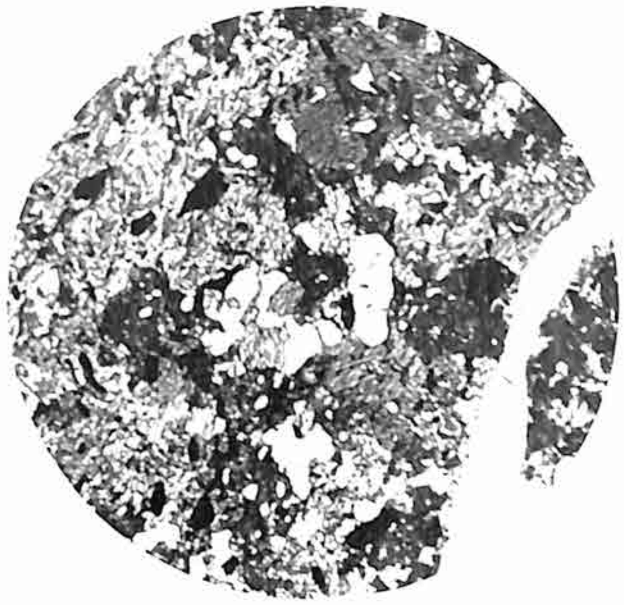


Fig. 1. Hornblende gneiss (para-gneiss) containing rolled-off apatite crystals. × 14. (V. 289).

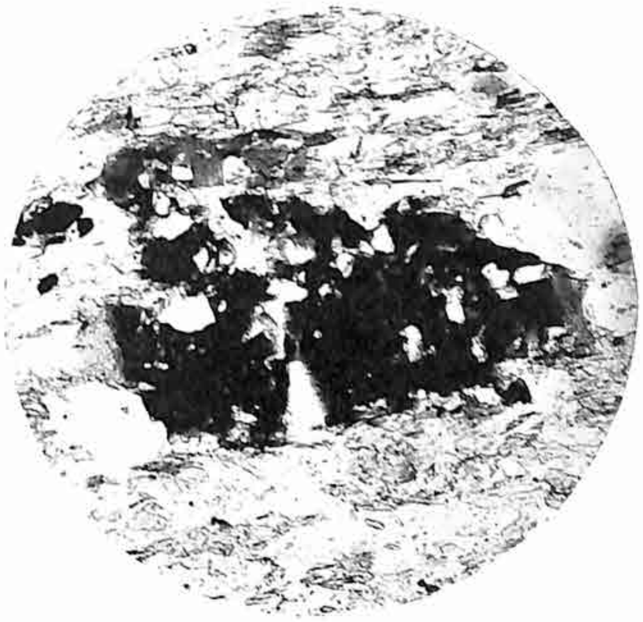


Fig. 2. Biotite porphyroblast in crystalline graywacke. × 40. (V Ez. 363).

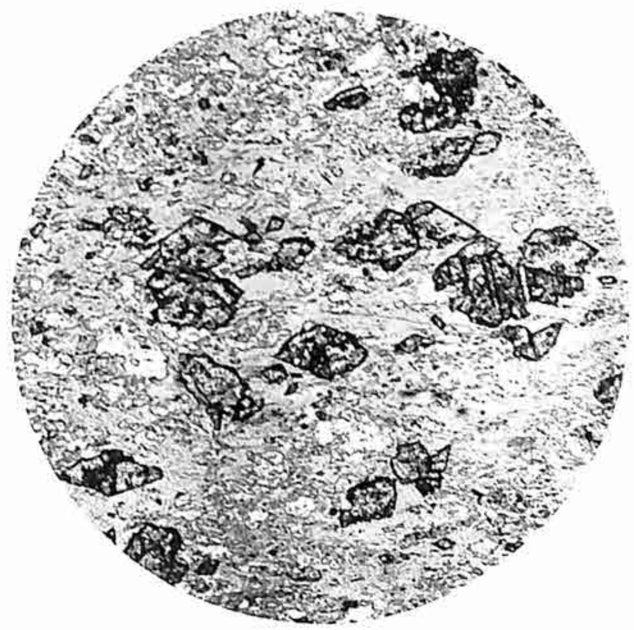


Fig. 3. Idiomorphic titanite crystals in quartz chlorite schist. × 32. (V. 1548).

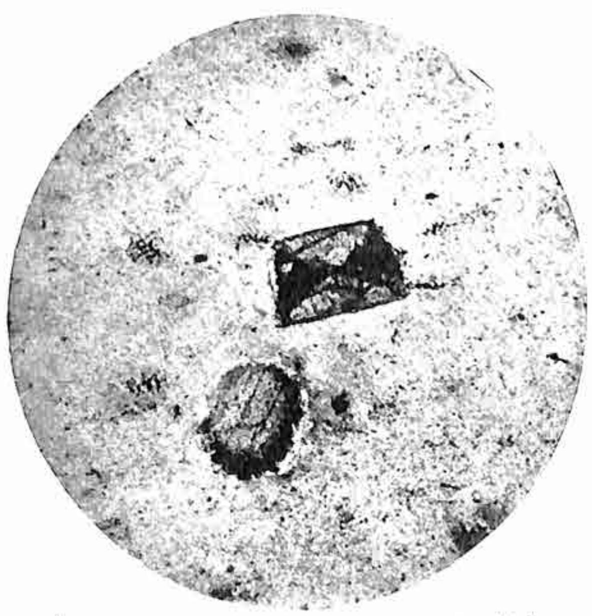


Fig. 4. Porphyroblasts of chloritoid in phylite; one of them showing time-glass structure. × 24. (V. 4044).

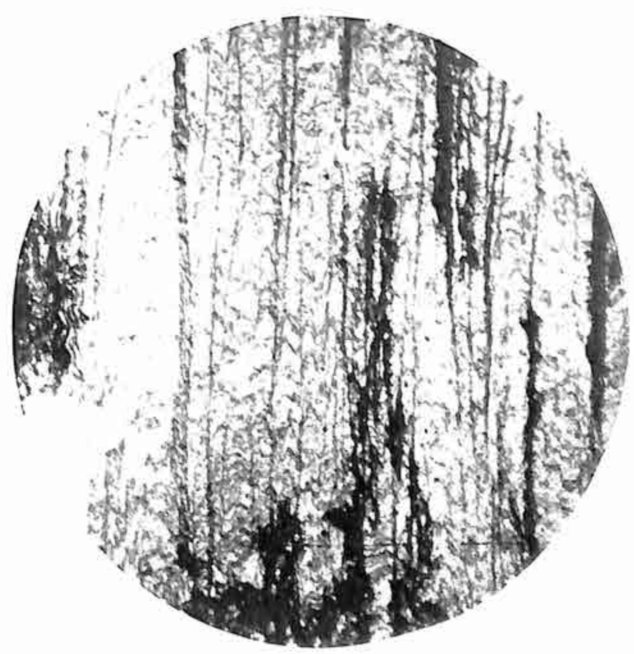


Fig. 5. Helicitic texture in phyllite. × 14. (V. 1642).

Plate 46.

Fig. 1. Magnetite quartzite. × 17. (V. 1579).

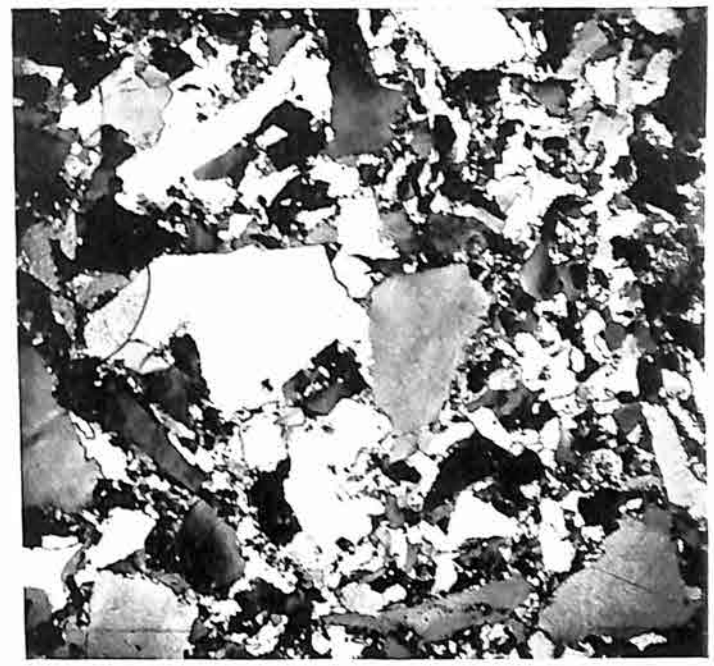


Fig. 2. Breccia-structure in quartzite. Crossed Nicols. × 17. (V. 1302).

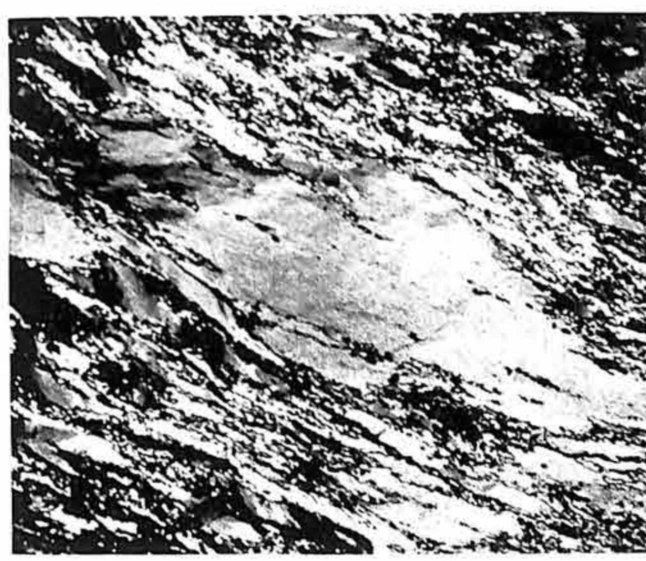


Fig. 3. Schistose quartzite showing undulose fields. Crossed Nicols. × 19. (V. 823).

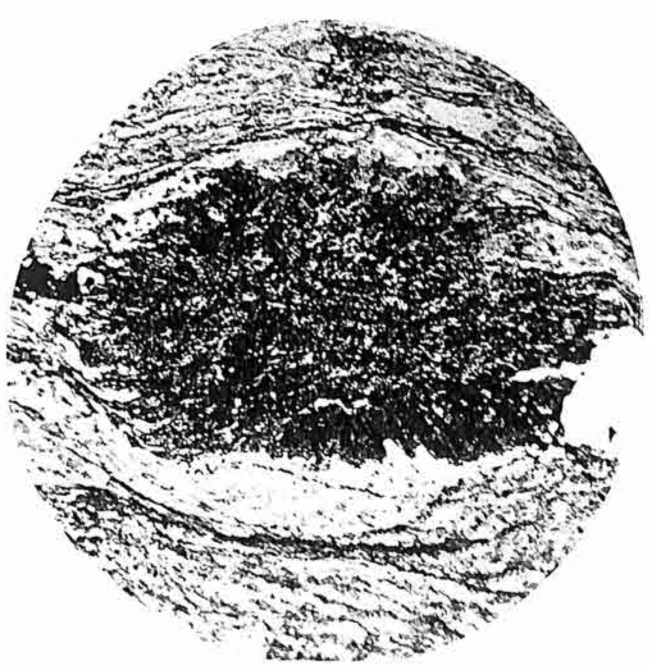


Fig. 4. Porphyroblast of chloritoid in chloritoid quartzite. × 28. (V. 11[illegible]).

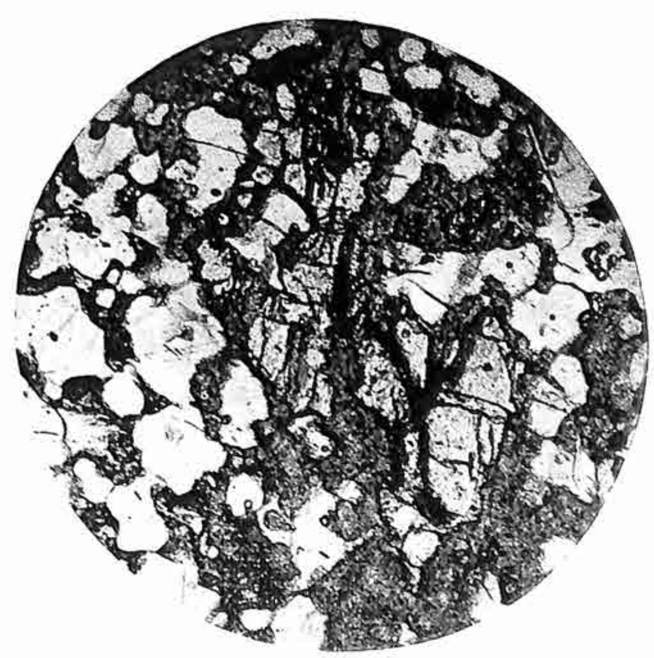


Fig. 5. Andalusite (showing cross-fractures) and sericite in andalusite hornfels. × 34 (V. 1[illegible]).

Plate 47.

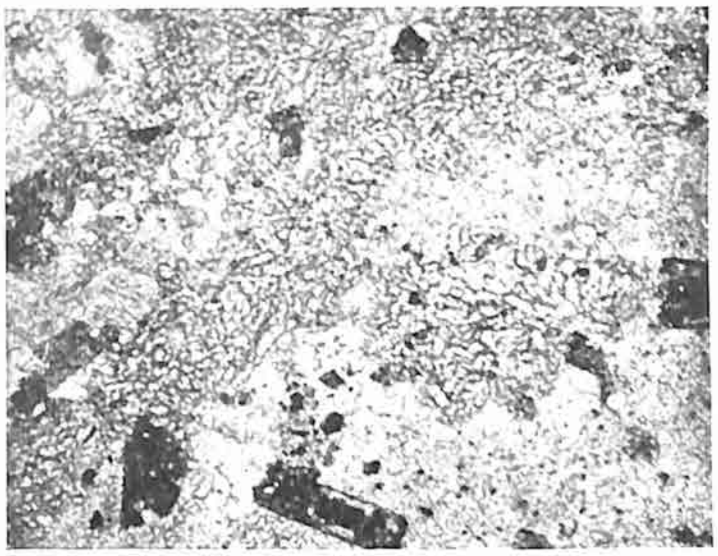


Fig. 1. Andalusite [illegible] showing small andalusite [illegible] × 20. (V. 218 A).

Fig. 2. Amphibolite. × 25. (V. 140).

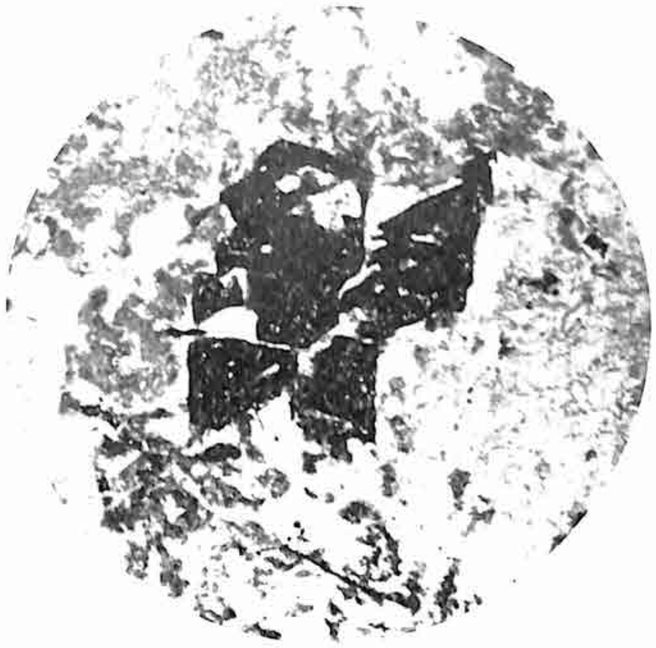


Fig. 3. Oreskeleton in epidiorite. × 30. (V. 1008).

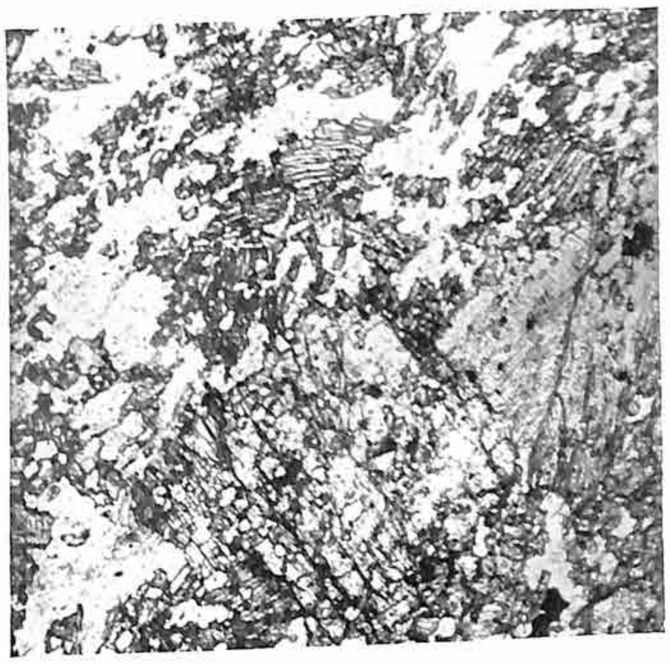


Fig. 4. Kyanite quartzite. × 22. (V. 1512).

Fig. 5. Intensely perforated hornblende in amphibolite. × 36. (V. 968).

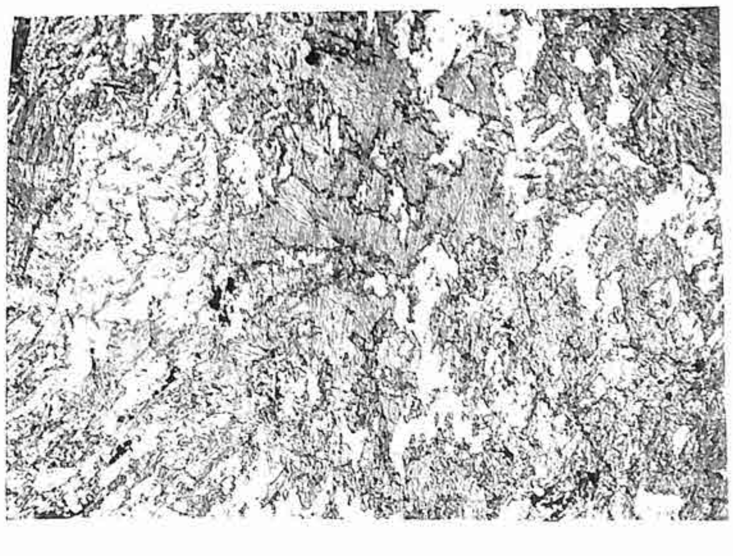


Fig. 6. [illegible] hornblende in [illegible] × [illegible] (V. [illegible]).

Plate 48.

Fig. 1. Crystalloblastic plagioclase enclosing numerous quartz-droplets in hornblende gneiss. × 60. (V. [illegible]).

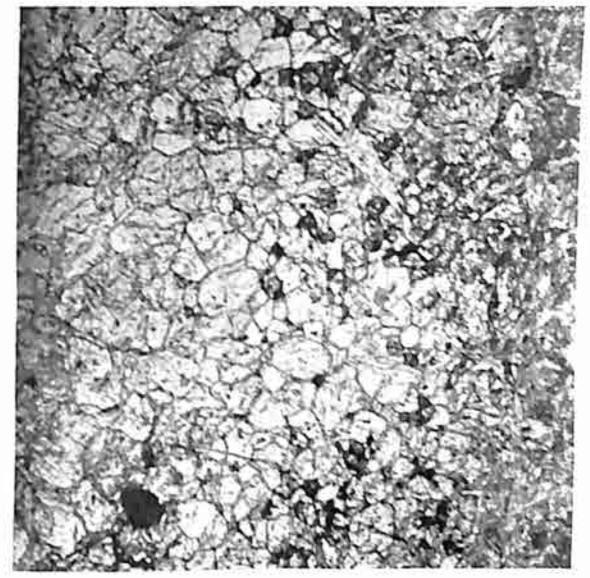


Fig. 2. Mozaic of pyroxene-grains in hornblende pyroxenite. × 20. (V. 367).

Fig. 3. Garnet-porphyroblast in hornblende gneiss. × 19. (V. 93).

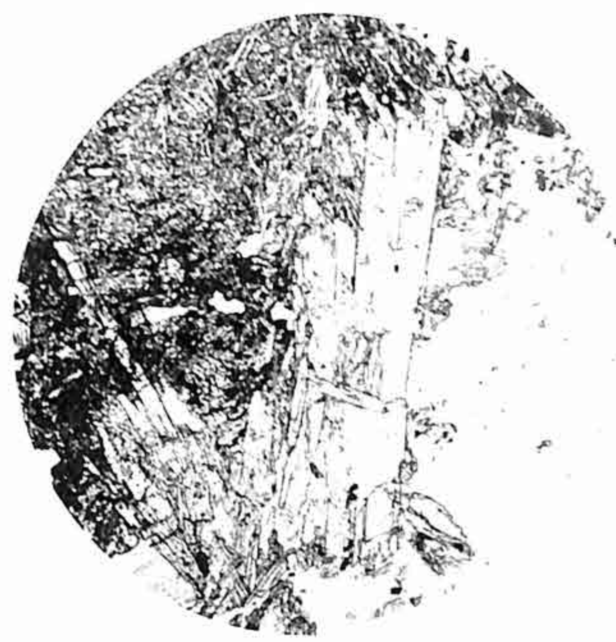


Fig. 4. Large gedrite-needle in hornblende gedritite. × 25. (V t z. 234).

Fig. 5. Idiomorphic plagioclase in hornblende gneiss (ortho-gneiss). Crossed Nicols. × 16. (V. 181).

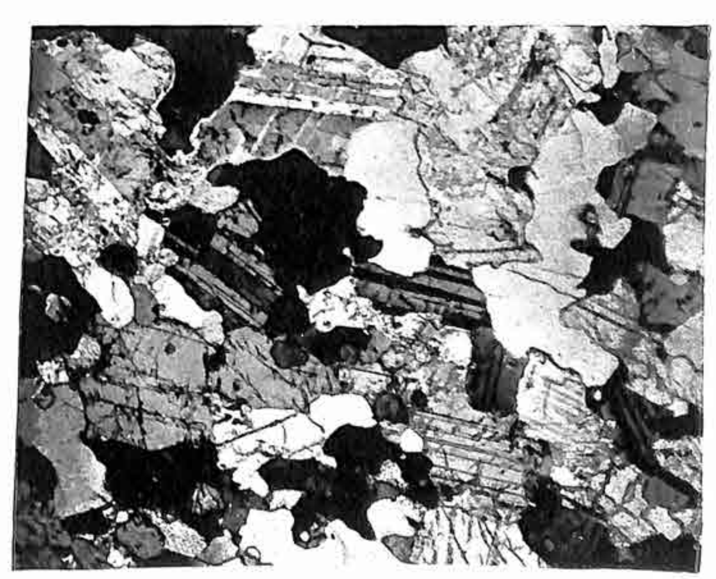


Fig. 6. Ortho-gneiss structure in the same rock as fig. 5. Crossed Nicols. × 15.