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J. H. WESTERMANN

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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 Dr. C. G. M. DE VOOYS, HOOGLEERAAR IN DE FACULTEIT DER LETTEREN EN WIJSBEGEERTE, VOLGENS BESLUIT VAN DEN SENAAT DER UNIVERSITEIT TEGEN DE BEDENKINGEN VAN DE FACULTEIT DER WIS- EN NATUURKUNDE, TE VERDEDIGEN OP MAANDAG 28 NOVEMBER 1932, DES NAMIDDAGS TE 3 UUR

DOOR

JAN HUGO WESTERMANN
GEBOREN TE LOOSDRECHT

N.V. A. OOSTHOEK'S UITGEVERS-MAAT[IJ]. — UTRECHT

AAN MIJNE OUDERS

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„Wel stil zijt gij en afgelegen,
Bij velen zelfs niet eens bekend;
Toch komt men U op kaarten tegen,
En ook Aruba is 't waarheen men mail verzend.

Maar Hij die U kent, die kan het weten
Wat schoons Gij hem heeft aan te biên,
En nimmer zal hij dat vergeten,
't Natuurschoon wat U hem liet zien".

E. J. BOELHOUWERS
(Amigoe di Curaçao).

INTRODUCTION.

These considerations on the geology of Aruba, the smallest island of the Dutch Leeward Islands of the Lesser Antilles, are the result of a geological excursion in the summer of 1930 under the leadership of Prof. Dr. L. RUTTEN, University of Utrecht (Holland). Aruba was surveyed for about 22 days by three groups of two geologists. The survey was done with the help of the geologists H. J. MAC GILLAVRY, P. J. PIJPERS, M. G. RUTTEN and L. W. J. VERMUNT. I give thanks here to those who rendered us good service during our stay on the island, especially to the governor of Aruba, Mr. L. WAGEMAKER, to lieutenant C. JANSSENS, to the propietor of the plantation Fontein, and to the drivers of the sand motor-trucks, who so many times gave us a lift.

The material brought together has been examined in the Geological-Mineralogical Institute in Utrecht, and is kept there (numbers A; the numbers D are the slides of the rocks). Besides, rocks have been studied which were sampled by I. BOLDINGH in the years 1909—1910 (numbers P, also in the Utrecht collections), those, sampled by Prof. K. MARTIN and described by Prof. J. H. KLOOS in the years 1885—1889 (in the Rijksmuseum van Geologie en Mineralogie, at Leiden), and those collected by Prof. J. A. GRUTTERINK in the year 1909 (Petrographic collection in the Gebouw voor Mijnbouwkunde in Delft).

Concerning the rock description the following must be remarked. Little or no attention has been paid to the true crystallographic and mineralogical properties of the constituent minerals. On the other hand, their mutual relation in the rock has been specially studied. In accordance herewith, the composition of the plagioclases has not been determined with the VON FEDOROW method but with the help of the tables of WEINSCHENK (51). As to the granularity and the magnitude of the crystals, they have been indicated in the rock descriptions in the way as suggested by IDDINGS (21, p. 192). Moreover, here and there the size of some special crystals has been added between brackets. The names texture and structure have been used in the English sense, not in the sense of ROSENBUSCH (see f.i. the Geological Nomenclator of the Geologisch-Mijnbouwkundig Genootschap voor Nederland en Koloniën. 1929). Chemical analyses of the examined rocks could not be given because of the great expense involved.

In order to show the denseness of the network of observations the map fig. 1 has been added in which the points of observation have been marked down.

The boundaries of the different formations and subformations could be marked down in the geological map without great difficulty. Nevertheless, the establishment of some boundaries is rather dependent on subjective judgments f.i. those between the limestone and the diorite detritus and between the diorite

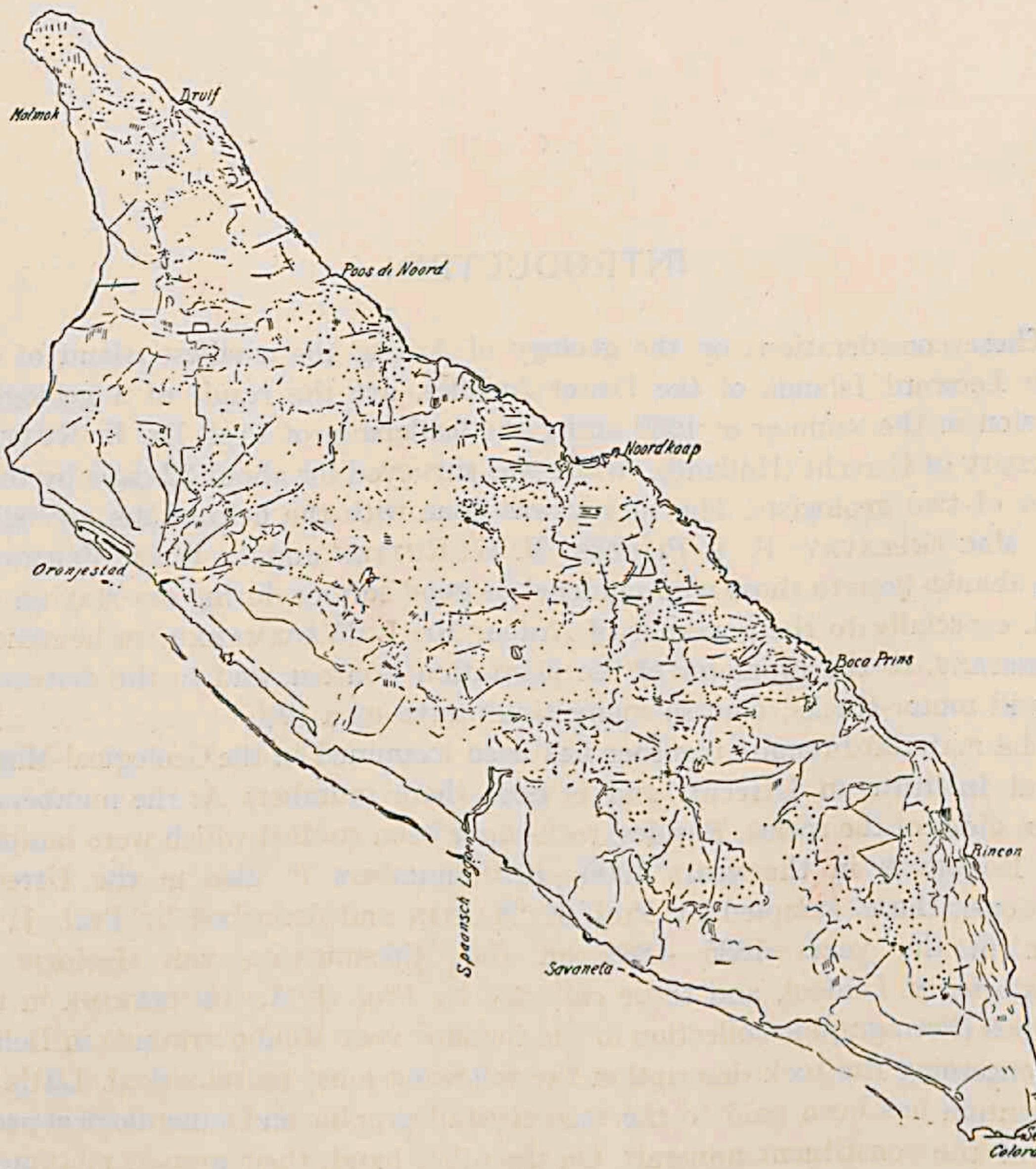

FIG. 1

and diorite detritus. As far as is possible and necessary the different differentiates in the batholith have been indicated in the map, as well as the subformations of the older system. *By no means I have aimed at completeness in this matter.*

The survey has been done with the help of the topographic map of Aruba 1: 20.000. This map lends itself excellently to orientation in the field and to the marking down of the geological data. [1])

As to the soil of Aruba, and also of Curaçao and Bonaire, samples of this soil from different places in the isles, taken and provided with annotations by us, are in the collection of the Koloniaal Instituut in Amsterdam (Holland).

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[1]) During the survey we had much profit from the observations made by Prof. K. MARTIN in 1885 (30), and from his geological map. Since MARTIN only stayed a few days on the island, it can be understood that we — in 1930 — were able to introduce several corrections both with regard to the geology and the petrography.

GEOLOGICAL LITERATURE.

The most important geological description is that by K. MARTIN (30) 1888. The rocks sampled by him have been described by J. H. KLOOS (25) 1887—1889. The Aruba fossil Mollusca have been described by J. LORIÉ (29) 1887 and by M. M. SCHEPMAN (see the list of determinations in MARTIN's book pp. 125—127, 1888). About the older literature and maps known already to MARTIN we can refer to his book pp. 1—6. In the "Bijdragen en Mededeelingen van het Historisch Genootschap, gevestigd te Utrecht" 51ste deel, 1930 Mr. B. DE GAAY FORTMAN communicated "Brieven van den Commissaris-Generaal voor de (Nederlandsche) West-Indische bezittingen J. VAN DEN BOSCH aan den minister voor de marine en de koloniën (1827—1829)", in which on pp. 241—247 a very short mentioning of the Aruba rocks and of the occurrence of gold can be found. MARTIN did not refer to A. STELZNER (44) 1877, who described amongst others limestone and phosphate of Aruba.

After 1888 the following publications came out. VAUGHAN published in 1901 (46) an article on fossil corals. In the years 1915 (47) and 1921 (48 and 49) he wrote more summarizing articles about the younger geology of the West-Indies, in which also Aruba occupied a place. E. D. VAN OORT (33) 1902 described some vertebrae out of the Colorado phosphate and discussed their age. E. SUESZ (45) 1908—1909 treated the geology of Aruba only in the general view of the Antilles as a whole. P. CHEMIN DUPONTÈS (9) 1909 only made some remarks on the Aruba gold and phosphate mining. G. DUYFJES published some articles about gold and phosphate mining, 1911 (14) and 1915 (16), and also a description of the Aruba landscape 1911 (15). A. JESURUN 1911 (24) and an unknown author 1910 (1) and ?1916 (2) devoted articles to the phosphate and its exploitation. I. BOLDINGH 1914 (6) gave on pp. 127—128 in his "Flora of the Dutch West Indian Islands" a very short geological description of Aruba. In the added map of the calcareous and non-calcareous soil of Aruba he indicated already – although wrongly – the large diorite outcrops in the SE-part of the island, which had not been found by MARTIN (see also the description). In the Encyclopaedie van West-Indië 1914—1918, SCHEPMAN wrote the chapter "Mollusca" (41), in which also the Aruba Molluscs are treated. A zoological and zoogeographic study of H. BURRINGTON BAKER 1924 (8) about the land and freshwater molluscs is of importance for the study of the younger geology of the islands. W. H. HOBBS (20) 1925 compared 'the Curaçao — Bonaire Arclet' with other Island Arcs and remarked something on the intrusive cores of the islands, the reef-caps and the anticlinal structure of the latest folding (pp. 255—257). L. M. R. RUTTEN published in 1931 (38) a résumé of the palaeontological knowledge of the Dutch West-Indies.

SHORT OUTLINE OF THE GEOLOGY AND THE GEOMORPHOLOGY OF ARUBA. [1]

(Plate I, fig. 1—3).

Aruba is a low island of about 186 square km., just N of the Venezuelan peninsula of Paraguana, separated from the latter by a sea, the greatest depth of which is about 200 m. The main axis of the island has a direction about NW–SE.

The island consists of three formations, all being quite different in age and in the nature of rocks:

1. the diabase-schist-tuff formation.
2. the quartzdiorite batholith with its differentiates.
3. the limestone and detritus formation.

The age of the former could not be determined, in consequence of the absence of index fossils. In connection, however, with the occurrence of similar formations of Cretaceous age on other Antilles, we can consider this older Aruba formation to be also of Cretaceous age. This formation crops out – chiefly in the central part of the island – in a hilly landscape in which the highest points of the island occur: Jamanota (188 m.), Arikok (185 m.), Seroe Kabaai (170 m.), Gran Tonel (155 m.). The principal rocks are diabases, uralite-diabases, diabase-tuffs (partly with Radiolaria), hornblende-schists and diabase-conglomerates. They constitute a volcanic complex with scanty foreign material. The diabase pebbles of the conglomerates seem to have their origin in a country between Aruba and Curaçao. The whole formation has been strongly folded. The folding can be recognized, however, only in the stratified rocks, which mainly show an almost vertical position and an E-W strike. The orogenic processes took place in older Tertiary (lower Eocene) or in youngest Mesozoic time. During this orogenesis the diorite batholith intruded into the older system (compare with similar intrusions on other West-Indian Islands) and a great part of the rocks of the latter has been metamorphosed in consequence of the contact action. Over a distance of about 2 km from the visible contact the diabases have been changed into uralite-diabases, the tuffs into hornblende-schists (also in consequence of the dynamo-metamorphism). Nearer the contact the rocks have been changed into strongly contactmetamorphic rocks, being amphibolites and amphibole-plagioclase-rocks. The latter rocks show in many places a strongly hybrid character and merge into the diorite. They occur also as inclusions in the diorite.

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[1]) See for the geomorphology also MARTIN (30) p. 40 'Orographische Gliederung'; the numbers indicating here the altitude are wrong.

It is impossible to say whether a partial roof-foundering took place during the intrusion, or not. In any case a great part of the roof (the older rocks) must have been eroded after the intrusion, so that today the quartzdiorite batholith occupies the greater part of Aruba. It has been denuded to a rather low level with an average altitude of about 40 m. (5—130 m.). The highest diorite hills lie along the NE-coast and in SE-Aruba. In distinction from the landscape of the older rocks the diorite landscape is generally a flat one, in which numerous "Felsenmeere" of big, roundish and exfoliated diorite blocks can be found (selective erosion). – The batholith is composed of many kinds of rock differentiates. The most common rock in it is quartzdiorite with hornblende and biotite as dark minerals. First-solidification-differentiates, older than and intruded by diorite, are hooibergite-rocks and gabbroic rocks. The former occur in the landscape as more or less steep hills and elevations, obviously preserved by selective erosion. A fine example is the high and cony Hooiberg (164 m.). The hooibergites consist mainly of hornblende, monoclinic pyroxene, plagioclase and quartz, and differ in texture from the diorites and gabbros. The gabbroic rocks can be found especially in the large massive of the Matividiri and adjacent hills. They are normal, quartz-bearing and partly hypersthene-bearing, gabbroic rocks, which have been strongly hornblendized and uralitized where they border on the younger diorite (contactmetamorphism). Granodioritic and granitic rocks seem to be of the same age as the diorites; they occur but here and there in the batholith.

The younger representatives of the magmatic sequence occur as dikes, not only in the batholithic rocks, but also in the rocks of the older formation. Consequently, the diorite batholith must also be present not far under the surface of this older formation. The dikerocks are dike-diorites, dike-granites, dike-granodiorites, diorite-porphyrites, vintlites, malchites (and other melanocratic rocks), dioritic aplites, granitic aplites, granodioritic aplites, quartz-albitites, gabbro-aplites, pegmatites. Very young magmatic and hydrothermal dike- and vein-rocks are quartz-rocks, quartz-epidote-rocks and epidote-rocks. The porphyritic dikes occur mainly along the N- and NE-coast. The strike of many of them does not differ much from the E-W direction (compare with the strike of the older schists).

The limestone lies unconformably on the two older rockformations, which must have been partly denuded before its deposition. Only a part of the island was under sealevel during the deposition, for almost the whole limestone complex contains diorite material. The limestone covering has been partly denuded and today it is found especially in SE-Aruba, as a zone, about 2 km. wide, along the S- and W-coast, and as a narrow, frequently interrupted border along the N- and NE-coast. The higher-situated beds show a clear dip and must have belonged to a slightly arched limestone-cap over a part of the island. These beds border on the sea-side on the lower and younger, about horizontal limestone terrace. The limestone is chiefly Quaternary Lithothamnium-limestone which also contains other organisms. Only in one place, on the high plateau in SE-Aruba, a Tertiary limestone, containing *Lepidocyclina*, has been found. The limestones in the SE-corner of the island have been phosphatized.

Large deposits of diorite detritus especially occur along the S- and W-coast, brought there by the "rooien" (small rivers which contain water only in the rainy season). Although the deposition must have taken place already before and during the deposition of the limestone, the greater part of the visible detritus must be younger than and lies on the limestone terrace. – The coastdunes are very young and occur along the E-, NE-, N- and W-coast (tradewinds). – Some handshaped inlandbays with a junctioncanal to the sea can be found; they are either entirely or almost entirely dry (f.i. Druif, Spaansch Lagoen). – The N-, NE- and E-coast is on the whole steep and shows many undercuts, wavecut chasms and coves in the rocks, the socalled "boca's" (tradewinds). In distinction herewith, the S- and W-coast is in general low and flat (except in the places where the terrace borders on the sea). Lying before and parallel to the S-coast a long, narrow, frequently interrupted shore-coralreef rises for the greater part above sealevel. In front of the W-coast only separate coralstocks are met with. These reefs and stocks occur on a submarine platform, maximum to about 10 m. deep. The shore-reef lies on the seaside of this platform and is separated from the coast by a lagoon. Just SW of this reef the depth increases fast, maximum to about 200 m.

THE DIABASE-SCHIST-TUFF-FORMATION.

This formation, consisting of diabasic rocks, schistose rocks, tuffoid rocks, conglomerates and breccias, is the oldest on Aruba. It occurs chiefly in the central part of the island, but it is also present in two smaller outcrops between Fontein and Rincon, on the Seroe Pretoe (N of Savaneta), in the northwestern corner of the island and in some other places. The rocks of this system are strongly folded, in such a way that individual folds cannot be recognized. The average strike is about N 90 E. The process of folding did not manifest itself very clearly in the diabasic rocks. Where the formation borders on the diorite batholith, its rocks show a clear contactmetamorphism. Consequently, the dioritic magma must have been intrusive into this formation and the batholith must be younger. The many dikes of diorite-differentiates in the formation, and the occurrence of many diabasic and schistose inclusions in the diorite (exogenous inclusions) point to the same relation in age. Hence, this formation is in fact the roof of the diorite batholith.

DIABASE-ROCKS

Diabase-rocks constitute a great part of the older formation (see the map). The bulk of the examined diabases are phanerocrystalline. The normal diabases are generally phanerocrystalline; the aberrant and micro-porphyritic ones are generally aphanitic. The diabases and the uralite-diabases could not be distinctly separated, since the pyroxene of the former shows a beginning and an advanced alteration in many rocks and since the pyroxene of the latter is not altogether altered in some rocks. Hence, transitional types must be present but they have been described in one of the two groups.

DIABASES

Macroscopically they are fine- to mediumgrained, rarely coarsegrained; dark- or lighter coloured, grayish or greenish; they have here and there a brown or reddish-brown crust of weathering.

Microscopic description: Most of the rocks are ophitic; the texture in D 12542 and D 12543 is ophitic to hypidiomorphic-granulose-gabbroic. Therefore, the diabase A 478—D 12542, which is medium- to coarsegrained, can be called a gabbro-diabase. The main constituent minerals are plagioclase and monoclinic pyroxene. There is less or more pyroxene than plagioclase. It is noteworthy, that the rocks with a partially hypidiomorphic-granulose-gabbroic texture contain more plagioclase than pyroxene. A number of diabases contain quartz, primary or secondary.

Plagioclase: The crystals are laths or prisms. In D 12535 and D 12547 they occur locally in sheaf-like bundles. The plagioclases show polysynthetic twinning. The original composition ranges from bytownite to oligoclase-andesine, and is mostly about labrador; some of these plagioclases show a beginning albitization along fissures. A few rocks only contain totally albitized plagioclases. Except in the latter rocks, several crystals are simply zonal. The plagioclases are more or less epidotized and sericitized. Bent crystals occur in some rocks. In a part of the rock D 12539 the plagioclase laths have been altogether changed into a grainy quartz-plagioclase aggregate, rich in epidote. In D 12544 too a bytownite aggregate took the place of the bigger and idiomorphic crystals in several spots and lies now between the pyroxenes. The plagioclase laths and prisms of D 12541 do no more exist as such, but have been wholly replaced by quartz, which occurs as grains between the pyroxenes, and by much epidote; the original lath- and prism-shape has partly been preserved, so that in this rock too an ophitic texture can be recognized.

The pyroxene is an almost colourless to very lightgreen diopsidic augite. Dependent on the relative number and the crystal-development of the plagioclases, the pyroxene crystals are only allotriomorphic between the more or less idiomorphic plagioclases or are quite 'cut up' by the plagioclase laths. In the former case, prismatic shape can be seen here and there; in other cases the pyroxenes are quite shapeless. The diabases with an ophitic to gabbroic texture also contain hypidiomorphic pyroxenes. The pyroxenes in D 12535 are partly conformed to the plagioclase laths, partly well-developed as long and narrow prisms. A few pyroxenes are twinned.

Alteration: In by far the most of the diabases the pyroxenes are partly, to a greater or smaller extent, uralitized and – in a further stage – chloritized. The crystals show different phases of uralitization, that is to say, a beginning uralitization along the borders and cleavage (fissures) unto a total alteration. In most of these rocks the uralite has been partly altered into chlorite; here and there, the transitional phases between pyroxene, uralite and chlorite are obvious. In many rocks the pyroxenes have altogether or partly a light-brownish colour especially along the borders or as spots; it is probable, that this brown colour indicates the first stage in the alteration process pyroxene $\rightarrow$ uralite.

The uralite is lightgreen-pleochroitic, parallel- or diverse-fibrous. Plagioclase and uralite are not quite sharply bordered on each other, for the uralite fibres radiate into the plagioclases; the latter also enclose many diminutive hornblende needles. In the rocks D 12537, D 12540, D 12544 and D 12547 uralite occurs too as non-fibrous, undivided crystals, with normal hornblende-cleavage and twinning here and there. These hornblendes, which are also allotriomorphic, occur besides fibrous uralite and represent probably no primary hornblende but the final stage of uralitization. This kind of uralite-hornblende occurs only in the western part of the diabase-massive; so, it must have come into existence in connection with the neighbourhood of the diorite intrusion (S of Kleine Jamanota, Arikok, E of Arikok, and Noordkaap); compare with the uralite-diabases.

The chlorite is lightgreen-pleochroitic, consists of fibres with steelblue interference-colours or of spherolites with lightbrownishgreen interference-colours. The chlorite, being altered pyroxene, is allotriomorphic between the plagioclases; moreover, chlorite may occur in them.

The pyroxenes in D 12543 contain, moreover, biotite along fissures; in the same rock chlorite seems to have originated from biotite (transitions!). In the rock D 12535 many pyroxenes, here and there with a good octangular shape, but on the whole as badly idiomorphic prisms, have been changed into ?serpentine and chlorite, parallel-fibrous and very lightgreen; the serpentinization especially occurs along irregular fissures and along the borders. Here and there remnants of the pyroxene seem to lie in this secondary mass. In the same rock chlorite occurs moreover as irregularly shaped and small masses between the quartz grains and also conformed to the plagioclases.

Hornblende: Primary green hornblende seems to be present in D 12536 and D 12548; in these rocks no true uralite could be found. The hornblende takes up only little room, and is quite allotriomorphic between or 'cut up' by the plagioclases; a single crystal shows twinning. The greater part of it has been altered into greenish to yellowish chlorite; at least, transitions seem to be obvious. D 12536 contains several pyroxenes, which are intergrown (!?)

with hornblende individuals (the different hornblende parts in the pyroxene have one and the same extinction). The latter hornblende too is here and there chloritized; even strongly chloritized hornblendes occur in intergrowth with little pyroxene.

Magnetite and titanomagnetite are present in a varying quantity; the titanomagnetite crystals show leucoxene flocks or titanite rims. The very big grains and skeleton-shaped grains lie allotriomorphically between the plagioclase laths and prisms. – Apatite has been only found in some diabases, as small needles and prisms. – Only a few rocks contain numerous diminutive grains or less, bigger grains of a mineral, which seems to be titanite (secondary?).

Quartz: Quartz is only present in part of the diabases described here. It seems to belong to the magmatic crystallization-sequence in the diabases D 12535, D 12536, D 12537, D 12542, D 12543 and D 12546. Their quartz occurs in larger or smaller amount and allotriomorphically between the plagioclase laths; the plagioclases in D 12536, D 12542 and D 12543 are here and there in intergrowth with it. It is not or slightly undulose and contains but here and there fluid-inclusions, partly arranged in planes. – The quartz is of a secondary origin in the diabases D 12539 and D 12541 and replaced partly or wholly the plagioclase crystals (see above). – It is problematical whether the quartz in D 12534 and D 12547 is primary or secondary. It is interstitial between the plagioclase laths, and occurs as a very finegrained, rarely coarser grained, aggregate. The grains of this aggregate seem to be cataclastic; in D 12547, they contain diminutive hornblende needles.

In some of the diabases veins occur. D 12538, for instance, contains narrow veins of chlorite-plagioclase and of epidote. D 12534 shows a narrow quartz vein.

Finding-places:

W. of Dos Playa and between Dos Playa and Rooi Fluit: A 470 – D 12534; A 471 – D 12535; A 472 – D 12536; A 484 – D 12548; A 485 – D 12549. W. of Boca Prins and between Boca Prins and Dos Playa: A 474 – D 12538; A 475 – D 12539; A 477 – D 12541; A 478 – D 12542; A 479 – D 12543. Near Quadirikiri (E-coast): A 482 – D 12546. E. of Arikok and Arikok: A 473 – D 12537; A 480 – D 12544. S. of Kleine Jamanota: A 476 – D 12540. Noordkaap: A 483 – D 12547.

URALITE-DIABASES AND CONTACTMETAMORPHIC URALITE-DIABASES.

(Plate II. fig. 1).

Since both kinds of rock differ only in some points and are on the whole the same, it seems better to unite them in one description; the points of distinction will be lifted out, where necessary.

Macroscopically these rocks are similar to the diabases. It is remarkable, that most of the common uralite-diabases are mediumgrained, whereas most of the contact-uralite-diabases are finegrained.

Microscopic description: Many of the diabases have a normally ophitic texture. Others are ophitic to hypidiomorphic-granulose-gabbroic or gabbroic: uralite-gabbrodiabases and contact-uralite-gabbrodiabases; a great deal of them have been sampled in the mountains E and NE of Spaansch Lagoen. The texture of another part of the contact-diabases is partly or quite deteriorated, so that only here and there the original texture can be recognized. The plagioclase crystals, defining the diabase-texture, have been partly or quite changed into a finegrained plagioclase aggregate: D 12554, D 12574, D 12578, D 12585, D 12590, D 12598. The rocks with this kind of texture occur all very near the contact; however, others which have also been sampled near the contact do not possess it (see the finding-places).

The rocks consist mainly of plagioclase and uralite-hornblende. There may be less or more uralite than plagioclase. On the whole, the gabbroic types and the ophitic contact-diabases contain more plagioclase than the normal, ophitic ones. Some rocks contain moreover some quartz of primary or secondary character. D 6176 has a flow-structure.

Plagioclase: On the whole, the plagioclase crystals occur in the same way as in the diabases. It can be remarked that bytownite and labrador-bytownite occur only in the contact-diabases. The crystals in D 12578, D 12582 and D 12584 contain diminutive, grainy inclusions (fluid-inclusions?); those of D 12557, D 12558 and D 12562 (mountains E and NE of Spaansch Lagoen) contain grayish or brownish spots, which are accumulations of diminutive, rod- or plate-shaped microlites.

Uralite-hornblende: The uralite-hornblende is about the same as that of the diabases; it is rarely brownish-green. Most of the gabbroic diabases and also some ophitic ones contain beside the allotriomorphic crystals uralite-hornblendes which, having originated from pyroxene prisms, are more or less prism-shaped. The uralite-hornblende of most of the normal and contact-diabases is fibrous, non-fibrous, or granular. Only fibrous uralite can be found in the normal diabases D 12553 and D 12567. The strongly contactmetamorphic diabases D 6176, D 12572, D 12574, D 12578, D 12579, D 12585 and D 12590 contain only nonfibrous hornblende. The latter, allotriomorphic, locally undulose and known already from the diabases, represents very probably the final stage of uralitization; at least, in the rocks D 12557, D 12558, D 12562 and D 12563 (mountains NE and E of Spaansch Lagoen) such hornblende crystals occur with hornblende-cleavage and pyroxene-shape (fig. 2). Separate needles or radial bundles of small hornblende needles stick in the plagioclase, whereas numerous needles, prisms and grains lie enclosed in the plagioclase. In some rocks the uralite has been altered into chlorite for a small part; the chloritization begins along cleavage-planes and fissures. The chloritization is not specially connected with the contactmetamorphism.

The essential contact-phenomenon in the contact-uralite-diabases is the occurrence of small, typically idiomorphic and well-cleaved (hornblende-cleavage) hornblende crystals (fig. 3). They occur in a greater or smaller quantity, dependent on the grade of contact-metamorphism, and especially in the bigger uralite-hornblende individuals. They must have been new-made out of the uralite-material, under the influence of the contactmetamorphic action of the diorite intrusion.

Hornblende individuals with enclosed bubbles of ?quartz occur in the contact-rocks D 6549, D 12572, D 12578, D 12579, D 12590 and D 12598. Most of these rocks contain quartz or quartz-veins; hence, there seems to be a connection between this quartz and the occurrence of quartz-bubbles, although other contact-diabases with quartz lack quartz-bubbles in the hornblende. Especially some hornblendes in D 12579 contain big quartz!-bubbles and are rich in quartz. The quartz must have been impregnated into the new-made hornblendes (hornblende-myrmekite; see also p. 95). — In D 6557 some of the pyroxenes have been changed into uralite and a very finegrained ?quartz aggregate.

Pyroxene, being almost-colourless diopsidic augite, occurs as cores here and there in the uralite of the normal rock D 12553 (east-slope of Jamanota) and of the contact-rock D 12584. Remnants of the same pyroxene also occur in the well-cleaved, allotriomorphic uralite-hornblende of the contact-rocks D 6557, D 12571, D 12572, D 12583 and D 12585 (Seroe Pretoe, N of Savaneta and NW of Shete). Hence, it is clear, that there is no sharp difference between the diabase and uralite-diabase.

Apatite occurs in several rocks; especially in the plagioclase. Magnetite and titano-magnetite occur as in the diabases. The greater part of the ore is tied to the uralite-hornblende. In the contact-diabases of the contactzone D 12561, D 12578, D 12582, D 12583, D 12584, D 12585 and D 12590 the titanomagnetite, locally with epidote and titanite, has been concentrated into grainy groups, in consequence of the contactmetamorphism (fig. 4). Primary or secondary titanite occurs in a few rocks as grainy masses.

Quartz: Many of the normal uralite-diabases and some contact-uralite-diabases contain quartz. In the normal diabases D 12555, D 12556 and D 12565 and the contact-diabases D 12562 and D 12579 it seems to be primary, and occurs interstitially and in a very small amount. The plagioclases are only partly idiomorphic with regard to the quartz; for the other part their borders are intergrown with it (D 12556, irregularly granophyric intergrowth). Hornblende needles of the uralite stick in the quartz. – The rock no. 3287 – D 2339 in the Delft collection (pebble from Rooi Taki, E of Spaansch Lagoen) is a normal quartz-bearing uralite-gabbro-diabase, the quartz of which is primary and interstitial. Besides, however, quartz and plagioclase constitute a fine granophyric-micrographic intergrowth, in which the plagioclase, with the composition of about oligoclase-andesine, has the same orientation as the nearest big plagioclase crystal or as its most peripheric zone. So, the quartz and the rather acid plagioclase restmaterial must have crystallized after the crystallization of the bulk of the plagioclase material (fig. 5). – The quartz amount in the rocks D 12563 and D 12590 is extremely small. The quartz is probably of a secondary character in D 6549 and D 12553: rather much quartz in very finegrained aggregates between the plagioclase laths.

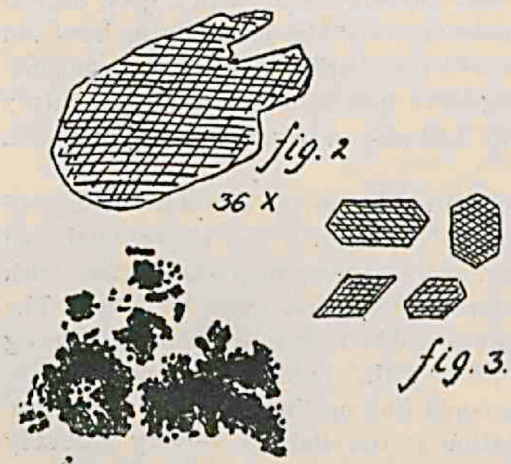


fig. 2 36 x

fig. 3.

fig. 4. 36 x

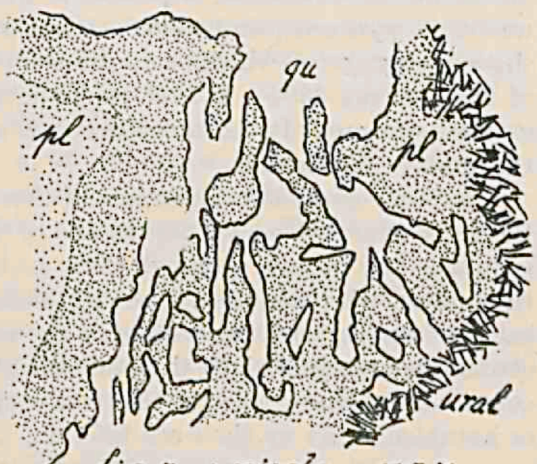


fig. 5. + nicols, 115 x

Many rocks contain epidote-zoisite grains or narrow epidote-zoisite-veins, the latter with or without quartz. D 12565, D 12567 and D 12579 are rather strongly epidotized, so that here and there the epidote replaced the plagioclase. – D 6549 contains, in the close neighbourhood of hornblende, diminutive plates of probably secondary biotite. – D 6176 contains a vein of quartz, some epidote and hornblende. – D 12579 contains a quartz-plagioclase-vein that gradually merges into the contact-diabase. The plagioclases are prismatic and bent albites; the quartz is intergrown with their borders. The plagioclase of the uralite-diabase itself is also albite. – A vein in D 12588 also gradually merges into the contact-diabase, and consists of a grainy aggregate of albites with some quartz, epidote, magnetite and small hornblende needles, the latter at the borders of the vein. – A vein in the contact-diabase D 12598, also gradually merging, encloses diabase fragments. It consists mainly of quartz, grainy bytownite and numerous diminutive hornblende prisms and grains; the plagioclases contain numerous quartz drops (sieve-texture). It must be mentioned, that the plagioclases of the invaded contact-diabase have the same basic composition, so that, it would seem, the plagioclase and also the hornblende of the vein material belong to the diabase, whereas the quartz is added material, having been impregnated into the plagioclases.

These veins are clearly connected with the diorite intrusion into the older series, and occur in the contactzone. The fact that the vein material in the latter three rocks is not sharply bordered on the invaded rocks possibly means that the diabases have been partly resorbed during the intrusion; probably, however, that the hornblendization (uralitization) of the diabases was not quite finished at the time, when the quartz-plagioclase material intruded (see also the discussion about the genesis of the uralite-diabase).

Finding-places:

E of Spaansch Lagoen: A 494 – D 12558; A 498 – D 12562 (SW-foot of Seroe Largo); A 499 – D 12563 (S of Seroe Largo). NE of Spaansch Lagoen: A 491 – D 12555; A 492 – D 12556; A 493 – D 12557. N of Spaansch Lagoen: A 490 – D 12554. Mira la Mar: A 565 – D 12588. NW of Arikok: A 583 – D 12598. NW of Shete: A 556 – D 12582; A 557 – D 12583; A 558 – D 12584; A 559 – D 12585. Sabanilla Abau (SE of Santa Lucia): A 564 – D 12587.

Near the coast of Andicouri: P 85 – D 6549. S of Noordkaap: A 503 – D 12567. Daimari: A 501 – D 12565. E-slope of Jamanota: A 489 – D 12553. Near Baranca Corra: A 551 – D 12578; A 552 – D 12579. Seroe Pretoe (N of Savaneta): P 96 – D 6557; A 507 – D 12571; A 508 – D 12572. Near Rincon (E-coast): A 497 – D 12561. Between Rincon and Fontein: P 97 – D 6176. S of Tibusji (NW): A 567 – D 12590. NW of Annaboei (NW): A 547 – D 12574. [1])

Professor J. A. GRUTTERINK sampled, amongst others, contactmetamorphic uralite-diabases on the Seroe Crystall and on the southeastern slope of the hill E of Malmok (NW-Aruba), amidst other contact-rocks. – The rock on the Seroe Crystall (no. 3356 – D 2408) still contains rare pyroxene remnants. – The hornblende of the rock no. 3395 – D 2445, on the hill E of Malmok, is present as non-fibrous, well-cleaved uralite with a good deal of unaltered pyroxene, and moreover as many new-made crystals; the latter occur here and there in aggregates, which lie allotriomorphically between the plagioclases. – The plagioclase of the rock no. 3396 – D 2446 from the same finding-place has been locally altered into a grainy aggregate. Its hornblende occurs as in D 2445, and also in aggregates together with the grainy plagioclase.

It is a remarkable fact, that in these three rocks and also in the contact-diabases of the Seroe Pretoe (N of Savaneta), and of the contactzone NW of Shete (see above) unaltered pyroxene still occurs, although these rocks have been sampled very near the contact with the diorite; whereas in other contact-diabases the pyroxene can no more be found. The cause of the partial preservation of the pyroxene may be looked for in a quick and strong contactmetamorphism, so that the already-made uralite of the diabase could change into contact-hornblende, whereas the remaining pyroxene could find no time to alter into uralite or hornblende. As we shall see later on, the uralitization of the diabases is very probably connected with the intrusion of the diorite batholith.

DISTRIBUTION OF THE CONTACTMETAMORPHIC URALITE-DIABASES

If we compare the finding-places of the uralite-diabases with those of the contact-metamorphic ones, it is very clear that the latter rocks chiefly occur in the close neighbourhood of the diorite contact and in the contactzone; whereas the normal uralite-diabases occur farther from the diorite. So, f. i. the samples taken just N of Spaansch Lagoen, on Mira la Mar, NW of Arikok, NW of Shete, on Sabanilla Abau, near the coast of Andicouri, near Baranca Corra, on the Seroe Pretoe (N of Savaneta), near Rincon, on the Seroe Crystall, on the hill E of Malmok (NW), S of Tibusji (NW), and NW of Annaboei (NW) are *all* contact-metamorphic diabases. One contactmetamorphic rock has been sampled on the SW-foot of Seroe Largo (E of Spaansch Lagoen), apparently far from the batholith; probably, however, the diorite lies not so very deep here in the underground (see also the distribution of the contactmetamorphic hornblende-schists).

ABERRANT, MICROPORPHYRITIC DIABASES.

Beside the normal diabases, aphanitic to very finegrained, porphyritic rocks have been collected, that are, moreover, a little aberrant.

So f. i. the rock A 495 – D 12559, which occurs very near and NW of Boca Prins. The rock contains small nests of quartz. Small phenocrysts lie in a very fine-textured

[1]) J. H. KLOOS (25) described some normally ophitic diabases and uralite-diabases. Abusively he reckoned the vintlite 120c among the uralite-diabases. The uralite-diabases 111 and 113 of Mira la Mar are contactmetamorphic, especially 111, although KLOOS ascribes the hornblendes a „Mangel eigener krystallographischer Begrenzung". Nevertheless, he observed, „dass hier die Amphibolmikrolithe auch in die primären Feldspathleisten ein- „dringen und Letztere ganz mit grünen Nädelchen durchspickt werden. Man kann diese „Erscheinung nicht anders deuten als dass hier eine angehende Pseudomorphose von Horn- „blende nach Feldspath vorliegt, in vollständiger Uebereinstimmung mit den Erscheinungen, „die in Diabasen beobachtet worden sind, wo solche in einer Contactzone von später empor- „gedrungenen Eruptivmassen angetroffen werden."

groundmass. The latter consists of an aggregate of radial-fibrous pyroxene, with numberless diminutive pyroxene needles and also plagioclase needles. The phenocrysts are plagioclases and pyroxenes. The former are lath- and needle-shaped crystals of an average composition; some of them show twinning. The pyroxenes are well-idiomorphic prisms of a colourless monoclinic pyroxene, a single of which shows twinning. Several veins and irregularly shaped nests contain dusty quartz, chlorite and epidote; rarely ?prehnite.

Another rock, A 506 – D 12570, has been sampled in Rooi Dwars, near Boca Prins (with an inclusion of altered tuff). It has been invaded by calcite. A few small phenocrysts lie in a fine-textured groundmass. The groundmass consists of very small and twinned plagioclase laths and needles, between which numerous pyroxene grains, small chlorite masses and very small calcite grains occur. A part of the rock is a little coarser grained and shows plagioclase needles which diverge in imperfect bundles. A few magnetites and a single pyrite are accessory. The phenocrysts are plagioclases and pyroxenes. The former lie partly in groups, and are partly idiomorphic, prismatic crystals, probably of an acid composition. The pyroxene phenocrysts are small prisms and grains of a colourless monoclinic pyroxene. A small fragment of ophitic diabase occurs enclosed. Small cavities are filled with radial-fibrous chlorite and/or calcite.

A 481 – D 12545 (Quadirikiri) contains a few phenocrysts of plagioclase and pyroxene. The plagioclase laths and needles of the groundmass are rather short and lie in sheaflike bundles. The pyroxene lies as grains between these plagioclases. The rock has been invaded by quartz-epidote.

ABERRANT, MICROPORPHYRITIC URALITE-DIABASES

Beside the normal uralite-diabases, aphanitic to very finegrained and partly porphyritic rocks have been sampled, which are a little different from the others.

A 505 – D 12569, collected S of Andicouri, contains some small phenocrysts in an ophitic groundmass. The plagioclase occurs as small, twinned laths of about oligoclase-andesine. The laths show a tendency to lie in imperfectly divergent bundles. The hornblende is fibrous. The phenocrysts are plagioclases and diopsides. The former lie here and there in groups and are twinned laths of an average composition. The pyroxenes are almost colourless grains and prisms, uralitized along borders and fissures.

A 502 – D 12566, near Daimari, is extremely finegrained. An ophitic texture can be recognized with difficulty. The plagioclases of the groundmass are very tiny laths which may show a tendency to lie in imperfectly divergent bundles; the uralite is parallel- or radial-fibrous. Magnetite is rare. The few phenocrysts are prismatic plagioclases and parallel-fibrous uralite-hornblendes. The diabase has been strongly invaded by narrow veins, which are rather sharply bordered but yet merge into the diabase; they consist of grainy albite, with some epidote and chlorite.

A 500 – D 12564, from the Jamanota, contains amygdules. The groundmass consists of an aggregate of radial-fibrous and plumy uralite-hornblende with here and there diminutive plagioclase needles. The phenocrysts are plagioclases and hornblendes. The former are small prisms and needles; quartz aggregates replaced some of them with preservation of the crystalform. The hornblendes are pale-green, short-prismatic, partly chloritized and ?epidotized. There are epidote-quartz-veins. The amygdules are composed of quartz, ?prehnite, epidote and calcite.

The rocks A 487 – D 12551 (near Seroe Blanco, SE – Aruba), A 488 – D 12552 (upper course Rooi Prins, near Juditi), A 496 – D 12560 (du Chef) and A 504 – D 12568 (on the top of the hill between Andicouri and Daimari) contain more uralite than plagioclase. The plagioclase laths and needles, twinned and here and there bent, lie in imperfectly divergent bundles and are of an average composition. The fibrous uralite lies between the plagioclases in these bundles and shows therefore a plumy character. In general, it also lies partly in the plagioclases, so that it partly replaced the latter. In D 12552 and D 12560 the uralite is partly chloritized. The latter rock still contains pyroxene. Magnetite is rare. D 12552 contains locally some interstitial quartz; this mineral also occurs as a grainy filling of cavities, together with a little ore. Many epidote grains in this rock conformed to the plagioclase laths. D 12551 and D 12568 contain a few plagioclase phenocrysts. Those in D 12551 are lamelled andesine prisms and laths. This rock also contains small fragments of normally ophitic uralite-diabase.

The rock A 487 constitutes a very small outcrop, wholly surrounded by diorite (near Seroe Blanco, SE – Aruba; see the map d). And yet, it does not show any contactmetamorphism; moreover, it encloses fragments of uralite-diabase. Although it is quite possible, that in one series the one diabase encloses fragments of the other, the lack of contact-metamorphism and the presence of enclosed diabase fragments seem to point to a dike younger than the diorite (and diabases). Apart from that, this rock very much resembles the above-described uralite-diabases, which belong to the older diabase-system.

GENERAL REMARKS ON THE ABERRANT DIABASES

Similar aberrant and microporphyritic types of diabases are rather widespread on Curaçao, as already Kloos (25) assumed: (p. 61) „Die Structur der dichten Diabase Curaçaos erweist deren Identität mit denen Arubas." The rock *A 495 can be compared with the „Dichte* diabaas met augiet in flink ontwikkelde schoofvormige mikrolith-bundels" as described by G. J. H. Molengraaff (31, p. 32). *The* rock A 500 can also be compared with this kind of rock, except *that* the pyroxene has been quite uralitized. The rocks A 502 and A 505 show a tendency towards the texture of the „Dichte diabaas met plagioklaasnaalden die tot onvolkomen bundels divergeeren" (Molengraaff, p. 31). A 506 can be *partly* and *A 481* can be wholly compared with the latter kind of Curaçao diabases. The four other rocks, described together, can be altogether compared with this kind of rock, except *that the pyroxene has* been uralitized totally or for the greater part. Although these rocks have also been found in the southern and central parts of the older formation, they seem to occur mainly in the northern and northeastern parts. As to the relation in distribution between these diabases and uralite-diabases, see below.

In a place W of Dos Playa dikes of such very finegrained (?microporphyritic) diabase seem to occur in normal quartz-diabase. – These aphanitic to finegrained diabases must have cooled very quickly. G. J. H. Molengraaff (31, p. 33) presumes that the magma of the aphanitic diabases on Curaçao flowed out of a submarine fissure. The geological and petrographic relations on Aruba neither point to such a submarine flowing-out nor plead against it.

RELATION BETWEEN THE DIABASES AND URALITE-DIABASES, AND GENESIS OF THE LATTER

As we have seen these two kinds of rock are not fundamentally different. The most important difference is the alteration of pyroxene, and, concerning this alteration the diabases merge into the uralite-diabases. If we compare the finding-places of the two rocks we come to the general conclusion that uralite-diabases are wanting in the easternmost part of the large outcrop of the older formation, that is to say, in some region between Boca Ketoe, Juditi and Boca Prins. On the other hand, the diabases occur mainly in this region, although several of them have a more northwestward, westward or southwestward occurrence (f.i. in the neighbourhood of Noordkaap, in the hills NE and E of Arikok, S of Kleine Jamanota). Moreover, the alteration of the diabases (uralitization, chloritization) seems to increase from east to west (local differences in alteration can exist here because of the occurrence of diorite- and porphyrite-dikes, see below), whereas the rocks found outside the above-mentioned region show a strong alteration and are consequently transitional types between diabase and uralite-diabase. Diabases have been found in the outcrop SE of Fontein too; those sampled near Quadirikiri are but little altered. At all events, the diabases are wanting in those parts of the older formation, which lie along the batholith, and occur chiefly in a region farthermost from the batholith; uralite-diabases are just wanting in the latter region.

The uralitization of the diabase may be connected with the strong folding of the older formation. Since, however, we can admit that the whole, older complex has been subdued to orogenic movements, it is hard to understand why in some places, in this case the above-mentioned region, the total uralitization did not come off. Therefore, if we take into consideration the special distribution of diabases and uralite-diabases, we must come to the conclusion that the process of uralitization is closely connected with the batholithic intrusion of the dioritic magma. Hence, this process of total uralitization is a kind of contactmetamorphism, which acted over a distance of about 2 km, that is to say, from the visible contact. As we have seen on p. 15 quartz-plagioclase material, connected with the intrusion, seems to have intruded into uralite-diabases before the uralitization was quite finished. This also points to this conclusion. – As we have seen above and as we shall see below, those uralite-diabases which lie near or in the contact-zone have been submitted to the strongest contactmetamorphism. Locally in the diabase-region W of Boca Prins uralitized diabases occur in the narrow contactzone of diorite- and porphyrite-dikes, f.i. A 539 which is invaded by narrow veins. On the other hand, the partial alteration of the rocks in this region is in many cases not visibly connected with the intrusion of a dike-rock but must be a slight effect of the batholithic intrusion, which had more influence in the rocks nearer the contact. At all events, the several dikes and veins here do not point to a close neighbourhood of the batholith in the underground.

The schistose and tuffoid rocks show similar relations to the diorite, which will be discussed below. – It must be mentioned that already MARTIN and especially KLOOS suspected that the uralitization had something to do with the intrusion, although they had not the disposal of many observations. MARTIN (30, p. 50) remarked: "Bekannt ist das Vorkommen der uralitisirten Diabase von Miralamar "sowie von Chetta am Fuss des Arikok, in beiden Fällen also von Punkten, "welche in der nächsten Nähe der Formationsgrenze von Diabas und Diorit "gelegen sind. Dagegen sind die Diabase, welche ich am Nordstrande geschlagen "habe, nicht metamorphosirt." And KLOOS (25, p. 61), taking into consideration the younger age of the batholith, remarked, "dass es dadurch den Anschein ge-"winnt, als läge in den Grünschiefern und Uralitdiabasen Arubas das Beispiel "einer Contactzone eines Dioritmassivs vor, welche in vieler Beziehung mit "bekannten Contacthöfen um granitische Gesteine übereinstimmt."

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE DIABASIC ROCKS.

The diabases occur in the landscape more or less alternatively with the other rocks of the older formation. They can be generally distinguished from these other rocks by their brownish to reddish-brown colour of weathering and often by the roundish shape of the diabase hills. In a few places, however, the difference is not very clear because of a more or less schisty character of the diabases. Nevertheless, such a schistosity is not visible microscopically. Where the rocks crop out they are covered with mountain waste, here and there in large masses.

The diabasic rocks occur mainly in the large outcrop of the older formation in the central part of the island. Besides, they have been found in the outcrop SE of Fontein and in that NW of Rincon. Very small outcrops lie about half a kilometer NE of Seroe Blanco (SE) in the diorite, on the top of the Seroe Pretoe N of Savaneta, on the top of the Seroe Crystall, in the contactzone E of plantation Westpunt (NW), on the top of the hill just E of Malmok (NW), on the top 27.80 (NW). – Big and round diabase blocks belonging to the outcrop of the hill E of Malmok occur far from this outcrop, that is to say along the slopes, and just W of the house of Westpunt.

SCHISTOSE AND TUFFOID ROCKS

Schistose and tuffoid rocks are widespread in the older formation. As will be shown, transitional types between these kinds of rocks are also present in the island and prove that the former originated from tuffoid rocks, very probably under influence of the diorite intrusion. The schistose character of these metamorphic tuffs is mainly connected with hornblendization. Therefore, most of the schistose rocks are hornblende-schists; locally also chlorite and epidote are the main constituent minerals. Moreover, there will be described tuffoid rocks which have been little or not hornblendized. The tuffoid rocks are very probably diabase-tuffs. In a few places curious, schisty, porphyritic rocks have been sampled.

HORNBLENDE-SCHISTS (METAMORPHIC DIABASE-TUFFS)

The following kinds of rock will be described: hornblende-schists without tuff relic-minerals; hornblende-schists which are clearly metamorphic diabase-tuffs; the same ones strongly invaded; hornblende-chlorite-schists; hornblende-epidote-schists.

Hornblende-schists s. str.: The rocks A 629 – D 12629 and A 633 – D 12633 are true hornblende-schists, that is to say, they consist almost totally of hornblende, whereas tuff relic-minerals cannot be found. Hence, it is questionable whether these rocks have a tuffoid origin. Both rocks have been invaded by vein material.

A 629 – D 12629 is a greeny and schisty rock, sampled N of Spaansch Lagoen. It shows a kind of banded structure: parallel layers and stretched lenses of hornblende-schist and vein material alternate in a more or less regular way; the two types of rock merge abruptly. The structure of the hornblende-schist is roughly parallel. The texture is about nematoblastic to fibroblastic. Here and there some plagioclase occurs. Small magnetite grains are rare, and occur in the vein material too. Brownish and small flocks may be leucoxene. The hornblende is present as bigger crystals, and as a more fibrous aggregate between the latter. They are green, prismatic, sound-bordered crystals, here and there idiomorphic; cleavage is developed, several of the crystals are twinned, whereas a few column-shaped ones are bent. The "veins" consist of a granular aggregate of albite to oligoclase, with numberless small hornblende needles, prisms and grains; the latter lie very roughly parallel. Here and there a little epidote and sericite can be seen. A true vein consists of epidote-zoisite, some quartz, albite and chlorite. As to the nature of the plagioclase layers and of the veins, see p. 24.

A 633 – D 12633 is a blackgreenish and finegrained hornblende-schist in contact with quartz-epidote-veins, sampled S of Seroe Blanco, near Spaansch Lagoen. The schist merges into the epidote-quartz-rock rather abruptly. The hornblende-schist is a diverse aggregate of rather big, short-prismatic and non-idiomorphic hornblende crystals. The latter are generally palegreen, terminally frayed, fibrous, here and there bent; some of them are well-cleaved, a few crystals are twinned, and here and there the hornblende is partly chloritized. Grainy zoisite-epidote and a very little plagioclase occur between the hornblendes. Besides, many grains and masses of titanite are present. The epidote-quartz-vein contains several titanite grains, as in the schist. In several places we see great masses of enclosed hornblende fibres, many of which have been chloritized; these hornblende fibres may have originally belonged to the hornblendeschist and may have been taken up by the epidote-quartz-liquid.

The hornblende-schist A 671 – D 12671 joins the other ones, but contains rather much chlorite (S of Seroe Largo). In a tangly aggregate of very lightgreen to almost colourless, fibrous hornblende crystals, between which a great amount of very palegreen, almost isotropic chlorite occurs, lie several big hornblende individuals. Amongst the smaller hornblendes many crystals occur, which have a good prism-shape and the characteristic hornblende-cleavage. The big hornblendes too are very lightgreen, not clearly prismatic, frayed and in part fibrous; a single one shows twinning. Several of these hornblendes are partly chloritized, in such a way that the hornblende material occurs as round spots in the centre of the chlorite. A very little plagioclase may be present here and there. Magnetite is abundant.

Hornblende-schists (metamorphic Diabase-tuffs) s. str.: Although the name hornblende-schist seems to be a little exaggerated for these rocks, which on the whole do not give the impression of being rather strongly metamorphic, this name can be used here according to H. Rosenbusch (37, p. 701), who wrote about this kind of rocks: "Die Textur der "Hornblendeschiefer ist mehr oder weniger deutlich schiefrig, wobei innerhalb der Schiefe-"rungsfläche die einzelnen Amphibolsäulchen bald richtungslos, öfter mehr oder weniger "parallel und nicht selten recht streng parallel liegen. Die Gesteine sehen dann gestreckt aus "und haben bei hinreichend feinem Korn oft den Seidenglanz gewisser gefälteter Phyllite "und Tonschiefer." As we shall see below the structure of the rocks described here agrees with that, described by Rosenbusch. On the other hand, the presence of a little plagioclase and of the relic-minerals plagioclase and hornblende, and the general geological and petrographic relations prove that we have not to deal with true hornblende-schists, as they have been described by Rosenbusch and Grubenmann f.i., but with not very strongly metamorphic tuffs. Therefore, the name "metamorphic diabase-tuffs" has been added, to indicate more or less the nature of these hornblende-schists.

Macroscopic description: The rocks are light- to darkcoloured, greenish to grayish, rarely black. Far the most of the greeny rocks and only part of the gray ones are more or less foliaceous (schisty). Several greeny rocks are, besides foliaceous, somewhat lustrous on the cleavage-planes (schist-planes). Some of the schisty rocks have a platy cleavage. On the whole these rocks are aphanitic. Rarely separate hornblendes can be distinguished. – A 650, A 661, A 664, A 678 and A 680 are similar; however, non-schistose.

Microscopic description: The rocks consist of a matrix, in which relic-minerals lie scattered. The matrix takes up much more room than these relic-minerals.

The matrix of D 12650, D 12661, D 12678, D 12680 and of D 6174, D 6544, D 6551 is a true diverse-fibrous hornblende felt. The four former rocks are macroscopically massive rocks without schistosity; the three latter, however, are macroscopically schisty rocks. The sections D 6174, D 6544 and D 6551, being parallel to the cleavage-planes, show that the separate hornblende needles lie without any order in the cleavage-planes. – The matrix of the rock D 12664, macroscopically non-schisty, is a diverse-fibrous to parallel-structured aggregate. – The matrix of the schisty rocks D 12634, D 12636, D 12637, D 12648, D 12651 (cross-sections perpendicular to the cleavage-planes) is a roughly-parallel-structured hornblende aggregate of diminutive needles and fibres; D 12637 is locally diverse-fibrous. – The matrix of the schistose rocks D 12630, D 12631, D 12635, D 12657, D 12677 (cross-sections perpendicular to the cleavage-planes) is a very fine- and well-parallel-structured hornblende aggregate; in D 12631 the aggregate shows a minute folding around the relic-minerals.

Hence, the texture of these metamorphic tuffs is fibroblastic; the structure is for most of them parallel, for the others massive.

In some of the schistose rocks (D 6544, D 6551; D 12636, D 12637; D 12635, D 12677) the matrix contains parts of greater denseness, not sharply bordered on the rest of the matrix. These parts are irregularly roundish, oval or lens-shaped (in section) and lie parallel in some of the sections which are perpendicular to the cleavage-planes. May be, they represent totally changed rock-fragments; on the other hand, the difference in denseness of the matrix may also have come into existence during the process of metamorphism, without connection with rock-fragments. In any case, unaltered rock-fragments in the metamorphic tuffs have not been found. – Very slight differences in composition and denseness of the matrix of the non-schistose D 12680 create a slightly banded structure. In the same rock the fineness of the hornblende felt changes from place to place.

Except in the rocks D 12630, D 12631, D 12648 and D 12657, the matrix of hornblende fibres contains, regularly distributed and in many places, grainy plagioclase, the composition of which is albitic in D 12664. The hornblende aggregate takes up much more room than the plagioclase; yet, the matrix has, in these rocks, a kind of open foliation structure. It must be remarked, however, that the small plagioclase nests do not only occur in the plane of cleavage; moreover, the massive rocks contain this plagioclase as well. The origin of this plagioclase is questionable. May be, it is the rest of the original tuff-matrix; very probably, however, it is of a secondary origin and is connected with the invasion of vein material (compare with the matrix of the unaltered and slightly altered tuffoid rocks).

D 6544 and D 6551 contain, beside the plagioclase, some chlorite in the matrix. D 12634 contains, beside the plagioclase, an isotropic substance between the needles of the hornblende aggregate which may be chlorite or glass. D 12648 contains no plagioclase, but regularly distributed spots of chlorite. Epidote grains occur in greater or smaller quantity in the matrix of many rocks. In D 6551 the grains occur between the parts of greater denseness. D 6544 is very rich in epidote and can be called an epidote-hornblende-schist. The many epidote grains in the matrix of D 12636 lie partly in parallel strings and are locally accumulated in such a way that in these places the rock looks like an epidote-hornblende-schist. The matrix of most of the rocks contains grayish or browngrayish, flocky particles or strings, being epidote or leucoxene.

These metamorphic tuffs contain a little ore: magnetite and titanomagnetite, rarely pyrite. The DD 6544 and 6551 contain a greeny or brownish, radial-fibrous or grainy zeolitic mineral, which is probably prehnite.

The above-described matrix can be regarded as the metamorphic matrix of originally tuffoid rocks. Inside this matrix bigger relic-minerals can be seen, being plagioclases, hornblendes, rarely quartzes; the maximum size of these crystals is about 0,3—0,4 mm. The quantitative relations between these minerals are different for the various rocks; in general, both plagioclases and hornblendes are present. In the cross-sections of the schisty rocks the longitudinal axes of the relic-crystals do not lie parallel to the schistosity, and the crystals lie without order in the matrix; except in D 12631, in which the prism-shaped crystals are rather parallel to the schistosity. Hence, in general, the process of metamorphism had no influence on the situation of the bigger tuff-crystals.

The plagioclase crystals are idiomorphic or non-idiomorphic, short-prismatic crystals or only fragments of crystals (compare with tuffs), rarely with rounded-off edges. They partly show lamelling; simply zonal plagioclases can be seen in a few rocks. In general, the composition is an average or rather acid one; some of the crystals could be determined as andesine and oligoclase-andesine. The crystals are fresh, rarely sericitized or partly albitized. In some rocks the diminutive hornblende needles of the matrix stick in the plagioclase or seem to stick in it; if they really do, this proves that even the plagioclase relic-minerals were somewhat subdued to the process of metamorphism.

The hornblende crystals are pale-green, non-idiomorphic, short-prismatic, terminally frayed; most of them in most of the rocks are parallel-fibrous and here and there bent, the others are non-fibrous; some are twinned. The hornblendes are generally unaltered; only a single one has been partly chloritized. A number of hornblendes in D 12630 are needle-shaped with frayed ends; probably, these hornblendes indicate the beginning of a stronger contactmetamorphism (see the general remarks, and the description of the contactmetamorphic hornblende-schists). This rock has been sampled N of Spaansch Lagoen and near the contact with diorite. — The hornblendes very probably are uralite crystals, that is to say uralitized pyroxenes; unaltered pyroxenes have not been found.

Both plagioclase and uralite crystals can be considered as relic-minerals, which were the bigger crystals and crystal-fragments in diabase tuffs. Probably, they originated from diabase magmas. The plagioclases have been more or less albitized and have a more acid composition than diabase plagioclases. The pyroxenes have been uralitized, very probably, during the process of metamorphism of the tuffs (compare with the unaltered tuff A 646—D 12646 on p. 28).

A single quartz crystalgrain in D 12648 may be a diabase mineral as well, or is foreign material. – Problematic remnants of Radiolaria can be seen in D 12657 and D 12680. – A few small and parallel-stretched quartz nests occur in D 12648. Small aggregates of diminutive biotite plates, with limonite, in D 12677, and a single biotite in D 12648 may be new-made.

Most of the rocks have been invaded by veins. This invasion of hydrothermal and more or less magmatic solutions must have been connected with the diorite intrusion. It is significant, that the rocks, sampled N of the line Mira la Mar—Rooi Prins, contain no veins, whereas far the most of those occurring S of this line, are more or less invaded. The veinminerals are epidote, quartz, plagioclase, chlorite, ore and ?prehnite. The veins are rather sharply bordered on the matrix; fragments of the latter may occur enclosed; or matrix and vein merge. As to the rock D 12650, the process of hornblendization has probably proceeded even after the intrusion, for the hornblende needles stick in the plagioclase-vein; the intruding liquid however may also have loosened the matrix hornblendes.

Finding-places:

Hill S of Jamanota: P 88—D 6551. Seroe Blanco (near Spaansch Lagoen): A 636—D 12636; A 637—D 12637. E of Spaansch Lagoen: A 634—D 12634; A 635—D 12635; P 87—D 6174. NE of Spaansch Lagoen: A 631—D 12631. N of Spaansch Lagoen: A 630—D 12630. Mira la Mar: P 78—D 6544. N of Mira la Mar: A 648—D 12648. S of Andicouri: A 677—D 12677; A 678—D 12678. W of Dos Playa: A 680—D 12680. Upper course of Rooi Prins, near Juditi: A 657—D 12657. SE of Gran Tonel: A 650—D 12650. S-foot of Gran Tonel: A 651—D 12651. Just N of Baranca Corra: A 661—D 12661; A 664—D 12664. [1])

Strongly invaded Hornblende-schists (metamorphic tuffs): In nature, these

[1]) Martin 96, sampled in the "rooi" N of Spaansch Lagoen, has been described by J. H. Kloos (25, p 47). Kloos did not describe the plagioclase and hornblende tuff-crystalls and did not recognize the rock as a metamorphic tuff.

rocks are not much different from the other metamorphic tuffs. Only the strong invasion of plagioclase material gave them another appearance.

The rock A 638—D 12638 is the only one, in which a parallel structure is wanting. Therefore it will be described apart from the others. This rock, found on the Seroe Cucu, consists for the greater part of a diverse hornblende felt. It is remarkable, that some needles show twinning. Relic-minerals are some hornblendes. The matrix is present as irregularly shaped masses, between which irregularly shaped „veins" occur. The latter consist of a very finegrained aggregate of plagioclase (oligoclase, oligoclase-andesine) and quartz, which contains moreover numerous hornblende needles. The hornblende-matrix gradually merges into the „veins". Also some of the hornblende relic-minerals lie partly in the material of the „vein". Grains of epidote are abundant in the „veins". Many irregularly shaped magnetites occur in both parts of this rock.

The rocks A 632—D 12632, A 658—D 12658, A 659—D 12659 and A 660—D 12660 are greeny or grayish, and schisty. They show a parallel structure and moreover a kind of banded structure. A slight minute folding is present too. They consist alternately of layers of unequal thickness, of stretched, flat lenses and irregularly shaped stretched masses of two kinds of rock-material: metamorphic tuff and vein-material. D 12658 consists for the greater part of plicated tuff layers, between which only a few layers of vein-material occur. The two kinds of rock-material are not sharply bordered, but merge.

The metamorphic-tuff layers consist of a very fine- and well-parallel-structured hornblende aggregate with a varying denseness, and with a few relic-minerals of plagioclase and hornblende. The hornblende aggregate curves around the latter. The vein-material partly or wholly encloses some of the relic-minerals. Besides, the rock D 12658 contains numerous epidote grains; it is remarkable that the hornblende aggregate also curves around these epidotes.

The vein-material in D 12658 consists of grainy plagioclase and chlorite fibres. In the other rocks it consists of plagioclase, with numberless small hornblende needles, some chlorite and many epidote grains; part of the latter have brownish colours. The plagioclases in D 12659 and D 12660 are lamelled and albitic; those in D 12632 are rather basic and look pressed; here and there also some quartz occurs. – A few titanomagnetites and magnetites do not especially belong to the metamorphic-tuff layers, but also occur in the veins.

During the process of metamorphism more or less magmatic and hydrothermal solutions, connected with the diorite intrusion, have intruded along fissures, which came into being at the same time under the influence of orogenic movements. These solutions have had a rather strong resorptive power, regarding the room, which is occupied by the vein-material in the rocks described here. The banded and parallel structure must have come into existence at that time. Very probably, the process of metamorphism proceeded after the intrusion, for the hornblende needles occur in the veins too. It is not probable that these needles have been loosened from the matrix.

Finding-places: These rock types have only been sampled in the southern part of the older mountains. NE of Spaansch Lagoen: A 632—D 12632. Upper course of Rooi Prins, near Juditi: A 658—D 12658. S of the Jamanota: A 659—D 12659; A 660—D 12660.

Hornblende-chlorite-schists (metamorphic tuffs): A 666—D 12666 (E-foot of Seroe Kabaai) is non-schisty, and invaded by veins. It is a diverse-fibrous hornblende aggregate with a varying denseness. In this aggregate the following minerals occur: calcite, chlorite and epidote grains. Magnetite is present as many diminutive grains, the distribution of which is not regular .A few plagioclases and hornblendes are relic-minerals. In this rock also occur remnants of Radiolaria(?); the Radiolaria have been replaced by ?silica and hornblende needles. Some of the veins prove the existence of faults through the rock. The veins consist of epidote, calcite, chlorite, quartz, plagioclase; the hornblende needles of the matrix stick here and there in them.

A 647—D 12647 (Du Chef) is a spotted and schisty rock. Microscopically, more or less regularly shaped, lenticular, roughly-parallel-structured hornblende masses lie parallel, and are not sharply bordered on interjacent masses of fibrous chlorite with steelblue interference-colours. In this chlorite also numerous hornblende fibres and needles occur, while here and there the transition between hornblende and chlorite is clear. The hornblende lenses are a little brown-coloured, probably by limonite; the chlorite is lightgreen: hence the spotted appearance of the sample. Magnetite is rare. Numerous diminutive flocks are leucoxene or epidote. A few hornblende relic-minerals have an anygiven situation in the described hornblende and chlorite masses. Some vein-like parts of the rock consist mainly of chlorite, grainy quartz and leucoxene or epidote flocks, and also enclose parts of the hornblende aggregate.

Hornblende-epidote-schist (metamorphic tuff): A 679—D 12679 (W of Dos Playa) is an aphanitic, blackgrayish rock, with varioles. Microscopically it is a mass of rather parallel and diminutive hornblende fibres, with numerous epidote grains, parallel-stretched plagioclase nests and also some plagioclase fragments. This mass contains peculiar, small and eggshaped elements, in which the hornblende fibres lie without order and which are a little more transparent; they are, however, not sharply bordered, and look like remnants of Radiolaria. Several bigger (1 mm to 3 mm diameter), round to eggshaped elements are similar, but contain moreover epidote grains and a few plagioclases. A typical connection exists between these non-sharply bordered, round elements and the structure of the rock (see fig. 6). The round elements must have behaved as rigid masses during the dynamometamorphism. Magnetite is rare. Some epidote veins with a little chlorite and limonite manifest a clear faulting in the rock. Two round elements also show faulted parts.

Martin 108, sampled in Rooi Prins, has been described by Kloos (25, p. 45). It is a hornblende-epidote-schist, strongly invaded by plagioclase.

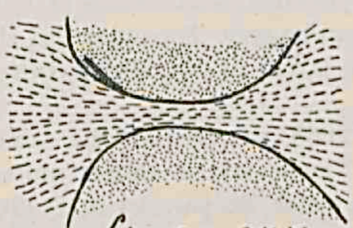


fig 6 24x

fig 7 real size

MORE OR LESS METAMORPHIC (HORNBLENDIZED) DIABASE-TUFFS.

These tuffs are less metamorphic than the hornblende-schists and represent the transition forms between the latter and the hardly altered tuffoid rocks. The rocks will be described according to decreasing metamorphism (hornblendization), as far as it is possible to judge of the grade of metamorphism. They are aphanitic to finegrained, dark- or lighter coloured; grayish, brownblue- or green-grayish.

A 655—D 12655 is the most metamorphic diabase-tuff and occurs westernmost of these rocks: NE of Arikok. The main part of the rock consists of a very fine-structured hornblende aggregate, with a little pyrite and magnetite. Bigger tuff-minerals, still preserved, are plagioclases and hornblendes. The former are fragments and well-idiomorphic prisms, lamelled and rather basic. The hornblende fragments are wholly or partly chloritized. Some rock-fragments are uralite-diabase; others cannot be defined. It is questionable whether the rock contains remnants of Radiolaria. This rock, occurring not so very far from the diorite, contains an irregularly shaped vein of grainy plagioclase, with numerous fibrous hornblende needles and prisms, and locally with zoisite, ore and titanite.

The rocks A 643—D 12643 and A 644—D 12644, sampled in the same place near Dos Playa, are little metamorphic tuffoid rocks. A 643 is schisty-stratified. A 644 has no distinct stratified structure. Both rocks contain numerous small ore- and limonite strings, which determine the „stratified structure" in D 12643. The matrix takes up more room than the bigger tuff-minerals. It looks very isotropic and very probably consists of a very fine-structured hornblende aggregate. Both rocks contain a great many small prisms and fragments of plagioclase, partly lamelled, and here and there zonal; their composition is average or rather basic (f.i. oligoclase-andesine, ?labrador). Crystals of uralite-hornblende are only present in D 12644. Lens-shaped remnants of ?Radiolaria can be seen in D 12643, and D 12644 contains some very finegrained albite aggregates, here and there full of ore.

The rocks A 641—D 12641 and A 642—D 12642, being little metamorphic tuffs, have been found in the same place, between Boca Prins and Dos Playa. A 641 is somewhat schisty with brownish and blackish layers. A 642 is lustrous and schisty, with irregularly shaped cavities, which are filled up with grayish-brownish, grainy and porous material. – D 12641 shows a stratified structure because of a difference in denseness; the less dense layers contain moreover many limonite grains. The matrix of the more dense layers consists of parallel, plicated and narrow layers of diminutive ?hornblende fibres together with limonite and diminutive plagioclase-like grains. The matrix of the less dense layers consists of an extremely finegrained plagioclase-like aggregate, in which a great many extremely tiny ?hornblende fibres lie without any order; here and there the narrow ?hornblende-layers with limonite, as described above, occur. – D 12642 has a parallel-structured matrix, almost isotropic with plagioclase-colours here and there, and with many diminutive hornblende fibres. – The rocks contain similar plagioclases, uralite-hornblendes and filled ?Radiolaria cavities as A 643 and 644; moreover, a few quartzes. D 12642 contains big, irregularly shaped fragments of other crystal-tuffs, richer in plagioclases (see the sample).

The rock A 665—D 12665, found near Boca Prins, is a tuffoid rock, somewhat epidotized and hornblendized. The sample is grayish-purple and a little schisty. Many epidote grains and many eggshaped or irregular masses of small dimensions, which consist of a very fine-fibrous ?hornblende felt, occur in an almost isotropic mass, which takes up only a very small room and in which feldspar- and chlorite-colours can be seen. The masses of ?hornblende felt seem to contain some rests of ?Radiolaria. The rock is full of ore. Bigger tuff-minerals are a very few plagioclase and quartz fragments.

The rocks A 667—D 12667 and A 668—D 12668, sampled in the same place, about 2 km. W of Boca Prins, are little altered tuffs. The matrix is almost quite isotropic, but probably contains diminutive hornblende fibres, which lie parallel in D 12668; moreover, epidote grains. A great many plagioclases of average composition occur as bigger tuff-crystals. Many uralite-hornblendes occur only in D 12667, while D 12668 contains egg-shaped ?Radiolaria cavities, filled with plagioclase and hornblende needles. Magnetite, a little pyrite and limonite.

The rock A 669—D 12669, sampled SW of Dos Playa, is also a somewhat metamorphosed and schisty tuff-rock. In a browny, isotropic-looking mass with diminutive hornblende fibres, epidote grains, limonite grains and ore in small strings and groups, many small grains of plagioclase, less of quartz, and uralite-hornblende prisms can be distinguished. A few small rock-fragments cannot be determined. This rock, lying rather westward, contains a narrow quartz-vein.

A 645—D 12645 is a ?Radiolaria-bearing tuff, with only a beginning of metamorphism; near Dos Playa. The rock contains calcite-amygdales. The differences in colour of the sample are due to a difference in limonitization. The matrix is an aggregate mainly of average plagioclase and also of quartz, with moreover diminutive hornblende needles. It contains some bigger, rather basic plagioclases, some of which are zonal. Several remnants of ?Radiolaria; their round or eggshaped to flat-eggshaped cavities have been filled with calcite. The latter mineral also occurs scattered as very small grains.

Kloos (25) described on p. 48 the "Mergelschiefer" of Dos Playa. It is a little hornblendized, calcite-bearing crystal-tuff with many plagioclase crystals and possibly with calcitized ?Radiolaria.

These tuffoid rocks only occur in the eastern regions of the older formation, that is to say, in the region between Boca Ketoe, Juditi and Fontein. Most of the samples have even been taken in the eastern part of this region, in about the triangular region between the lower course of Rooi Prins and Dos Playa. Veins are as good as wanting in these rocks.

In connection with the metamorphic tuffoid rocks described here, the rock A 654—D 12654, which has been found W of Dos Playa, can be described. It is a VARIOLITIC TUFF (?) LITTLE METAMORPHIC. — Macroscopic description: The varioles which are "herauspräpariert" at the brown-weathered surface show a clearly spheroidal construction. They have a diameter of about 1 cm., and partly touch each other; here and there a bigger variole embraces a smaller one (see fig. 7). The varioles are aphanitic and grayish, and their spheroidal forms can be seen here and there in the fracture-planes. The interjacent rockmass takes up less room than the varioles, and is finegrained and grayish. - Microscopic description. The varioles: The spheroidal construction is manifested only by the fact, that a narrow peripheric border is a little denser than the central parts. The varioles consist of an almost isotropic matrix, with numerous diminutive ?hornblende fibres. In this matrix numerous crystals and crystal-fragments can be seen: calcite, ?diopside, ?hornblende, plagioclase, epidote. Moreover, there occur strange, brownish, ?organism-like elements and rather much pyrite. The interjacent mass is a little coarser grained than the rock of the varioles. The latter are rather sharply bordered on this mass. The same matrix and crystals as in the varioles occur here; however, a little more calcite and epidote are present. Many roundish and angular-rounded-off parts with a greater denseness, between which here and there chlorite, can be seen.

It is difficult to understand the genesis of this rock. Possibly, epigenetic concretions came into existence in a muddy deposit, which contained much tuff-material. The interjacent mass between these concretions has been replaced afterwards by coarser grained tuff- and muddy material (the interjacent mass is a little coarser grained than the varioles, and is rather sharply bordered on them). The rock has been diagenetically altered, and after that also little metamorphosed (hornblende fibres). Probably, organic material was present in the original deposit (calcite, pyrite, ?organisms). The matrix seems to have been a ?colloidal amorphic mass. The replacement of the original interjacent mass seems to point to a slight change in level.

NON-HORNBLENDIZED TUFFOID ROCKS, LITTLE OR HARDLY ALTERED.

The little altered tuffoid rocks will be described first, the hardly altered ones after that.

The rocks A 683—D 12683 and A 684—D 12684 have been found in the outcrop SE of Fontein. A 683—D 12683 is mainly a dark-purple rock with reddish-brown strings of magnetite and limonite. Between these ore zones we see an isotropic, locally perhaps siliceous matrix with diverse-fibrous ?talc (parallel extinction, + zone, n = about 1,59), ore, ?leucoxene, epidote and ?prehnite prisms. Bigger tuff-minerals are partly rounded-off plagioclase crystals and fragments, and quartz grains. ?Radiolaria. - A 684—D 12684 is a schisty, mainly purple rock; a great part of it is occupied by magnetite and limonite, while no unaltered matrix can be seen. In the mass of ore a great many parallel-stretched, lense- and flat-lense-shaped parts occur, composed of a very fine-structured, roughly-parallel-fibrous aggregate of ?talc. Besides, several round, roundish or angular quartzes and Radiolaria (!?) are present.

The little-altered crystal-tuff A 682—D 12682 (Rooi Prins, near Kasoenti) is a greenish-gray, schisty rock, lustrous on the cleavage-planes. It is an accumulation of partly bent albite prisms and fragments with titanomagnetite, cemented by chlorite with leucoxene. Narrow veins of calcite consist of undulose individuals, which show here and there lamellar twinning.

The rock A 674—D 12674, sampled on the northeastern slope of the Jamanota, is schisty and purple-grayish. The matrix seems to be isotropic, but probably consists of a very finegrained quartz aggregate, in which much magnetite occurs in small groups. These groups are separated by zones, almost free of ore. Moreover, the matrix contains numerous epidote grains, here and there brown, and also many roundish epidote aggregates, locally with chlorite. As bigger tuff-crystals several quartzes and plagioclases are present.

The calcite-bearing tuff (?!) A 653—D 12653, W of Dos Playa, is aphanitic and bluish-gray. It is an almost isotropic rock, consisting for a great part of small zoisite-like grains. Calcite, possibly secondary, occurs scattered through the rock. Moreover, some magnetite, limonite and, as tuff-minerals, some plagioclase fragments can be seen.

The crystal-tuff A 681—D 12681 occurs as an inclusion in diabase of Rooi Dwars, near Boca Prins. The blackgrayish rock is an accumulation of small crystals, between which a kind of cement occurs, grayish and flocky in reflected light. Most of the crystals are ?prehnite, which is probably pseudomorphic after plagioclase or pyroxene; the prehnite occurs as finegrained aggregates in prism-shape, here and there with quartz or chlorite. Several crystals occurring as well-cleaved, colourless grains and prisms are probably monoclinic pyroxenes. Also a few quartz fragments, remnants of ?Radiolaria, and many pyrite grains are present. Narrow calcite-veins and widespread, grainy calcite.

A crystal-tuff from Dos Playa is the aphanitic, darkgrayish and schisty rock A 646—D 12646. In an almost isotropic matrix innumerable and very small mineral-fragments and less remnants of ?Radiolaria lie close together. Many small strings and grains of ore indicate a parallel structure. Diminutive epidote or leucoxene grains are widespread. The small crystal-fragments are partly-lamelled andesines and labradors, and less diopsidic augites.

It is noteworthy that the two latter rocks are the only ones of the little and non-hornblendized tuffoid rocks which contain unaltered pyroxenes.

The rocks occur in about the same region as the partly hornblendized tuffs. Moreover, they have been found in the diabase and tuff region SE of Fontein. Only the rock A 674 lies outside these regions, and has been sampled on the northeastern slope of the Jamanota in a zone about 20 m. wide, lying in the midst of strongly metamorphic tuffs and other rocks. Beside a few calcite-veins in some of the rocks, they do not contain vein-material.

Appendix: Another rock, possibly also tuffoid, is A 640—D 12640, found near Boca Prins. It is aphanitic, greenish-gray, and contains white nests. It consists of a finegrained aggregate of radial-fibrous grains, with a very little magnetite, and locally with calcite. Several amygdaloid cavities are filled with: radial-fibrous ?prehnite, quartz, calcite and epidote. Fissures are filled with calcite, epidote and quartz. This rock may be an altered amygdaloidal rock.

SCHISTY, PORPHYRITIC ROCKS

(belonging possibly to the older formation, possibly to the diorite batholith).

A 266—D 12265 (Jamanota); A 780—D 13078 (Seroe Blanco, near Spaansch Lagoen); A 781—D 13079 (lower course Rooi Prins).

Macroscopically phenocrysts can be seen in a schisty and greeny groundmass. Microscopically, the structure is parallel in consequence of flowing and moreover of dynamic processes. The plagioclase phenocrysts are strongly altered, rounded-off albites. Hornblende phenocrysts can be recognized only in D 12265; they are partly broken and are transitional into strings of hornblende fibres, epidote and chlorite. Similar strings in the two other rocks, together with sericite and leucoxene, may also have originated from hornblende. A single round quartz phenocryst without a reactionrim occurs in D 13079. The groundmass of D 12265 consists of albite laths, quartz and partly chloritized hornblende. In that of D 13079 the hornblende has been totally changed into stringy chlorite, biotite, sericite and leucoxene. The groundmass of D 13078 is banded by chlorite zones, rarely by quartz zones; it is a quartz-plagioclase aggregate with numberless parallel hornblende needles and chlorite. A little ore and apatite are accessory. D 12265 has been invaded by quartz and albite.

Hence, these rocks have mainly a vintlitic character and might belong to the batholithic rocks, except for their schistosity. Since porphyritic and vintlitic dikes without schistosity and belonging to the diorite batholith occur in the older formation too, it is difficult to put the latter and the former in one group of rocks. Therefore, these rocks have been described under the schistose rocks of the older formation. However, since the diorite intrusion has occurred during the folding of the older rocks, the possibility exists that locally the porphyritic dikes have been subdued to the last phases of the folding, whereas in other places similar dikes intruded after these phases had finished. – In our fieldnotes A 266 has been indicated as an aberrant schist with a dike appearance, A 781 as lenses in schisty rocks, and A 780 as a schist.

GENESIS OF THE TUFFOID ROCKS

As we have seen above, the tuffoid rocks can be generally considered as diabase-tuffs with bigger diabase-minerals. The quartzes in the tuffs may have originated from diabase magma which crystallized here and there into quartz-bearing diabases, but may also be of foreign origin (compare with the quartz-sandstone A 656, and with the diabase-conglomerates). In the latter case the tuffs with this foreign material are tuffites. – Some of the rocks contain remnants of Radiolaria proving their deposition in a sea which was rather shallow, the quartz-sandstone and the conglomerates, which can be probably considered as terrigenous deposits, occurring alternatively with the tuffoid rocks (see also G. J. H. Molengraaff (31) p. 21). The presence of the conglomerates points to non-submarine eruptions. The matrix of the tuffoid rocks, when not altered, is generally isotropic and probably an amorphic (?colloidal) silicic acid. Possibly in many rocks this matrix came into being in muddy and shallow water near the volcano (siliceous volcanic mud). Radiolaria must have lived there. Other tuffoid rocks, however, may have been deposited on land.

RELATION BETWEEN THE NOT AND LITTLE HORNBLENDIZED TUFFOID ROCKS AND THE STRONGLY METAMORPHIC TUFFS (HORNBLENDE-SCHISTS S.L.), AND GENESIS OF THE LATTER.

If we compare the finding-places of these different rocks, it becomes clear that the strongly metamorphic tuffs generally do not occur E of a line Boca Ketoe-Juditi, whereas the bulk of the non-hornblendized and little hornblendized tuffoid rocks can be found between this line and Fontein, and also in the outcrop SE of Fontein. That is to say, the latter two kinds of rock occur farthermost from the batholith; it is of significance, moreover, that the rock sampled westernmost (A 655, NE of Arikok) is the most metamorphic of them. So, it is very probable that the metamorphism was due to the diorite intrusion, and besides to the process of folding. The hornblendization must have been closely connected with the intrusion, whereas the schistosity must have been the result of strong orogenic movements in the older formation. The hornblendization can be compared with the uralitization of the diabases. The metamorphism cannot be the result only of the folding, for it would be incomprehensible then why certain rocks have not been metamorphosed. So, the hornblende-schists s.l. are the product of both dynamo- and contactmetamorphism; they show a clear schistosity. The little hornblendized tuffs have been less subdued to contactmetamorphism because of the greater distance and show but here and there schistosity, whereas the non-hornblendized tuffs only have been folded and do not show clear effects of contactmetamorphism; there is no schistosity in the latter rocks. Obviously, the folding of the older formation could only bring forth schistosity in the case of hornblendization of the tuffs.

The above-described idea concerning the genesis of the metamorphic tuffs is supported by the following facts. Veins, which are so abundant in the metamorphic tuffs and which are connected with the intrusion are almost wanting in the less metamorphic and non-hornblendized tuffs. – As we have seen in some of the strongly metamorphic tuffs, the process of hornblendization may have proceeded still after the intrusion of plagioclase-quartz-veins.

Hence, the relation described here is the same as that between the diabases and uralite-diabases.

The process of dynamometamorphism must have occurred at the same time as that of contactmetamorphism, for the hornblende needles and fibres, resulting from the contactmetamorphism, lie parallel in most of the hornblendized tuffs. Also the minute folding around epidote grains in some of the strongly invaded hornblende-schists makes this probable, for the epidote must be connected with the invasion, and the minute folding is the result of the folding process. Moreover, the banded structure in these rocks must have come into existence thanks to a folding process during the invasion of vein-material, the latter connected with the diorite intrusion. So, we must come to the conclusion that *the diorite batholith intruded during the folding of the older formation.* It is noteworthy here that many of the dioriteporphyrite and other dikes in the older formation, which belong to the batholith, have the same strike as the schistose and tuff rocks; this seems also to point to an intrusion during the folding.

Martin (30) did not pay attention to the genesis of the "Grünschiefer", but called them here and there "Sedimentärgesteine." He compared the hornblende-schists with the schists of Venezuela and thought them to be very old: (p. 56) "Das legt im Verbande mit der grossen ,,Analogie, welche die Inseln überhaupt zu dem Festlande in ihren geognostischen Verhält- ,,nissen aufweisen, die Annahme nahe, dass die Grünschiefer und Amphibolite das Grund- ,,gebirge darstellen und der archaeischen Schichtenreihe angehören." – Kloos (25) called them "stark metamorphosirte Sedimente" (p. 47). As has been mentioned already above (see diabases, p. 19), he also faced the possibility that the hornblende-schists and uralite-diabases of Aruba are "das Beispiel einer Contactzone eines Dioritmassivs" (p. 61).

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE SCHISTOSE AND TUFFOID ROCKS

In the landscape the schistose rocks can be distinguished from the diabases because of their light colours and schistosity. The difference in appearance, however, between the more or less altered tuffoid rocks and the finegrained and aphanitic diabases is in many places rather small. Since the little and non-metamorphic tuffs do not show a clear schistosity the distinction between these rocks and the hornblende-schists is always clear.

Both the schistose and tuffoid rocks show in most places a clear strike and dip; that is to say, the former show strike and dip of the schistosity-planes, the latter often those of the bedding-planes. The strikes which do not differ so much from the E-W direction (N 80 E, N 90 E, N 100 E, N 110 E) largely prevail. The average strike is about N 95 E.

Locally in the "rooi" on the SE-foot of the Jamanota the strike of the hornblende-schists changes from W to E gradually from N 95 E into N 145 E, N 90 E, N 145 W and back again to N 95 E; so, the schistosity-plane forms here a bending outwards towards the south over a rather short distance. – Especially in the hills S of Andicouri and Noordkaap aberrant strikes have been found f.i. N35, 45, 60, 125, 135E. – S of Seroe Blanco a malchite dike N 135 E cuts across hornblende-schists, unconformably. It is remarkable that the schists NE of the dike have a N90E strike and those SW of the dike a N105E strike. – Dips towards the north and towards the south have been found in about the same number. Most of the schistosity- and bedding-planes are vertical or very steep. Less steep dips have been found too; they lie between 40° and 90°, many of them being about 50°.

The rocks only occur in the older formation between Spaansch Lagoen, Andicouri and Fontein and in the outcrop SE of Fontein. — According to MARTIN (30) they only occur in the W—E "rooien" Prins and Tamboe and also in the E—W "rooi" W of Rooi Prins. He considered them little resistant rocks which have been eroded deeper than the surrounding and more resistant diabases. Since the strike of the rocks is about E—W, these "rooien" must have got also a somewhat E-W direction. Although the schistose and tuffoid rocks have a much greater distribution, the idea of MARTIN about genesis and direction of these "rooien" must be right. Other "rooien" in which we found the same rocks show these properties too. However, the rocks do not occur only in "rooien" but are also present on the slopes and the tops of the mountains. Since the schists are the principal rocks in the southern mountains they must occur here, besides in the valleys, on the slopes and the tops. So f.i. the Seroe Blanco, Seroe Cucu, Seroe Largo and Kleine Jamanota mainly consist of schists. On the other hand, in the central and northern parts of the formation where the diabase is more widespread, the different mountains and the tops, f.i. the Seroe Kabaai and Du Chef, Mira la Mar, Seroe Boonchi and Arikok consist for the greater part of diabase, whereas in these regions the schists and tuffs have been more eroded and form the valleys, generally.

The "dunkelgraue Mergelschiefer als anstehendes Gestein an der Boca dos Playos" (p. 60), according to MARTIN (30) possibly belonging to a Cretaceous formation comparable with that of Curaçao and Bonaire, are common tuff-rocks in the schist-tuff series (see also J. H. KLOOS (25) p. 48).

GEOLOGICAL RELATION BETWEEN THE DIABASES AND THE SCHISTOSE-TUFFOID ROCKS

MARTIN (30), taking into consideration the distribution of the schist-tuff-rocks to the best of his knowledge, came to the conclusion, (p. 56) "dass die Sedimentärgesteine das Liegende der Diabase darstellen" and are older than the diabases. The occurrence and distribution could be very well understood, according to him, (p. 55) "da bei deckenförmiger Auflagerung des Eruptivgesteins (diabase) die Sedimente am ehesten in den tiefst eingeschnittenen Schluchten "und somit in dem höchsten Theile des Gebirges, woselbst die Erosion am wirk-"samsten thätig war, blossgelegt werden mussten." KLOOS (25), however, who compared these rocks with similar ones from other islands and took into consideration the strongly metamorphic character of the schists, remarked on p. 60 "so wird man eher zu der Annahme neigen, dass die Diabase und Uralitite sammt "den Schiefern zu einem und demselben gefalteten Schichtensystem gehören."

The geological occurrence and distribution of the different rocks and also the fact that the schist-tuff-rocks are for by far the greater part true, although more or less metamorphic, diabase-tuffs, prove, as KLOOS assumed, that the diabases and schist-tuff-rocks belong to one and the same folding-system and that the former occur as interstratified beds between the schists and tuffs.

The geological relation between diabases and schist-tuff-rocks can be seen very clearly in the southern mountains which mainly consist of schists, and can be seen only locally in the central and northern parts which consist mainly of diabasic rocks. The diabase occurs alternatively with the schistose and tuffoid rocks. In many places the rocks occur as a pell-mell. Especially in the southern parts of the formation, however, the diabase occurs as large masses and intercalations in the schists. If we look at the map and take into consideration the prevailing E-W strike of the schist-tuff-rocks we see several diabase beds and masses bordering more or less conformably on the schists and tuffs. There are, however, also many diabases which lie unconformably between the other rocks. Some diabase masses and beds in the southern parts strike N 80 E, N 70 E, N 60 E and N 50 E, hence differ rather much in strike with the surrounding schists.

Since it is admissible that the diorite and its differentiates intruded during the folding of the older formation and since contactmetamorphism in the tuff and schist rocks, where they border on the diabase, has not been found, it is not probable that the diabases – which represent another type of igneous rocks than the dioritic ones – intruded also during or even after this folding. Therefore, the diabases – which obviously belong to the series of diabase-tuffs – must have crystallized before the folding, and must have formed true lava sheets between and on the tuff beds and moreover irregularly shaped intrusive masses and dikes in these beds. Although locally the diabase is macroscopically a little schisty (f.i. N 75 E) folding cannot be recognized in these rocks which behaved as rigid masses between the bedded tuffs.

Where the diabase lies unconformably in the other rocks, the unconformity locally might also be the result of faulting during the folding.

CONGLOMERATES AND BRECCIAS

The older formation consists, besides of diabase, schists and tuffs, also of conglomerates and breccias. Many of them contain pebbles of diabase and can be called diabase-conglomerates. A quartz-sandstone will also be described in this chapter.

BRECCIAS

They do not contain diabase fragments. There is a great difference between them and so they will be described apart from each other. Some have a more or less conglomeratic character; others have an indistinct, breccious character. The green to gray to purple fragments are irregularly shaped, acute-angular or rounded-off, and lie in a grayish to green to yellowish cement. Fragments and cement may be not sharply bordered.

The cement of A 727—D 12691 (W of Dos Playa) is a pressed plagioclase aggregate, with some chlorite, pyrite, magnetite and calcite. – Fragments and minerals: 1. fragments of a very finegrained hornblende aggregate with grainy, pressed quartz, some ore and albite, in reticulated texture; this plagioclase and that of the cement seem to be the same. 2. very fine-structured hornblende aggregate, here and there calcite-bearing. 3. some pyroxenes and plagioclases. 4. strange, grainy aggregates, the elements of which are browny in the centre and biaxial-positive. 5. irregularly shaped isotropic masses. 6. ??diabase.

The cement of A 732—D 12696 (SE of Dos Playa) is a dusty, grainy aggregate of partly lamelled albites with here and there some quartz, the whole somewhat parallel-structured. Many epidote grains and prisms and ?prehnite crystals are present; besides, some pyroxenes and apatites. – The fragments, more or less surrounded by an aggregate of ?sericite, ?prehnite and epidote, are 1. very fine-structured hornblende felt, with or without epidote. 2. epidote masses and 3. chloritic and isotropic masses. Little ore is present.

The cement of A 736—D 12700 (Rooi Dwars, near Boca Prins) is a dirty-looking ?siliceous aggregate with quartzes, pyroxenes, pyrite, magnetite and ?prehnite-nests. The fragments are 1. chlorite with a rim of ?prehnite. 2. chlorite masses with small "suns" and crystals of ?prehnite, and some quartzes and plagioclases; many of these masses have a ?prehnite rim too. 3. aggregates of ?prehnite. 4. aggregates of ?epidote with quartz, chlorite and ?prehnite amygdules; transitional into (2.). 5. some hornblende felts with plagioclases and pyroxenes.

The cement of A 730—D 12694 (near Boca Prins) is a pressed-looking quartz aggregate with epidote and some limonitic magnetite. The "fragments" look like concretions; their periphery is brownish. They are yellowish-transparent in section; some are quite isotropic, others for the greater part. They are extremely finegrained aggregates; each "grain" is radial-fibrous. Curious and very small, oval elements lie scattered in the "fragments".

The cement of P 77—D 6543 (top Jamanota) is grainy epidote with quartz and some magnetite. The fragments are 1. diverse- and parallel-fibrous hornblende aggregate, with or without epidote; a single fragment with remnants of ?Radiolaria. 2. a few grainy epidote aggregates. 3. looks like a chert and is transitional into (1). 4. a diverse-fibrous aggregate of hornblendes, some quartz and epidote. 5. some hornblende crystals.

The cement of A 731—D 12695 (NW of Boca Prins) consists of chlorite with zoisite grains and prisms and some limonitic magnetite; in several places ?prehnite needles and prisms, surrounded by quartz grains, occur, the whole with a dark rim. The fragments are very fine-structured, diverse-fibrous hornblende aggregates, here and there with plagioclase laths.

DIABASE-CONGLOMERATES (Plate II, fig. 5—6).

Since the most typical pebbles and fragments in these rocks are diabase, whether uralitized or not, we can call them diabase-conglomerates. Some of the rocks have a more breccious character.

Since many rocks contain the same types of diabase it is better first to give a general description of these types. – 1. The diabases, whether uralitized or not, are normally ophitic. – 2. The diabases can be quite compared with the "Dichte diabaas met plagioklaasnaalden, die tot onvolkomen bundels divergeeren" (G. J. H. MOLENGRAAFF (31) p. 31). They are aphanitic, dark rocks. The long plagioclase laths diverge in imperfect bundles and are often bent. Allotriomorphic augite grains lie between these plagioclases. Chlorite may be present, as an alteration mineral or in amygdules. The uralite-diabases of this kind show the same texture. The uralite, however, is on the whole not present as grains but as fibrous, long individuals between the plagioclases and has, by that, a plumy development. It replaced, moreover, more or less the plagioclases, so that in some rocks the uralite takes up much more room than the plagioclase (type *a*, uralitized or not). – 3. The diabases can be compared with the "Dichte diabaas met veldspaath-mikrolithen, augietkorrels en schoofvormige augiet-mikrolithbundels" (G. J. H. MOLENGRAAFF (31) pp. 31—32). The rock is aphanitic and contains a few plagioclase and augite phenocrysts. The plagioclase occurs as laths and as needles. The augite occurs as grains and as spherolites. When uralitized, the uralite is present as fibrous grains and as spherolites; uralite phenocrysts. (type *b*, uralitized or not). – 4. The diabases can be quite compared with the "Dichte diabaas met augiet in flink ontwikkelde schoofvormige mikrolithbundels" (G. J. H. MOLENGRAAFF (31) p. 32). They are aphanitic and microporphyritic. Only a very few phenocrysts occur and are plagioclase and pyroxene. The plagioclases are only few in number and occur as laths and needles. The pyroxene occurs almost wholly as very fine-structured spherolites; in some rocks these spherolites are browncoloured. Ore is very fine-scattered in these spherolites. The rocks are finer structured than type *a*, and differ only slightly from type *b*. When uralitized, the uralite occurs in spherolites too; pyroxene and uralite can be distinguished only with difficulty in these rocks. Uralite phenocrysts. In some rocks, chlorite or epidote occur between the spherolites, rarely in their core (type *c*, uralitized or not).

Some fragments are not sharply bordered on the cement. The pebbles vary in size. They reach a maximum size of about 5 cm. but many of them can be seen only under the microscope. They are generally roundish, rarely irregularly shaped, white, grayish, greenish, bluish or brownish, and lie in a grayish to purple, greenish or yellowish cement.

The following conglomerates have been found in the diabase-tuff outcrop SE of Fontein.

A 737—D 12701. The cement is a microbreccia of partly sericitized plagioclases, colourless augites, magnetites (diabase-constituents!), between which epidote, chlorite and locally also quartz occur. The rock-fragments are: 1. normally ophitic diabase. 2. type *a*. 3. type *c*. 4. a strongly magnetitized and limonitized, very fine-structured, diverse hornblende aggregate with locally some plagioclase, some pyroxenes and more epidote grains. 5. some small chert-like fragments.

The "cement" of A 738—DD 12702, 12703 occurs as strings between the fragments, and is an isotropic, epidote-rich mass. The rock-fragments and enclosed minerals are 1. type *c*. 2. fragments, consisting of a very finestructured, partly isotropic siliceous and plagioclase aggregate with much epidote, sericite, chlorite, rare magnetite and pyrite, and here and there enclosed plagioclases and remnants of ?Radiolaria. Veins of quartz with epidote, chlorite and muscovite. (Altered tuff). 3. some fragments, consisting of quartz, chlorite and epidote. 4. some plagioclase crystals; a single one is broken and cemented by chlorite.

MARTIN 107 and 116 have been described by KLOOS (25, p. 48). Although MARTIN called them diabase-conglomerates, KLOOS did not recognize them as conglomerates but described them as diabases with an "abrupte Wechsel in der Structur, der erst durch das Mikroskop enthüllt wird." In fact, 116 is not conglomeratic in the sections and is a loose pebble. – MARTIN 107 has a microbreccious cement of plagioclase fragments and augite grains in a plagioclase or quartz aggregate. Its rock-fragments are 1. ophitic diabase. 2. type *a*. 3. type *c*. 4. a "pebble" of a very finegrained quartz-epidote-aggregate. MARTIN 116 only shows type *a*.

The rocks 3230 I—D 2291, 3230 II—D 2292 and 3232—D 2293, sampled by professor J. A. GRUTTERINK contain the types *a* and *c*.

The following conglomerates occur very near Dos Playa.

A 733—D 12697. The cement is a ?siliceous aggregate with locally calcite, and with plagioclase, pyroxene and some quartz crystals. The pebbles: 1. fine-ophitic diabase with a tendency towards type *a*. 2. type *c*. 3. most of the fragments are extremely finegrained and cannot be recognized (?diabase). 4. some browny isotropic elements.

A 726—D 12690. The cement is a quartz aggregate with some chlorite and calcite, and contains the fragments: 1. fine-ophitic diabase. 2. an "ophitic" rock of little sericitized plagioclase (andesine, labrador) and quartz, with some chlorite, calcite, pyrite and leucoxene; locally also allotriomorphic potashfeldspar (this rockfragment may be of a foreign origin, and seems to be the groundmass of a porphyritic rock). 3. a diverse-fibrous aggregate of hornblende needles, with grainy plagioclase, little quartz and pyrite. 4. a fine-structured hornblende felt. 5. a coarser hornblende felt with quartz grains and nests, chlorite individuals with blue interference-colours, and some pyrite.

The following rocks occur W of Dos Playa.

A 728—D 12692 (between Dos Playa and the uppercourse of Rooi Fluit). The cement is a pressed-looking, grainy aggregate of mainly plagioclase (partly lamelled oligoclase-andesine) and less quartz. Here and there accumulations, bundles and "stars" of diminutive hornblende needles occur, and locally some calcite and chlorite too. Pyrite and magnetite. The fragments and minerals are 1. type *a*, uralitized. 2. extremely fine-structured hornblende aggregates with a few plagioclases; they show here and there a reticulated texture with some chlorite. 3. some partly uralitized pyroxenes, uralite crystals and plagioclase prisms.

A 729—D 12693 (the long hill-ridge between Arikok and Dos Playa). The cement is an epidote mass, at the same time a hornblende felt, in which occur many hornblende and plagioclase fragments, a single quartz and also very small fragments of uralite-diabase and hornblende felt. The bigger fragments are: 1. ophitic uralite-diabase. 2. type *a*, uralitized. 3. type *c*, uralitized. 4. very finegrained epidote aggregate. 5. as 4 but full of parts of hornblende felt; moreover, a few plagioclases and hornblendes may belong to the cement.

On the top of the Jamanota the following samples have been found.

The cement of A 734—D 12698 is a pressed-looking quartz-plagioclase aggregate with epidote and ore, which seems to have partly resorbed some of the rock-fragments and which occurs as veins in the latter. The pebbles are: 1. type *a*, uralitized. 2. type *c*, uralitized. 3. some plagioclases and hornblendes.

The cement of A 735—D 12699 is an epidote mass with nests of pressed-looking quartz and rare magnetite. The fragments are: 1. ophitic uralite-diabase. 2. type *a*, uralitized; the uralite almost totally replaced the plagioclase in some fragments. 3. some epidote aggregates. 4. some loose hornblendes.

Martin 110 has been described by Kloos (25, p. 55) and has not been recognized by him as a conglomerate either. The cement is siliceous and contains epidote, ore and many uralite and plagioclase fragments. The rock-fragments are: 1. ophitic uralite-diabase. 2. type *a*, uralitized. 3. type *b*, uralitized. 4. type *c*, uralitized.

The rocks 3303—D 2354, 3304—D 2355 and 3305—D 2356, sampled by professor J. A. Grutterink, contain 1. normally ophitic uralite-diabase 2. type *a*, uralitized. 3. type *b*, uralitized. The two latter rocks moreover type *c*, uralitized.

QUARTZ-SANDSTONE

A 656—D 12656 (near Dos Playa). The grainy and greenish rock has a psammitic texture. Its cement takes up a little more room than the grains, and is a very finegrained ?siliceous one, in which many, probably authigenous, diminutive sericite plates and chlorite occur. A little granular titanomagnetite with leucoxenic flocks is present. Allogenic constituents are many small quartz crystal-fragments.

It is questionable whether these quartz fragments are terrigenous constituents (originated from older, pre-existing rocks) or whether they originated from the neighbouring volcanic rocks; hence, whether they are foreign minerals or whether they must be considered as tuff mineral from the diabasic magma. In connection with the occurrence of diabase-conglomerates and breccias on the island the foreign origin of the quartzes is probable.

OCCURRENCE, DISTRIBUTION, GEOLOGY AND GENESIS OF THE BRECCIAS

The breccias mainly occur in the same parts of the older formation as the slightly and non-hornblendized tuffoid rocks, and lie between the latter. They do not much differ from the latter and can be considered as macrobreccious tuffs, for they contain loose tuff-crystals (plagioclase, apatite, pyroxene, uralite-hornblende). A few quartzes may be of a foreign origin. In several rocks the cement seems to be relatively young and is probably connected with the diorite intrusion. The very finegrained hornblende aggregates, which occur as fragments, can possibly be compared with the hornblende-schists (metamorphic tuffs). If they really can, these fragments can have been enclosed before the metamorphism (hornblendization) or after the metamorphism. In the first case, the breccias should have been formed together with the tuffs and out of these rocks. It is however incomprehensible, that in this case the hornblendization of the enclosed tuff fragments should have occurred in that part of the older formation of which the rocks are not or but slightly hornblendized. It is also strange that several of these rocks should contain hornblendized tuffs beside non-uralitized pyroxene crystals, whereas the whole rock should have been subdued to the process of metamorphism (the rock from the Jamanota, however, which lies outside the above-said region contains uralite-hornblende crystals). In the second case, if the fragments should have been enclosed as hornblendized tuffs, we must conclude that the breccia is younger than the older formation and has been formed after the metamorphism (after the diorite intrusion). Since the breccias seem to occur as beds between the tuffoid rocks, the latter supposition is however not very probable. There is also a third possibility, namely, that the hornblende-rocks are different from the metamorphic tuffs and that they have existed as such already before the metamorphism of the older formation (see also the diabase-conglomerates).

All in all, these breccias are somewhat enigmatic.

OCCURRENCE, DISTRIBUTION, GEOLOGY AND GENESIS OF THE DIABASE-CONGLOMERATES

The diabase-conglomerates are rather widespread in the older formation but have not been found in the southwestern part (E and NE of Spaansch Lagoen). They occur as concordant beds between the schistose and tuffoid rocks, which have the common strike (N 110 E, N 90 E); the dips are very steep, in some places less steep (f.i. 50 S). The thickness of the beds varies; in some places a thickness of 25 m. has been measured. In the outcrop SE of Fontein f.i. a N 110 E striking rock complex has been found; a bed (about 7 m. thick) of purple, altered tuff occurs here between a breccia bed and a diabase-conglomerate of more than 20 m. thickness. Since the conglomerates are more resistant than the surrounding rocks they form here and there tops. So f.i., they occur on the top of the Jamanota, form the very long hill-ridge between the Arikok and Dos Playa, and a wide ridge SW of Dos Playa. In many places, however, such a selective erosion is wanting.

Where the conglomerates lie near the diorite-contact they are strongly invaded by veins, f.i. SW of Seroe Boonchi.

There is a striking agreement between the distribution of the uralitized diabase-conglomerates and that of the uralite-diabases, which means that the considerations on the nature of the process of uralitization (see diabases) also hold good with regard to these conglomerates. – The rocks occurring SE of Fontein and near Dos Playa do neither show uralitization in the cement nor in the diabase pebbles. They contain, however, very finegrained hornblende aggregates, which may have been enclosed as such in the conglomerates. In that case, these hornblende-rocks must have been present as such together with the unaltered diabases and diabase-tuffs, and even may be still older. – The rocks occurring W of Dos Playa and on the top of the Jamanota show uralitization both in the cement and in the diabase pebbles. The uralitization in the cement can occur only as an alteration of the pyroxene crystals and also as a hornblendization of the whole mass. In some of these rocks also fragments of hornblende aggregate occur, but, since these rocks have been clearly submitted to the process of metamorphism it cannot be said whether these fragments are hornblendized tuffs or older rocks.

The cement of some conglomerates is probably invasion material, connected with the diorite intrusion (quartz, plagioclase, epidote etc.; resorption-phenomena). The microbreccious cement gives the impression of being composed of tuff material, which must very probably have originated from the close vicinity. The clearly tuffoid fragments too originated from closeby, very probably.

If we take into consideration the common occurrence of the diabase pebbles types *a* and *c* in the conglomerates, the small distribution of these types in the diabases of Aruba, and the true pebble shape of the cemented rocks, the conclusion is obvious that most of the diabase pebbles probably have not originated from the Aruba diabases. Since the rocktypes *a* and *c* are widespread on Curaçao (see MOLENGRAAFF (31)), we can admit that the probable origin of these pebbles lies here, if not in the territory between Curaçao and Aruba. In this connection, it must be mentioned that a Curaçao rock of the Utrecht collection (C 290 – D 12212 Rooi Beroe, S of Seroe Manuel – NW Curaçao) is a conglomerate with diabase pebbles of type *a* (!). – The quartz grains found in several Aruba rocks of the older formation may have originated from these regions as well.

DIORITE BATHOLITH.

Common properties of the minerals of the batholith: The batholithic rocks, both plutonic and dike rocks, show several common properties. Their plagioclases are, to a more or less great extent, sericitized and epidotized. In many rocks there is a clear connection between such an alteration and the occurrence of epidote veins. The latter mostly contain quartz, and sometimes chlorite too. Several plagioclases have been albitized along fissures; a strong albitization often is connected with a strong epidotization. In many rocks there can be seen a connection between a strong alteration of the plagioclases and a strong distortion in the rock. Distortion phenomena are wide-spread; they manifest themselves mainly in the quartzes and plagioclases. The quartzes are slightly to strongly undulose, "Streifen" quartzes, cataclastic or marginally cataclastic. The distorted plagioclases which occur less often than the distorted quartzes can be undulose, bent, flexed, faulted or broken.

The plagioclases of most of the batholithic rocks show a polysynthetic twinning, rarely a cross-lamelling. — Except in most of the lamprophyres the quartzes (the porphyrite and vintlite phenocrysts too) contain fluid-inclusions which are arranged in planes (lines) as though along former cracks. According to Iddings (23, p. 537) the secondary nature of the inclusions is indicated in this case, a crack having been filled up with quartz except in the spaces occupied by liquid and gas. The distribution may be indefinite too; Iddings calls the latter primary fluid-inclusions. The quartz may contain limonite.

The hornblendes often show a fine twinning according to (100); the composition-plane sometimes is irregular, and intergrowth may occur as well. Alteration is not common and mostly a slight one. The alterationproducts are chlorite, epidote and rarely calcite. Undulose or bent hornblendes rarely occur. — Many biotites have partly or wholly been changed into chlorite with titanite; the titanite occurs as parallel and lenticular aggregates between the cleavage laminae of the chloritized mica. Other alterationproducts are epidote and quartz; the latter may be undulose. Some biotites are bent, fibrous or frayed, locally connected with the chloritization. The secondary chlorite is fibrous or spherolitic and green-pleochroitic, with beautiful, steely-blue or purple-blue interference-colours (+ character of zone); or it is spherolitic, palegreen-pleochroitic with a greenish-grayish-brown, velvet-like interference-colour (— character of zone). The chloritization begins along the cleavage-planes.

The above-mentioned properties of the minerals of the batholithic rocks have not been mentioned again in the following rock-descriptions, except where necessary. It can also be remarked here that some of the plagioclases of the contemporaneous dike-rocks and of the aplites and the albitites are simply zonal and rarely show recurrence.

QUARTZ-DIORITES

The batholith is a quartz-diorite batholith. The quartz-diorites occur mainly as quartz-hornblende-biotite-diorites, less as quartz-hornblende-diorites; quartz-biotite-diorites are of a minor importance.

Macroscopic description: Depending on the amount of ferromagnesian minerals the diorite is light- or darkcoloured. The rock is in general mediumgrained, rarely coarsegrained and finegrained. The feldspar is grayish-white; the hornblende occurs as blackgreen or black, well-shaped prisms (maximum length about 25 mm.); the quartz grains are gray, here and there brown-yellow; the biotites are black, lustrous plates.

QUARTZ-HORNBLENDE-DIORITES (plate II, fig. 8)

Samples: A 37—D 11949; A 38—D 11950; A 43—D 11955; A 44—D 11956; A 80—D 12048; A 81—D 12049; A 771—D 13069; A 775—D 13073.

The texture is holocrystalline and hypidiomorphic-granulose; the main constituent minerals are plagioclase, hornblende, quartz, (orthoclase) and (pyroxene).

Plagioclase is in general the most important mineral. It shows an isometric or more prismatic development, and is idiomorphic or hypidiomorphic. Chlorite and calcite occur but here and there in the plagioclase. The plagioclases are on the whole zonal; the peripheric zones are more acid than the core, at least in those plagioclases where no reversal of normal order of zoning (recurrence) occurs. It is commonly observed that the inner zones and cores of the zonally built plagioclases are more nearly equant than the outer zones or the final shape of the crystals (see also IDDINGS (21) p. 216). The cores of the zonal plagioclases are on the whole more altered than the more acid peripheric zones, and even the more basic recurrent zones show a greater alteration than the acid ones. The plagioclases vary in composition from oligoclase to andesine, and are especially oligoclase and oligoclase-andesine. In D 11955 and D 12049 some plagioclases occur with quartz-bubbles or vermicular quartz; probably as a result of resorption-action of the end-stage quartz-liquid.

Orthoclase, occurring only in a few rocks, is at any rate of minor importance, allotriomorphic, and younger than the plagioclase. In D 11949 the orthoclase works in with the plagioclase, and seems to be somewhat cataclastic.

Hornblende is quantitatively most important in some rocks but is commonly the second mineral. The crystals are here and there irregularly distributed in the rock and occur in groups, as if they had drifted together. They are idiomorphic or hypidiomorphic. Many hornblendes and plagioclases border on each other in an irregular way. Other hornblendes are idiomorphic with regard to the plagioclase, or enclose idiomorphic plagioclases. Cleavage is always well-developed, and colour, pleochroism and extinction point to the common green hornblende in most cases. Here and there the colour is more browngreen. In D 11950 and D 12048 zonal hornblende has been found with a darker coloured, browngreen, irregularly shaped core, which possesses a higher refraction than the lighter coloured periphery. Certain sections through these crystals show spots of the lightcoloured periphery in the core because of the irregular shape of the latter. Nevertheless, the extinction is for both parts one and the same and that of green hornblende. It is questionable whether lightgreen biotite fibres and spherolitic biotite, which locally have been found in hornblende, are secondary products or of a primary origin. The hornblende looks here and there bleached. In some hornblendes very small quartz-bubbles or very small vermiform quartz-inclusions occur in great or small quantities. These inclusions can only be recognized as quartz in very thin sections and also in those places where they occur in connection with the normal quartz (fig. 8). About their genesis, see p. 95.

Pyroxene occurs only in D 11956 as a few colourless diopsidic augites, in intergrowth with and surrounded by hornblende. It contains some limonite and ore, and has been partly or totally uralitized.

Quartz is interstitial between the older minerals, in greater or smaller amount. The older minerals plagioclase and hornblende often show resorption-holes, the latter having been filled up with quartz (fig. 9). Around such resorption-holes some plagioclases possess a kind of corrosion rim existing of diminutive, grainy, dusty particles. Similar rims occasionally occur in the more acid zones of a zonal plagioclase with reversal of normal order of zoning. They are probably due to resorption and corrosion by a more basic liquid. About the significance of this resorption-phenomenon, see p. 94.

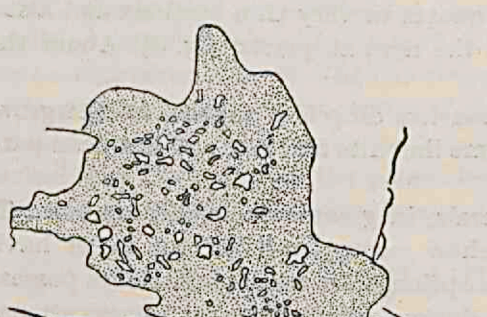
Accessory minerals: Apatite is common as small prisms and needles, enclosed in the feldspar, quartz and hornblende; occasionally it occurs in groups of grains. — Magnetite is often tied to the ferromagnesian minerals. It sometimes occurs with a narrow rim of epidote. Locally the ore has been altered into limonite, or into leucoxene (titanomagnetite). — Titanite is occasionally present as more or less idiomorphic crystals, often near the hornblende and the magnetite. Limonite has been infiltrated in some rocks, especially along the cracks of the quartz, and between the crystals.

QUARTZ-HORNBLENDE-BIOTITE-DIORITES (plate II, fig. 7)

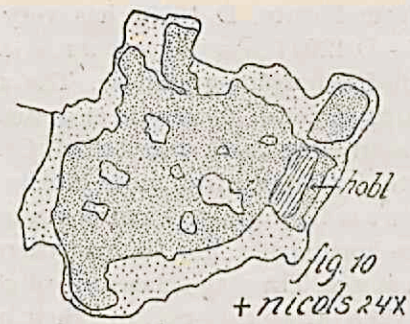
Samples: P 68—D 6168; A 36—D 11948; A 41—D 11953; A 45—D 11957; A 46—D 11958; A 47—D 11959; A 48—D 11960; A 49—D 11961; A 50—D 11962; A 51—D 11963; A 52—D 11964; A 53—D 11965; A 54—D 11966; A 55—D 11967; A 57—D 11969; A 58—D 11970; A 59—D 11971; A 60—D 11972; A 61—D 11973; A 288—D 12299; A 291—D 12300; A 304—D 12313; A 759—D 13065; A 761—D 13067; A 773—D 13071.

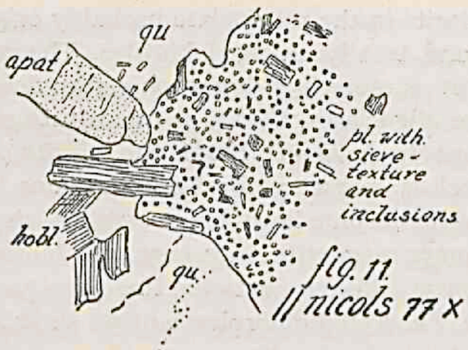
The main constituent minerals are plagioclase, hornblende, biotite, quartz, (orthoclase).

The feldspars have the same general properties as those of the quartz-hornblende-diorites. — The average composition of the plagioclases seems to be a little more basic than that of the plagioclases of the quartz-hornblende-diorites, andesines occurring in about the same quantity as oligoclases and oligoclase-andesines. In a few rocks the cores are labrador; in D 12300 the core is andesine, the periphery oligoclase-andesine; in D 11971, D 11953 and D 13067 plagioclases occur with an andesine core and with an oligoclase periphery. In D 11971 some microperthitic potashfeldspar occurs. — In many rocks we can see plagioclases, composed of many zones, while such zonal crystals have a repeated recurrence; with this recurrence, resorption effects are often connected, more basic liquid having partly resorbed an earlier formed, more acid zone. In D 11970 f.i. such recurrence and resorption effects occur in a big plagioclase composed of about thirty zones. In many rocks the following curious phenomenon can be seen: plagioclases composed of a core and one more acid zone show the mineral of the zone, besides in resorption-holes of the core, also inside the core, as irregular spots. It can be understood that such an occurrence depends on certain sections through plagioclases which show a partly resorbed core and a surrounding more acid shell. Especially in D 11963 the described phenomenon is very clear (fig. 10); the more altered core is about labrador, the fresh shell is andesine or oligoclase-andesine; the same twinning occurs in both. The shell is in general not idiomorphic with regard to the quartz. — In D 6168 the acid shell itself has a zonal character; its zones merge gradually and still more acid layers are present around the resorptive layer. — In the rocks D 11972 and D 13067 myrmekitic plagioclase borders on orthoclase. In D 11953 irregular, granophyric intergrowth of plagioclase and quartz occurs. A plagioclase in D 11957 contains a zeolitic mineral (spherolitic, brown-yellow, parallel extinction, + optical character of zone, n > n-plagioclase), possibly pectolite or okenite. — In D 12313 and D 13067 some plagioclases and hornblendes show resorption-holes filled up with orthoclase.



The hornblende has the same general properties as in the quartz-hornblende-diorites. — In D 11948 and D 12300 fibrous-looking hornblende occurs. The latter rock contains a hornblende with a very palegreen core, around which an ore rim; the core consists of many fibres, passing off in the surrounding and normal hornblende. In D 11960 remnants of partly resorbed hornblende occur in a plagioclase; it is remarkable that a narrow rim of plagioclase





around the hornblende remnants is more acid than the rest of the plagioclase, and therefore shows another extinction-angle.

Biotite is quantitatively the second dark mineral in most of the rocks; by exception it may be more important than the hornblende. In many cases the biotites are found near the hornblendes; or they occur in the rock as streaky aggregates, as if they had drifted together. The plates are rarely idiomorphic, more hypidiomorphic or allotriomorphic. In many rocks fresh biotite is no more present, only the wholly changed mineral. Primary inclusions are apatites, magnetites and zircons. Pleochroic haloes have not been observed. Sagenite-textures are rare. As to the genetic relation between biotite and plagioclase-hornblende the following may be remarked. Where the biotites occur in "streaks" between the other minerals the former probably crystallized in an early stage of the magma consolidation. Generally, the minerals border on each other in an irregular way. In some cases, idiomorphic plagioclases and hornblendes lie inside the allotriomorphic (chloritized) biotite. Quartz probably is always younger than the biotite. It is questionable whether resorption-holes are present in the biotite. Here and there it borders on the quartz with a black ore rim; the latter may be a corrosion-rim.

Quartz is in general the same as that of the quartz-hornblende-diorites. In D 11972 big quartz individuals poikilitically enclose many idiomorphic and hypidiomorphic plagioclases and hornblendes. In D 12313 and D 13067 the quartzes locally lie in crystal-groups.

In several rocks the apatite occurs included in magnetite. Magnetite is the same as in the quartz-hornblende-diorites. Titanite is occasionally present, and near the dark minerals; it may occur around magnetite, perhaps as a secondary mineral (titanomagnetite). Apatite, magnetite and titanite occur here and there in groups, f.i. in D 12313. — D 11963 contains pyrite with a magnetite rim, around which an epidote rim is found. — D 11959 seems to contain some hematite tied to epidote, especially in feldspar. — Curious complexes of many magnetite grains in chlorite (D 11973), and groups of magnetites, apatites, chlorite, epidote and titanite (D 11961) may have originated from biotite, very rich in magnetite and apatite inclusions. — The genesis of chlorite-veins (D 11964), of calcite between quartz crystals (D 11959) is connected with late-magmatic or postmagmatic processes.

GENERAL REMARKS ON THE QUARTZ-DIORITES AND THEIR MINERALS.

In most of the diorites more plagioclase than hornblende is present; the few cases that hornblende is the most important we have almost exclusively to deal with quartz-hornblende-diorites. The quartz-hornblende-biotite-diorites with a small quartz amount possess but little biotite; those with much biotite (as much as hornblende or more) are very rich in quartz, the latter being the second mineral.

QUARTZ-BIOTITE-DIORITES

Samples: A 62—D 11974, just E of Hooiberg; A 72—D 12039, Seroe Canashito; A 73—D 12041, W of Hooiberg; A 76—D 12044, Seroe Janchi.

Only in D 12041 a little hornblende is present. In general, the rocks are similar to the described diorites. — The plagioclases of D 11974 are oligoclase. Its biotites are hypidiomorphic. Chlorite in the plagioclase probably originated from biotite. D 12039 has very dusty albites, and totally changed biotites. The rock A 76—D 12044 possibly occurs as a dike. Its texture is more hypidiomorphic-granulose than allotriomorphic-granulose. The plagioclases are oligoclases. Biotite is quantitatively the third mineral. Muscovite is present as a few plates. In A 73—D 12041 the biotite crystals occur irregularly distributed. One part of the rock is coarser grained and contains less quartz, less magnetite, more biotite and a few non-idiomorphic hornblende crystals; the other part is finer grained and contains more quartz, more magnetite, in general less biotite, and no hornblende. For the rest there is no fundamental difference between these two parts which merge. The plagioclases are oligoclase-andesine. The hypidiomorphic biotites show here and there a sagenite-texture; their borders look limonitic-leucoxenic.

OTHER TYPES OF QUARTZ-DIORITES

Beside the described diorites some other types occur on the island, although locally: gabbroic quartz-hornblende-diorites, Seroe Colorado diorites, aberrant quartz-hornblende (-biotite)-diorites and strongly altered diorites.

GABBROIC QUARTZ-HORNBLENDE-DIORITES (Samples: A 423—D 12508, upper-course of Rooi Santoe; A 448—D 12524, W of Sumpina, near Matividiri): These rocks are on the whole similar to the normal quartz-hornblende-diorites, but there are some typical differences. The plagioclases, which are andesines, contain numberless diminutive, microlitic inclusions like those of the pyroxene-gabbros and – gabbrodiorites (see there). The hornblendes have an irregular shape and partly enclose idiomorphic and hypidiomorphic plagioclases. They have been clearly resorbed at their borders by a quartz-rich residuum and contain many quartz-bubbles. There is a close connection between these resorption-holes and the quartz-bubbles. Beside the bigger hornblendes, several aggregates of small crystals are present in D 12524. Also much quartz and many quartz-bubbles occur between and in the crystals of these aggregates.

THE QUARTZ-DIORITES OF THE SEROE COLORADO: These diorites occur in a small outcrop on the SE-cape of the island (see the map "D"). They are a little aberrant from the normal quartz-diorites. Three samples have been examined: MARTIN 97, MARTIN 104 and A 39—D 11951. The two latter rocks are about the same; MARTIN 97 forms a transitional type between them and the normal diorites.

MARTIN 97 is, in general, normal. Here and there quartz and plagioclase intensively work in with each other, so that the plagioclase-border contains quartz-drops: transition into a plagioclase sieve texture. The hornblende is on the whole non-idiomorphic, and locally has conformed to earlier crystallized plagioclases; it looks frayed. The biotite exclusively occurs in aggregates of very small greenish-brown plates, which are tied to the hornblende or have clearly conformed to the plagioclase crystals. Grainy and stringy titanite is present in these aggregates. Very probably these aggregates are primary (see the relation with the plagioclase).

A 39—D 11951, a quartz-hornblende-diorite, is a darkcoloured dioritic rock in which long apatite needles can clearly be seen. A hypidiomorphic-granulose texture, however not a clear one, can be recognized. – The plagioclases (oligoclase to oligoclase-andesine) work in with each other, or occur in intergrowth. They are very dusty and indistinctly broadly lamelled. The plagioclases look very strange in account of numerous inclusions, being for the greater part quartz-bubbles (sieve texture; the quartz-bubbles have different orientation) 'for the other part very small hornblende prisms and fragments, and also a few biotite plates' apatite needles and magnetite crystals. Resorption-holes occur in the plagioclases as well and have been filled up with the younger quartz. – Hornblende is present for a small part as remnants of big, idiomorphic crystals, and for the greater part as aggregates of small hornblende crystals, the latter still showing more or less the shape of the original big crystals.

In some aggregates remnants of the origina l hornblende have been preserved. The small hornblendes of the aggregates are partly idiomorphic; pleochroitic from dark-bluishgreen to brownyellow; non-twinned; quartz-bubbles occur included. Between the small hornblendes of the aggregates quartz occurs. – Besides as inclusions in the plagioclase, quartz occurs interstitially, especially in groups of crystals. It contains numerous fluid-inclusions. Magnetite is abundant, as grains, crystals or as big skeleton-shaped individuals, the latter lying in hornblendes and plagioclases. The ore can especially be found in the hornblende aggregates. Apatite occurs as many very long needles and prisms stretching through different plagioclases, hornblendes etc. They are occasionally broken according to the basal cleavage (fig. 11).

MARTIN 104 has been described by J. H. KLOOS and is about the same as A 39—D 11951, The principal difference is the following: the plagioclase is more or less idiomorphic with regard to the quartz or not at all idiomorphic; in the latter case here and there granophyr-like intergrowths occur. Some reddish-brown, strongly pleochroitic grains with a distinct cleavage are probably orthite.

Very probably the acid, late-stage consolidation-liquid has played a part in the alteration of these rocks. The common, primary, green hornblende prisms have been transformed into aggregates of possibly Na-rich, bluish-green hornblende, quartz and magnetite, for the greater part, probably. The sieve texture of the plagioclases has come into existence by this late magmatic action as well and can be compared with the normal myrmekite and hornblende-myrmekite. Quartz-liquid must have partly resorbed the plagioclase and must have been impregnated in it (see p. 94). May be, also the dusty character of the plagioclases and the occurrence of very small hornblendes and biotites in these plagioclases are connected with the above-mentioned action.

On the other hand, there is a striking similarity between these rocks and several of the dioritic rocks which occur in the contactzone of the older formation (see f.i. the altered diorite A 546—D 12573, NW-Aruba, and other rocks described in the chapter on the contactrocks). So possibly, the Seroe Colorado diorites lie near the contact with older rocks, and owe their aberrant properties to endomorphic contactmetamorphism.

ABERRANT PYROXENE-BEARING QUARTZ-HORNBLENDE-DIORITE. (A 426—D 12511): This finegrained and darkcoloured rock contains about as much plagioclase as hornblende, less quartz and a little pyroxene. The plagioclases are especially lath-shaped. Many laths are idiomorphic with regard to the hornblende (sub-ophitic texture), although their outline is not quite straight everywhere. Many are zonal; their composition is oligoclase-andesine to andesine. Idiomorphic hornblende prisms are rare; many of the crystals have conformed to the plagioclases. In many crystals there occur irregularly shaped pyroxene cores, which are a little limonitic; the hornblende does not look uralitic, so that probably pyroxene and hornblende occur in normal intergrowth.

ABERRANT QUARTZ-HORNBLENDE-BIOTITE-DIORITE (A 425—D 12510): The plagioclases of this darkgrayish, finegrained rock are especially lath-shaped. Some bigger, non-idiomorphic crystals, simply zonal, look phenocrystic. Hornblende occurs as long prisms, badly idiomorphic or non-idiomorphic, here and there in crystal-groups.

These two rocks occurring near Bushiribana are aberrant in granularity, in the crystal-development of plagioclase and hornblende, and partly in texture and mineral-content. This aberrance is very probably connected with the close neighbourhood of the gabbros and gabbro-diorites of Bushiribana.

STRONGLY ALTERED DIORITES: 1. A 40—D 11952 is an epidotized quartzdiorite, with distorted albites. Quartz locally occurs in irregularly granophyric intergrowth with plagioclase. Hornblende and biotite have been almost wholly changed into chlorite and epidote. – 2. The rock P 82—D 6547 is a strongly pressed quartzdiorite with totally changed ferromagnesian minerals, which now are present as long-shaped or irregularly shaped chlorite-epidote-calcite masses. The plagioclases too have been strongly albitized, sericitized, epidotized and calcitized. May be also secondary quartz can be found. – 3. A 75—D 12043, a quartz-hornblende-biotite-diorite, shows alteration-effects due to the neighbourhood of a younger quartz-dike. Its plagioclases have been strongly altered. The hornblendes have been wholly transformed into aggregates of chlorite, quartz and calcite, more or less with preservation of the prism-shape, and the biotites have been totally changed into chlorite with titanite. Calcite is present between the crystals as well; chlorite, with or without calcite, occurs in narrow veins. – 4. A 750—D 13057 (Seroe Crystall) is a hornblende-epidote-rock. Hornblende is the most important mineral. The crystals work in with each other and with the epidote individuals. The hornblende is locally very palegreen and contains irregularly shaped quartz-bubbles. Epidote occurs as well-cleaved individuals, in groups between the hornblendes. Only a little quartz is present between the other minerals or in "veins"; it seems to have been impregnated into the hornblende locally. Ore, apatite and titanite are rare. This rock may represent a ?quartz-hornblende-diorite, flooded by hydrothermal solutions, the plagioclase of which has been replaced by epidote and quartz. In the neighbourhood of this rock several quartzose dikes occur. [1])

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE QUARTZ-DIORITES (plate I)

On the whole, the diorites occur in a weathered phase. Over large distances the rock crops out as heaps of big, roundish and exfoliated monoliths ("Wollsack-bildung", pillow-structure), which lie scattered in plains of diorite-detritus, and which are autochthone. Where these heaps lie close together socalled "Felsen-meere" occur. The diorite, however, also appears in very low elevations and "thresholds" (f.i. in the roads), or as common, little weathered, acute-angular rocks.

Although the rocks are strongly weathered in many places the diorite can be clearly recognized in those parts of the outcrop which have a greater hardness and which have been preserved by selective erosion. So, it can be clearly seen that the diorite occurs as lighter and darker coloured types which gradually merge into each other, as well as in coarser and finer grained rocks. – Locally, the diorite is thick bedded. In the diorite hills just E of Malmok such beds seem to have a N 135 E strike and a dip towards SW. The diorite in the outcrop N of Savaneta seems to occur here and there in beds with an EW strike. The diorite can also have a gneissose character; a strike of N 120 E in it could be measured.

As has been mentioned above the quartz-hornblende-diorite is less widespread than the quartz-hornblende-biotite-diorite. The former does not form distinct massives in the latter, but the rocks merge into each other. This can be seen f.i. in the sample A 378. The number of finding-places of the quartz-hornblende-diorite seems to increase in the batholith outcrop from SW to NE (compare with the gabbros, the porphyritic and lamprophyric dikerocks). The northern and northeast-

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[1]) J. H. Kloos described several quartz-hornblende-biotite-diorites, sampled by Martin. Of one of the rocks, Martin 97, described under the Seroe Colorado diorites (see there), he gives a chemical analysis. In 124* the biotite partly occurs in aggregates of very small plates, with a little chlorite, titanite and ore; see also 97. Abusively he calls 144 a local variety of the diorite; *it is an enriched amphibolite. In the rock* 92 the "*Mikroklinperthite*" are crosslamelled plagioclases and the "Augit" is epidote. His suggestions about the mechanical stresses on p. 21—22 are wrong. *All the minerals and the whole rock have been submitted to mechanical stresses during* and after the consolidation, in consequence of slight orogenic movements in the batholith. For the rest, I do not see why Kloos calls certain hornblende-groups "Krystalltrümmer."

ern parts in the outcrop are very probably the highest parts in the batholith. – The quartz-biotite-diorites also merge into the quartz-hornblende-biotite-diorites. They are of a very minor importance, and occur, as far as we can see, only in the southern and southeastern parts of the batholith outcrop.

The diorite is not only batholithic but occurs, besides, as dikes in the older batholithic massives, that is to say the gabbro and hooibergite massives, and as dikes in the older diabase-tuff formation as well. The latter have been found as normal wall-like dikes but also as pipe-dikes. It is very common that the diorite in these dikes is porphyritic in the "Salband", here and there even vintlitic. Many of the dikes lie in or near the contactzone between the older series and the batholith, f.i. near Mira la Mar, near Seroe Boonchi, NNW of Arikok, E and NE of Santa Lucia. A single dike crosses the contactzone. Some dikes, however, have been found farther from the visible contact, that is to say, about 2 km W of Boca Prins and in the diabase outcrop SE of Fontein. – The dikes contain here and there fragments of metamorphic diabases taken up from the country-rock. A few strikes of the dikes could be measured: N 40 E, N 75 E, N 100 E, N 110 E (two dikes), N 135 E. The dike SE of Fontein has been strongly disturbed (orogenic movements after the diorite intrusion).

DIORITIC ROCKS CONSOLIDATED BEFORE THE MAIN PART OF THE DIORITES (SEGREGATIONS, ENDOGENOUS INCLUSIONS)

A 759—D 13065; A 760—D 13066; A 761—D 13067.

These early crystallization products of the dioritic magma are darkcoloured, finegrained rocks with several bigger crystals of plagioclase (max. about 8 mm.), hornblende (max. about 8 mm.) and biotite (max. about 7 mm). These rocks are not sharply bordered on the normal diorite, and their crystals normally work in with and between each other. They contain more hornblende and less quartz than the diorite, but show in general the same properties as the normal diorites. D 13065 and D 13067 contain a little potashfeldspar; it is curious that this potashfeldspar is wanting in the normal diorite of D 13065. Some big plagioclase and hornblende prisms have no phenocrystic character. Some big biotite crystals in D 13066 and D 13067, unaltered or partly altered, enclose poikilitically many non-idiomorphic plagioclases and a few hornblendes, which stick partly in the biotite; and contain moreover ore, apatites, a single zircon and very small rutile needles (sagenite).

These rocks occur especially in the northern and northeastern parts of the batholith (compare with the gabbros) and form large endogenous massives on the Seroe Plat, the Seroe Crystall and between these mountains and Seroe Gerard. The diorite occurs in it as irregular dikes and streaks but also merges gradually into these rocks. The rock has also been found as smaller inclusions in the diorite between Ajo and Sumpina, near Koeroeboeri, N of Jaburibari, in the surroundings of Alto Vista, on the Matoguera, NW of Hooiberg.

These dioritic rocks must have been segregated from the batholithic magma and *must have crystallized in the top of the batholith* near the roof (see also the gabbros). The finegrained character points to a quick cooling. The dioritic magma must have intruded into these roof massives and must have consolidated at a time when these massives were not yet quite consolidated (see the transition). The smaller inclusions must have been loosened and some of them must have been sunken in the batholithic chamber. It is questionable whether the original roof phase was different from the rocks described here. The quartz and orthoclase may be added minerals, in consequence of the flooding and reaction with younger dioritic magma and with an end-stage consolidation residuum of this magma (see f.i. N. L. BOWEN (7) p. 199: "the magma can attack these inclusions, reacting "with them in such a manner as to convert them into the crystals with which "it is saturated"). So the same residual liquid in the crystallizing dioritic mass may have reacted with both the older minerals of the inclusions and those of the diorite itself (see also p. 94).

HOOIBERGITE-ROCKS [1]) (plate I, fig. 1—2).

In several places in the diorite landscape, which is in general a flat one, we meet curious steep hills and smaller elevations, that have been preserved by selective erosion. Fine examples of these hills and elevations are the high, cony Hooiberg (164 m), E of Oranjestad, the Seroe Bientoe (85 m.), the Wara Wara (98 m.) the Seroe Compa, the Seroe Pretoe (E of the Hooiberg), the Turibana and others. These hills are composed of a beautiful, darkcoloured, igneous rock, in which many big hornblende crystals are particularly striking. – It is a remarkable fact that the above-mentioned massives of darkcoloured rocks present innumerable dikes and veins of lightcoloured rocks in several places, especially at the borders. Here and there these dikes are rather wide and contain smaller and bigger fragments of the darkcoloured rock, which must have been loosened by and enclosed into the intruding magma, that afterwards consolidated as lightcoloured dike-rocks. The latter are proved to be mainly aplitic and dioritic rocks. Hence, the darkcoloured rock must be older than the surrounding diorite, which sent its dikes and veins into this rock (plate III, fig. 7—8).

HOOIBERGITES

Macroscopically the hooibergite-rocks are very beautiful and mostly coarsegrained rocks, which are mainly composed of big and smaller, idiomorphic hornblende crystals (size varying from about 1 mm to 15 mm.); these hornblendes lie in a fine grained, greenish, brown-greenish or brown-grayish "groundmass", which contains a certain amount of lightcoloured minerals. This "groundmass" takes up about as much room as or more room than the bigger hornblende crystals.

Microscopic description: The hooibergites contain as main constituent minerals hornblende, plagioclase and quartz. In most of the rocks the hornblende is the most important mineral and comes strongly to the front. In many of them this mineral takes up more room than the plagioclase and quartz together. An exception is D 12314, with about as much hornblende as plagioclase. In by far the most of the rocks the plagioclase takes up more room than the quartz, except in D 12318. Beside the differences in quantity of the main constituent minerals with the common quartz-hornblende-diorite, there is another difference between

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[1]) Named after the Hooiberg, which is mainly composed of this rock.

these hooibergites and the diorites, that is to say, the difference in the sequence of crystallization: only the hornblende crystals show idiomorphism, whereas both plagioclase and quartz occur as allotriomorphic crystals interstitially between the hornblendes.

The hornblende is found in bigger, isometric crystals and in smaller ones, both short prisms. The smaller crystals work in with the bigger ones (crystallization at about the same time!), and lie, moreover, in and between the plagioclase and quartz individuals. In general, the hornblende is idiomorphic with regard to the plagioclase and the quartz. The idiomorphism, however, is not everywhere absolute; this may be caused by a certain resorption-action after the crystallization of the hornblende and before that of the plagioclase and quartz, or it may have been caused by the fact, that plagioclase and quartz began their crystallization at a time, when the crystallization of the hornblende was not quite finished. The hornblende is the normal green one; in D 12314 some hornblendes possess lightgreen rims; in D 12315 the hornblende is here and there almost colourless; in D 12318 some big hornblendes possess lightgreen and darkgreen zones. Some of the smaller hornblendes show twinning. Most of the hooibergites with intrusive dikes show diminutive quartz-bubbles included in those hornblendes, which lie near or in the contact-zone (see also p. 96).

The plagioclase individuals occur as rather big and allotriomorphic crystals between the big hornblende crystals and more or less poikilitically (as oikocrysts) around the small ones. They are irregularly bordered on and work in with the quartzes (both of the same age!); in D 12314 plagioclase and quartz occur in granophyric intergrowth, here and there. The composition of the plagioclases ranges from oligoclase to albite; probably they have their original composition. Some of the oligoclases in D 12314 and D 12318 seem to have a slightly zonal extinction.

The quartz is granular and allotriomorphic between and around (poikilitically) the hornblendes.

Accessory minerals: In most of the rocks a few apatite prisms and grains can be found, enclosed in quartz, plagioclase or hornblende. — In most of the rocks some titanite grains occur, especially tied to the hornblende. — Magnetite occurs as a few small grains; a single crystal has an epidote rim.

Hence, the probable sequence of crystallization is the following: Hornblende began to crystallize; only in the second place the remaining part of the magma crystallized to a more or less aplitic mass of plagioclase and quartz between the already existing hornblende crystals.

Finding-places:

Hooiberg: P 101—D 6560; A 326—D 12318; A 327—D 12319. Seroe Bientoe: A 352—D 12330. Seroe Pretoe (NW of Hooiberg): A 328—D 12320. Seroe Pretoe (E of Hooiberg): A 324—D 12315. Cashero (Seroe Compa): P 81—D 6546. S of Seroe Compa: A 323—D 12314. Seroe Tres Kabees: A 325—D 12317.

PYROXENE-HOOIBERGITES AND PYROXENE-BEARING HOOIBERGITES (plate III fig. 1, 2 and 8.)

Macroscopic description: The pyroxene-hooibergites show big and small, idiomorphic hornblende crystals in a finegrained "groundmass", greenish or greengrayish (in this "groundmass" hornblende and feldspar can be distinguished). The "groundmass" takes up about as much room as, or more room than the bigger hornblendes. The rock A 333 is very darkcoloured; the distinction between the big hornblendes and the "groundmass" here, is not so clear, so that this rock looks more gabbroic. A 335 is a very darkcoloured hornblende-rock, with plagioclase-quartz nests, regularly scattered.

Microscopic description: The main constituent minerals are hornblende, pyroxene, plagioclase and quartz. Potashfeldspar has been found in D 12326, beside plagioclase. Hornblende is most important and takes up, on the whole, more room than the pyroxene. Plagioclase generally takes up more room than quartz, or is present in about the same amount. Hornblende together with pyroxene take up (much) more room than plagioclase together with quartz. In D 6178 the hornblende seems to take up more room than pyroxene, plagioclase and quartz together. The rock D 12328 is somewhat different in parts from the others; it exists of groups of big hornblendes and pyroxenes, between which aplitic, allotriomorphic-granulose nests of plagioclase and quartz occur, also visible macroscopically. The hornblende-pyroxene groups also contain some allotriomorphic plagioclase and quartz, and on the other hand some hornblende crystals, mainly idiomorphic, can be seen in the plagioclase-quartz nests. — The main differences between these pyroxene-hooibergites and the normal, dioritic or gabbroic plutonic rocks are the differences in quantity of the main constituent minerals and the difference in the sequence of crystallization: only the hornblende and the pyroxene show idiomorphism.

The hornblende can be compared with that of the hooibergites in dimensions, colour, shape, idiomorphism and texture-relations with plagioclase and quartz. Some hornblendes are brownish-green or have browngreen and lightgreen zones (D 12328). Many pyroxenes stick in the hornblende crystals; hence, many of the hornblendes do not show a fine prism-shape. In D 6561 and D 12324, which are very rich in pyroxene and in which the "groundmass" takes up more room than the big hornblendes, the smaller hornblendes mainly occur in a mass of pyroxene crystals, which are moreover intergrown with many of them. Some secondary fibrous hornblende occurs in D 12322 and D 12326. A part of one of the big hornblendes in D 6177 is of a very lightgreen and is composed of several irregularly shaped individuals; lines of ?ore radiate from this part into the surrounding normal hornblende. It is very curious in D 12324, that plagioclases are irregularly intergrown with some big hornblendes. The hornblendes, which lie near or in the contact-zone caused by the intrusive dike-rocks, possess very small quartz-bubbles (see also p. 96)

The pyroxene occurs as prisms and crystalgrains between the big hornblendes, and in and between the plagioclase and quartz individuals. They stick in the bigger hornblendes, so that in the slides several hornblendes seem to enclose poikilitically many pyroxene crystals; around several of these pyroxenes narrow rims of lighter green hornblende occur, which have the same extinction as the whole crystal; in these spots the hornblende is a little thinner, on account of the underlying, colourless pyroxene in the slide. Pyroxene crystals rarely show idiomorphism with regard to the hornblende; in general, pyroxene and hornblende are of about the same age: both work in with each other, and most of the pyroxenes are intensily intergrown with hornblende. As to the relation between pyroxenes and plagioclase-quartz, the former generally are idiomorphic with regard to the latter. The pyroxenes are colourless to very lightgreen diopsidic augites. In most of the rocks some twinned pyroxenes occur; in a single intergrowth of pyroxene and hornblende the two minerals have the same twinning-plane (see f.i. D 12326). Many pyroxenes are more or less ?limonitized along their cleavage-planes and along fissures.

The plagioclase occurs as allotriomorphic individuals between and around the hornblendes and pyroxenes. The rocks D 12324 and D 6561, very rich in pyroxene, contain only a very little plagioclase and quartz, allotriomorphically between the pyroxenes. The plagioclases are irregularly bordered on and work in with the quartzes ; only in D 6559 some plagioclases are more or less idiomorphic with regard to the quartz. A kind of granophyric intergrowth between both minerals can be seen in D 12322. The composition ranges from oligoclase-andesine to albite, probably the original composition. D 2277 contains asingle zonal crystal.

Potashfeldspar can be found only in D 12326, as a few allotriomorphic crystals of ?microcline; it is particularly striking, that part of this potashfeldspar is also allotriomorphic with regard to idiomorphic quartz!

Quartz, apatite, titanite and magnetite occur in the same way as in the hooibergites. D 12321 contains a hornblende with a big, more or less skeleton-shaped titanite.

In connection with the characters of the different minerals, the probable sequence of crystallization is the following: Hornblende and pyroxene began to crystallize; only in the second place the remaining part of the magma crystallized into a more or less aplitic mass of plagioclase and quartz, between the older hornblendes and pyroxenes.

Finding-places:

Hooiberg: A 331—D 12323; A 332—D 12324; P 99—D 6177; P 99—D 6178; P 100—D 6559; P 102—D 6561; Martin 157—D 2277. Seroe Bientoe: A 336—D 12329; A 353—D 12331. Cashero (Seroe Compa): P 80—D 6171. Seroe Pretoe (NW of Hooiberg): A 328—D 12320; A 329—D 12321. N of Zumbo: A 330—D 12322. Turibana: A 333—D 12326. Jaburibari: A 335—D 12328.

TRANSITION-ROCKS

Hooibergite and pyroxene-hooibergite (pyroxene-bearing hooibergite) merge into each other in A 328—D 12320. This can be clearly seen in the sample: the brownish-grayish "groundmass" of the hooibergite merges into the greenish-grayish one of the pyroxene-hooibergite. The transition in D 12320 is a continuous one, that is to say, the crystals of the two rocks work in with and between each other in a regular way.

The rock A 334—D 12327 is more or less transitional between pyroxene-hooibergite and quartz-hornblende-pyroxene-diorite; it is a dioritic pyroxene-hooibergite, from the top of the Seroe di Poos di Noord. Generally it agrees with the normal pyroxene-hooibergites; the main difference is, that the plagioclases are more or less idiomorphic with regard to quartz and potashfeldspar and that they finished their crystallization at about the same time as hornblende and pyroxene. Hornblende is most important; the pyroxene takes up less room than feldspar. Hornblende and pyroxene are quite normal. The plagioclases are oligoclase-andesines, some of which are zonal. Microcline occurs between and around the more or less idiomorphic, darkcoloured minerals and plagioclase, and is irregularly bordered on the quartz.

Another transition-rock is A 354—D 12332, a hooibergitic quartz-hornblende-diorite, which occurs at the southfoot of the Seroe Bientoe. The rock has the appearance of a common diorite, with a hypidiomorphic-granulose texture. The plagioclases, however, are not idiomorphic with regard to the quartz; the hornblendes are idiomorphic or not with regard to plagioclase, and idiomorphic with regard to quartz. Hence, the texture agrees very much with that of the hooibergites. The plagioclases are oligoclase-andesines. The hornblende occurs more than plagioclase; some of the crystals have a darker core, and several hornblendes contain numerous quartz-bubbles. Quartz is rather abundant. Narrow and small fissures through some of the hornblendes have been filled with probably quartz.

The rock A 355—D 12333 is a transition-rock from the southeastern slope of the Hooiberg. It is a gabbro-diorite 'an andesine-hornblende-rock with gabbroic texture, and locally a little quartz.

A 371—D 12340, occurring on the SE-foot of the Wara Wara, is a dioritic, finegrained and darkcoloured transition-rock, an aberrant quartz-hornblende-diorite. A dioritic, hypidiomorphic-granulose rock, in which darkgreen, non-twinned hornblende is present in many small and short prisms (not in bigger crystals). Many of the oligoclase-andesines are more or less lath-shaped and zonal.

As to the significance of the transition-rocks, see below (p. 50).

PETROLOGY AND GEOLOGY OF THE HOOIBERGITE-ROCKS

Hooibergites and pyroxene-hooibergites occur both in the same massives; from f.i. the Hooiberg, the Seroe Bientoe, the Seroe Compa, the Seroe Pretoe (NW of the Hooiberg) both hooibergite and pyroxene-hooibergite have been sampled. Pyroxene-hooibergite seems to have a wider distribution than the hooibergite, for the greater part of the samples proved to be pyroxene-hooibergite. There seems to be no fundamental difference between both kinds of rock. As we shall see below, the pyroxene-hooibergites are more or less metamorphosed into hooibergitic rocks at their borders against intrusive dikes, that is to say, the amount of hornblende in the contact-zone increases at the cost of pyroxene. So, all the hooibergites might be metamorphosed pyroxene-hooibergites. In those places where the pyroxene-hooibergites have come into contact with rather narrow dikes, the metamorphosed zone has been developed only over a distance of some centimeters. Hence, if the hooibergites really are metamorphic pyroxene-hooibergites, the metamorphism must have been caused by a much more active magma, probably by the surrounding parts of the dioritic magma. Yet, the hooibergites do not occur especially at the borders of the massives, no particular order existing seemingly in their distribution. The Seroe Tres Kabees, however, seems to consist only of hooibergites, not of pyroxene-hooibergites.

As to the nature of these hooibergite-rocks, they have quite the properties of plutonic rocks. They are a little different from the diorites and are moreover a little older, but still seem to belong to the rocks of the diorite batholith.

MARTIN (p. 45 and 46) observed, that the darkcoloured rocks of the Hooiberg show a more clear alternation with lightcoloured rocks at the borders of the massive than in the centre. From these fieldobservations he drew the conclusion, that the Hooiberg-rocks mainly represent concentrations of amphibole and augite in the common quartz-diorite: (p. 46) "Ich schliesse aus diesen Verhältnissen, "dass der Hooiberg den Mittelpunkt einer im Gebiete des Quarzdiorites statt-"gehabten Zusammenziehung von Hornblende und Augit darstellt, welche sich "im weiteren Umkreise des Berges allmählig verliert, bis das Gestein in den nor-"malen Quarzdiorit übergeht." Also KLOOS (25) accepted this opinion: (p. 27) "Die mikroskopische Untersuchung konnte diese Auffassung nur bestätigen" and "so haben wir es augenscheinlich mit einem gleichalterigen Eruptivgestein zu "thun, worin sich Augit und Hornblende lokal angereichert haben."

Upon our renewed and nearer examination the hooibergite-rocks proved to be of an other nature. The difference in age between diorite and hooibergite-rocks could be clearly determined, although this difference seems to be only a small one, and although the latter rocks very probably belong to the batholith-rocks, which is proved by their mineralogical composition. As to the origin of the hooibergite-rocks, we may consider them first-solidification-differentiates in the batholith chamber. Very probably these differentiates came into existence against the batholith roof (see f.i. DALY (12) p. 245). It is questionable whether these rocks have still this situation in the batholith, or not. In connection with the distribution of the massives, the latter supposition seems to be the more probable (see below). At all events, the hooibergite-rocks crystallized before the diorites, to irregularly shaped masses. Thus, the diorite magma could attack these already consolidated masses and could intrude into them. Most of the intrusions have a true dike-form, but here and there kinds of transition-rocks came into being (see p. 49). Similar transition-rocks being darkcoloured diorites, rich in hornblende, surround f.i. the massives of the Seroe Tres Kabees, of the Seroe di Poos di Noord, of the Zumbo and others. So, in several places these massives do not border sharply on the surrounding normal, dioritic rocks but merge more or less. Other massives, however, f.i. the Hooiberg and Seroe Bientoe, are on the whole rather sharply bordered on the surrounding diorite, which is a common lightcoloured diorite here. For the understanding of the process of intrusion in the older hooibergite massives, the remarks of DALY (12) on pp. 245 and 362 are very instructive.

THE DISTRIBUTION OF THE HOOIBERGITE MASSIVES

The principal finding-places are the following: Seroe Pretoe (NW of Hooiberg), Hooiberg, Seroe Bientoe, Papilon and surrounding tops, Jukuri and surrounding tops, Wara Wara, three small elevations S of Seroe Pretoe (E of Hooiberg), Seroe Pretoe (E of Hooiberg), an elevation S of Seroe Compa, Seroe Compa, Zumbo and surrounding tops, some elevations N of Zumbo, an outcrop on the south-foot of the Jaburibari, three outcrops S of Gabilan, outcrops on the Seroe di Poos di Noord, outcrops E and N of Alto Vista, outcrops between Seroe Pela and Seroe Tres Kabees, Seroe Tres Kabees, two tops of Kamai, Turibana. Most of these outcrops have been indicated in the geological map.

So, the massives are rather irregularly distributed in the western and northern part of the diorite-batholith outcrop, whereas it is remarkable that they have not been found in the two southeastern outcrops of the batholith. If the massives really represent the basic parts of the batholith magma, first crystallized against the batholith roof, it is strange that they do not occur in the close neighbourhood of the boundary with the older diabase and metamorphic-tuff rocks, which in fact constitute the batholith roof. Therefore, we may accept that the hooibergite massives represent sunken fragments of this early crystallized, basic magma; whether these fragments only sank over rather a short distance or quite down to the bottom remains questionable. At all events, if the latter is true, the batholith cannot reach very deep, and since it did not reach very high either, it may have had a laccolith-shape (compare with H. CLOOS (10) "Das Batholithenproblem"). The shape of the hooibergite massives varies rather much. The Hooiberg and Wara Wara are roundish in horizontal projection; the Seroe Bientoe has a very irregularly bordered horizontal projection. Oblong shape can be seen in the Seroe Pretoe (E of Hooiberg), the Seroe Compa, the elevation S of Seroe Compa, the Turibana, the Jukuri. Other massives are composed of smaller ones, which lie in one straight line (plane); these smaller massives each can have an oblong shape: the Seroe Pretoe (NW of Hooiberg), the three small massives S of Seroe Pretoe (E of Hooiberg), the massives of Zumbo and those N of Zumbo, the Seroe di Poos di Noord, the massives of Seroe Tres Kabees; or each of the massives can have a more roundish shape: the massives of Papilon, those N of Jukuri, those of Kamai, and those S of Gabilan. – The strike of the oblong massives varies. The meaning of the oblong shape is questionable; may be, the oblong massives represent plate-shaped roof-masses, which have been sunken and tilted into an almost vertical position.

CONTACT OF THE HOOIBERGITE-ROCKS WITH INTRUSIVE DIKE-ROCKS (plate III, fig. 7)

The massives of hooibergite- and pyroxene-hooibergite-rocks have been invaded by numerous dikes and veins, especially at the borders [1]). The dike rocks are quartz-hornblende-diorites, quartz-biotite-hornblende-diorite, hornblende-diorite, hornblende-granodiorite, dioritic aplites, biotite-granite-aplites, quartz-rocks; rarely pegmatites and malchites.

Contacts of the hooibergites and pyroxene-hooibergites with intrusive dike-rocks could only be studied at some dioritic aplites, quartz-hornblende-diorites and hornblende-granodiorites. There seems to be no fundamental difference in qualities between the contacts of these dike-rocks with hooibergite and those with pyroxene-hooibergite. A difference between the contacts of the different dike-rocks with hooibergite-rocks seems not to exist either.

Samples: Contacts between hooibergite-rocks and dioritic aplites: A 325—D 12317; A 328—D 12320; A 332—D 12325; A 336—D 12329; P 102—D 6561. Contacts between hooibergite-rocks and quartz-hornblende-diorites: A 324—D 12315; A 326—D 12318; A 327—D 12319; P 81—D 6546; P 99—D 6178; P 102—D 6561. Contacts between hooibergite-rocks and hornblende-granodiorites: A 352—D 12330; A 353—D 12331. Contact-phenomena also can be seen in A 335—D 12328 (pyroxene-bearing hooibergite with aplitic nests).

Macroscopic contact-phenomena: Only those hooibergite-rocks, which are sharply bordered on the intrusive rocks, possess a narrow rim, blackcoloured and very rich in hornblende, at the contact. This rim only could be found at the contact with some dioritic aplites and quartz-hornblende-diorites: A 325 (about 3 mm. wide), A 326 (the rim occurs but here and there), A 332 (less than 1 mm. to 5 mm. wide), P 81 (the rim is not very important), P 102 (about 1 mm. to 3 mm. wide). On the other hand, the hooibergite-rocks, which are not so sharply bordered on the intrusive rocks, do not show contact-rims. So, if the intrusion of the dike-magmas took place at the time, when the hooibergite-rock was quite or about quite consolidated (see the rocks with a sharp border), a contact-rim could develop. On the other hand, if the intrusion took place in a partly consolidated hooibergite-rock (see the rocks, which are not sharply bordered on the dike-rocks), a contact-rim did not develop. Notwithstanding the failing of a contact-rim in the latter hooibergites, these rocks still show contact-phenomena, which can be detected under the microscope.

The dike-rocks in A 332 (dioritic aplite) and in A 352 and 353 (hornblende-granodiorites) contain several fragments of hooibergite-rock, which have become inclosed in the liquid dike-magma, during the intrusion of these dike-magmas; these fragments are only in A 332 very rich in hornblende (compare with the hornblende-contact-rim, also present in A 332). A 353 contains, beside the hooibergite fragments, also inclosed hooibergite-hornblende crystals; the latter are much bigger than the hornblende crystals of the granodiorite itself.

The different dikes are normally shaped; only the dike of A 336 is irregular. Narrow tongues or apophyses originated from dioritic aplite dikes, can be seen in A 332 (quartz tongues), A 336 (aplitic tongues), and P 102 (aplitic tongue, poor in hornblende). The dioritic dikes in A 326 and P 99 show a flow-structure, manifested by the hornblende prisms, which lie roughly parallel to the borders. The dike in P 81 contains hornblende crystals only in a zone, 1 cm. wide, lying alongside the hooibergite, and not in the central part of the dike; so, the peripheric part of the dike has the composition of diorite, whereas the central parts look more aplitic and pegmatitic ("Nachschub" of the aplitic magma?). On the other hand, the border of the dioritic dike of P 99 (some mm. wide) is free of hornblende; this aplitic border sends an almost hornblende-free aplitic apophysis into the hooibergite-rock.

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[1]) The massives must have been very much fractured at their borders, so that the dioritic and aplitic magmas could easily intrude. The great quantity of aplitic intrusions may be connected with the (originally) high situation of the massives in the batholith, if at least the massives came into being there. See also the considerations of Daly on this strong invasion by acid magma (12), p. 245 and 362.

Microscopic contact-phenomena: Hooibergite-rock and the different intrusive rocks can be clearly distinguished from each other, thanks to the difference in quantities of the main constituent minerals (especially of hornblende) and thanks to the difference in texture. Nevertheless, the rocks are not sharply bordered on each other (nor the hooibergites with macroscopically sharp borders either!), and the crystals on both sides normally work in with and between each other. – Notwithstanding the fact, that hooibergite-rock and intrusive dike-rocks are not sharply bordered on each other, the intrusive dikes must be younger than the hooibergites. Beside the fieldobservations, the petrographic facts too point to this difference in age. So, the intrusion of the dike magmas must have taken place at a time when the hooibergite-rocks were not quite consolidated. As has been mentioned above, there must have been local differences in the phase of consolidation during the intrusion (contact-rim or no contact-rim). However, a certain magmatic solution of the older hooibergite-rock, quite consolidated, by the intruding magmas may have been one of the causes that, after the final consolidation, the crystals of both rocks have worked in with and between each other. Probably, also interchange of material has taken place to a more or less great extent.

It is very curious, that the hooibergite in D 12318 contains more quartz than the quartz-hornblende-diorite, which intruded into it.

Exomorphic contact-phenomena, magmatic stoping and assimilation in the hooibergite-rocks: Magmatic stoping on a small scale can be seen in D 12325; the aplitic magma worked here as a wedge and loosened fragments from the pyroxene-hooibergite; one hornblende fragment "is on the point" of tearing off from the pyroxene-hooibergite (fig. 12). During the enclosing of hooibergite fragments by the dike magma, the latter intruded into these fragments here and there, so that the peripheric hornblende crystals have been loosened and now lie like a garland of separate individuals around the fragments, in the dioritic aplite. D 12330 and D 12331 too contain fragments of hooibergite-rock, enclosed in the hornblende-granodiorite magma. – Effects of assimilation can be distinguished in D 12315, D 12325 and D 12331; the dike magmas or the final consolidation-residuum of the dike magmas have assimilated parts of the hooibergite-hornblendes, so that now feldspar and quartz crystals of the dike-rock stick irregularly in the partially resorbed hooibergite-hornblendes.

Contact-phenomena in the hooibergite-rocks are manifested almost exclusively in the hornblende minerals. It is a remarkable fact, that in the pyroxene-hooibergites, generally, the amount of hornblende in the contact-zone increases at the cost of pyroxene; even in some rocks, the contactzone does no more contain pyroxene. It is also very remarkable, that well-developed hornblende-contact-zones (without pyroxene) only occur in the pyroxene-hooibergites (D 12325 and D 6561). The pyroxene-hooibergites with a decreasing amount of pyroxene towards the contact are D 12320, D 12329, D 6178 (compare with D 6177).

D 12320—A 328 consists of pyroxene-bearing hooibergite, hooibergite and a dike of dioritic aplite, the pyroxene-bearing part of the hooibergite-rock being separated from the aplite by the hooibergite. All three rocks merge gradually into each other; so, it seems to be obvious that the pyroxene-hooibergite has been metamorphosed into a hooibergitic rock at its border by the intruding aplitic magma. Moreover, it must be mentioned, that the composition of the plagioclase of the pyroxene-hooibergite is about oligoclase-andesine, whereas the composition of the hooibergite-plagioclase is albite-oligoclase to oligoclase.

The hornblende-contact-zone in D 6561 (pyroxene-hooibergite and dioritic aplite) is about 4 mm. wide and merges gradually into the pyroxene mass of the pyroxene-hooibergite; hornblende and pyroxene crystals on both sides work in with and between each other. The distinction between this hornblende-contact-zone and the dioritic aplite is, of course, clear; however, the crystals on both sides also here work in with and between each other in a quite normal way. The contact-zone is an aggregation of grainy hornblende crystals, that include numerous small quartz-bubbles; some of the crystals show a darker green core and a lighter green periphery. Between these hornblendes small quartz nests occur, as it were interstitially; there is a connection between the quartz of these nests and the quartz-bubbles in the hornblende. Also some non-idiomorphic plagioclases altered and dusty crystals, can be found between the hornblendes. As accessory minerals some very big apatite grains, and a very little ore are present; in the pyroxene-hooibergite and very near this contact-zone the amount of magnetite increases. Probably, the pyroxene of the border of the pyroxene-hooibergite has been transformed into hornblende plus quartz (of the contact-zone), as a result of the contact-action by the intruding aplite magma. The hooibergite may also have been enriched with quartz out of the quartz-rich aplitic magma.

The contact-zones in D 12325 (pyroxene-hooibergite and dioritic aplite) are not so very different from the hooibergite; the big hornblendes contain small quartz-bubbles; there is less plagioclase than in the hooibergite, however more quartz between the pyroxenes; the latter seem to have been partly resorbed by the quartz liquid, which may have originated from the quartz-rich aplite magma. Magnetite is wanting. The enclosed fragments of the pyroxene-hooibergite, lying in the aplite-rock, do no more contain pyroxene; they consist of an aggregate of hornblendes (with quartz-bubbles), between which quartz and plagioclase occur.

The hooibergite, bordering on the dioritic aplite in D 12317, is almost normal; among the hornblende crystals, however, there are no big individuals; all are small, short prisms; probably, this development of the hornblende is also the result of contactmetamorphism.

A contact-phenomenon, present in almost all the invaded hooibergite-rocks, is the occurrence of small quartz-bubbles (in a more or less great quantity) in those hornblendes, which lie near or in the contact-zone. The zone, in which such quartz-bearing hornblendes occur, is different in width in the different rocks; for D 12318 a width of about 3 mm could be determined. This zone in D 6178 contains a little more quartz than the proper pyroxene-hooibergite farther from the contact; so, an enrichment with quartz out of the quartz rich quartz-hornblende-diorite magma seems obvious. This enrichment has not only taken place as an enlargement of the already existing, interstitial quartz masses, but also as an impregnation of the hornblende crystals with quartz ("hornblende-myrmekite"; see also p. 96).

It is curious, that D 12328, a pyroxene-bearing hooibergite without an intrusive dike-rock but with aplitic nests (see pyroxene-hooibergites), contains some hornblendes with quartz-bubbles. As in the diorites, the final consolidation-liquid, rich in quartz, must have enriched the hornblende: autometamorphism.

Endomorphic contact-phenomena in the intrusive dike-rocks: Contact-phenomena in the dike-rocks are rare. Only the following alterations in connection with the close neighbourhood of the hooibergite-rock could be found. It is remarkable, that in most of the dike-rocks the plagioclases are very or rather dusty. In D 12319, D 6178, D 6546, D 6561 the plagioclases are especially very dusty close to the contact, and they are the more dusty, the nearer they lie to the hooibergite-rock. – Some dioritic dike-magmas enclosed hooibergite-hornblende crystals; at least, some big hornblendes in these dike-rocks look very much like hooibergite-hornblendes: D 12315, D 12319, D 12331, D 6178. The hooibergite-hornblendes in the latter rock contain small quartz-bubbles! – D 12319 shows moreover the remarkable

phenomenon, that the zone of the quartz-hornblende-diorite-dike, bordering on the hooibergite and about 4 mm. wide, is richer in quartz and hornblende than the diorite farther away from the hooibergite, consisting for the greater part of plagioclase.

GABBROS.

Here and there in the batholith we meet very darkcoloured, mediumgrained rocks which are gabbroic. Besides, a large massive of gabbros is that of the Matividiri, which borders on the diorite, on the sea and for a small part on the older rock-system (plate I, fig. 1). Several kinds of gabbro have been sampled, hypersthene and augite-bearing gabbros and augite-bearing gabbros (gabbrodiorites).

QUARTZ-BEARING HYPERSTHENE-AUGITE-HORNBLENDE-(BIOTITE-) GABBROS.

The texture is typically hypidiomorphic-granulose-gabbroic. The main constituent minerals are plagioclase, orthorhombic and monoclinic pyroxene, hornblende, biotite and quartz. Quartz is wanting only in D 12528, biotite is wanting only in D 11945. Plagioclase takes up more room than one of the other minerals. In general, the pyroxene takes up more room than the hornblende, except in D 11943 and D 11945, which are rich in hornblende. The monoclinic pyroxenes take up more room than or about as much room as the orthorhombic ones. Biotite and quartz are generally of a minor importance, if present.

The plagioclases are more or less prismatic. Except in the most peripheric parts they look very dusty because of numberless diminutive microlites, occurring in very small needles, rods and bent plates in several parallel-systems (these parallel-systems seem to be connected here and there to lamel-systems); the distribution of the microlites has something to do with the polysynthetic twinning and the zonal structure. The microlites look brownish in reflected light and give the plagioclases a dark colour in the sample. Many of the plagioclases have a zonal structure, here and there with (repeated) recurrence; the zonal structure is more or less regular and has here and there quite the character of the curious structure in some of the plagioclases in D 11963 (see p. 40). The composition is andesine to labrador; except in D 11945: bytownite to labrador-bytownite. In several rocks plagioclases occur with green chlorite, uralite or biotite along fissures; these minerals are alteration-products of the dark minerals. Only the rocks sampled on the Matividiri, Sumpina and Kadiwari contain several pressed crystals.

The monoclinic pyroxene crystals are hypidiomorphic, less allotriomorphic with regard to the plagioclases. They are prismatic, very palegreen to almost colourless diopsidic augites. Several of them show a twinning. Some pyroxenes in D 11943, D 11945, D 12528 and D 12529 have quite changed into lightgreen, parallel- or diverse-fibrous uralite; in D 11943 and D11945 such uralite aggregates contain ore, partly as a rim.

The orthorhombic pyroxenes are idiomorphic or hypidiomorphic with regard to the plagioclases, and in general idiomorphic with regard to the monoclinic pyroxene. Hence, the orthorhombic pyroxene must have crystallized before the augite. The crystals are short-prismatic or isometric hypersthenes, with a slight pleochroism from very palegreen to very pale-pink, and rarely colourless. The hypersthenes have been partly, along their border and along fissures, or totally changed into talc, which occurs as a brownish, parallel-fibrous aggregate; here and there some greeny uralite along the border of this talc aggregate and a rim of ore are present as well.

The hornblende is, in general, non-idiomorphic; hypidiomorphic or allotriomorphic with regard to the plagioclases. It is present in well-cleaved, light- or darkgreen-pleochroitic crystals, which are of a primary origin. Hornblendes in D 11942, D 11943 and D 11945 contain small quartz-bubbles; several augites in D 11942 contain them too. In D 12528 the transition hornblende → uralite is clear.

Texture-relations hornblende-pyroxene (fig. 13): The augite crystals are intensively intergrown with hornblende, that is to say, the latter mineral occurs as small pieces in the pyroxene and in many cases also as an irregularly shaped rim around the pyroxene; these different parts have one and the same extinction and belong to one and the same hornblende crystal. Here and there the intergrown augite and hornblende have the same twinning-plane (see f.i. D 11943). Also augites occur which are in intergrowth with two hornblende crystals. The intergrowths prove that the two minerals must have crystallized at the same time. (Probably it is out of question that the hornblende forms here a younger resorptive replacement-mineral in and around the pyroxene, like quartz here and there in feldspar). — No intergrowth can be seen between hornblende and hypersthene. The latter occurs as rounded-off and hollowed-out crystals with a narrow hornblende rim or quite enclosed in bigger hornblende individuals. The hypersthenes must have crystallized before the hornblende.

As to the relation between hypersthene and hornblende we must consider the genesis of these two minerals by the light of the reaction principle as it has been described by Bowen (7, pp. 54—62); see also Erdmannsdörffer (18, pp. 185 and 273). Hypersthene and hornblende here occur very probably in a discontinuous reactionseries and have a reaction-relation. During a phase of slow cooling the hypersthenes could react with the surrounding liquid and have become rounded-off and partly hollowed-out. The following phase of rapid cooling caused the crystallization of a hornblende "reactionrim" (in the meaning of Bowen) or corona around the partly resorbed hypersthenes. So, in fact, the above-described relation between the two minerals is due to the change in rapidity of cooling. — There are no such reaction-relations between orthorhombic and monoclinic pyroxenes here, nor between the monoclinic pyroxene and the hornblende either.

Biotite is present as a few and small plates, non-idiomorphic and especially in the close neighbourhood of and around ore. In D 11942 it also occurs in intergrowth with hornblende.

Quartz is in general allotriomorphic.

Magnetite grains are especially tied to the dark minerals. Here and there they have conformed to the latter and show an irregular shape. Very small ore particles occur besides in alterationproducts also in some of the unaltered pyroxenes. — In most of the rocks a few apatites occur. — Limonite occurs along fissures of some of the hypersthenes and augites.

Finding-places:

Sumpina (S of Matividiri): A 452—D 12528; A 453—D 12529. Kadiwari (S of Matividiri): A 454—D 12530. Matividiri (near and N of the top): A 451—D 12527. Wariroeri (near the coast): A 33—D 11945. Seroe Crystall: A 30—D 11942; A 31—D 11943. W of Matividiri: A 459. N of Zumbo: A 460. Near Seroe Janchi: A 458. [1])

QUARTZ-HORNBLENDE-AUGITE-(BIOTITE-)GABBRODIORITES

These rocks are darkcoloured, gabbroic or dioritic. The texture is hypidiomorphic-granulose to gabbroic. There is more or less plagioclase than hornblende and pyroxene together; at all events, the former is in general the most important mineral. The hornblende generally takes up more room than the augite, while biotite is a third dark mineral; the latter is wanting in D 11941, D 11947 and D 12526. Quartz is not very important; its amount is greater in the dioritic and smaller in the gabbroic rocks.

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[1]) Martin sampled two hypersthene-gabbros, one NW of Bushiribana (135) and another E of Bushiribana (130*); the latter is free of quartz. Kloos considered all the hornblende secondary hornblende after augite and hypersthene, and did not recognize the primary hornblende. The uralitization of the augite and the alteration of the hypersthene into talc in 135 have abusively been described by him as a beginning serpentinization of the hornblende. In 130* the augites have partly been uralitized and the hypersthenes show a beginning alteration into both talc and uralite.

The plagioclases are about the same as those of the hypersthene-gabbros with regard to the shape and the microlitic inclusions. It is very peculiar that plagioclases in D 11941 and D 11968 are intergrown with quartz. Part of the plagioclases are simply zonal. The original composition varies from oligoclase to labrador-bytownite. Distortion phenomena are common. Some crystals contain narrow veins of chlorite and of hornblende material, evidently in connection with the alteration of the dark minerals.

Only in D 11947 and D 12525 some orthoclase occurs allotriomorphically between the plagioclases and hornblendes.

The hornblende is the common green or browngreen one, rarely idiomorphic. In most cases it is as old as the plagioclase or it has conformed to and around the idiomorphic plagioclase crystals. According to the cleavage in the idiomorphic crystals the hornblende must be primary. Quartz-bubbles may occur.

Monoclinic pyroxene is present as colourless diopsidic augites, which rarely occur as separate and rather idiomorphic crystals and mainly are intergrown with hornblende. The latter occurs as small pieces in the pyroxene and also as a kind of rim around it; here and there a common twinning-plane exists. The intergrown pyroxene core may be limonitic along the fissures. In many places the pyroxene has been uralitized, so that hornblendes occur with a core of grainy or fibrous, secondary hornblende, here and there also with chlorite, very finegrained ore and quartz-bubbles. In D 12521 no unaltered pyroxene is present: several crystals consist of secondary hornblende, with chlorite and with a kind of chlorite rim; the latter mineral probably originated from hornblende. Also in D 11954 and D 11968 the pyroxene has been totally changed into uralite, chlorite and leucoxene.

Biotite is allotriomorphic with regard to the idiomorphic plagioclase.

The quartz is interstitial. In reflected light the quartzes of D 12523 show a bluish colour, caused by numberless filiform, microlitic inclusions.

The magnetite grains in some rocks have narrow rims of titanite, or are leucoxenized. Apatite.

Finding-places:

N of Santa Lucia: A 450—D 12526. Kadiwari: A 462. SE of Bushiribana: A 449—D 12525. Bushiribana: A 42—D 11954; A 56—D 11968; A 445—D 12521; A 446—D 12522; A 447—D 12523; A 461. Seroe Sumpina (N of the Crystallberg): A 29—D 11941. About 0,5 km N and NE of Seroe Janchi: A 444—D 12520; A 28—D 11940; A 35—D 11947. [1])

During the course of the crystallization of these hypersthene-augite- and augite-gabbros fractionation has occurred in consequence of the zoning of the plagioclases and of the formation of hornblende coronas around the hypersthenes. This fractionation has led to the crystallization of plagioclase zones of an average to rather acid composition, of biotite, quartz and in a single rock even of potashfeldspar. Compare with Bowen (7) chapter VI, The fractional crystallization of basaltic magma.

OTHER GABBROIC ROCKS

A 34—D 11946 is a quartz-free hornblende-augite-gabbro, sampled on the Jaburibari. The gabbroic rock consists mainly of bytownite and hornblende; monoclinic pyroxene is the second dark mineral. The pyroxenes are small, granular or prismatic, colourless diopsidic augites, here and there twinned. Pyroxene and hornblende occur in intergrowth in the normal way as well. A zeolitic mineral, possibly pseudomorphic after plagioclase, is colourless to somewhat yellowish; parallel- to radial-fibrous or with forms of frost-flowers; low interference-colours; $n < 1.53$; parallel extinction; + zone. It may be natrolite.

A rock, which clearly shows the transition between quartz-hornblende-diorite and

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[1]) Martin sampled two augite-gabbros, one on the Seroe Crystall (133) and the other one in Bushiribana (133*). Kloos wrongly considered all the hornblende secondary after pyroxene; part of it certainly is primary and is in intergrowth with augite. Some of the augites in 133* seem to have been wholly or partly altered into ?talc.

hornblende-augite-diorite is A 32—D 11944, sampled about 1 km N of Alto Vista. Macroscopically a darkcoloured, mediumgrained rock merges into a lightcoloured dioritic rock with big hornblende crystals (up to 15 mm. long). - The quartz-diorite is rich in quartz and contains zonal oligoclases; the latter take up more room than the hornblende. The hornblende contains quartz-bubbles. Ore and titanite occur in intergrowth in a chlorite-titanite mass. - The augite-diorite is more or less gabbroic. The plagioclases probably take up less room than the dark minerals, of which hornblende is most important. They are irregularly zonal and show one core and one zone; their composition could be measured as labrador to oligoclase. The hornblendes show a pleochroism from browngreen to pale-brownyellow and are irregularly coloured here and there, although their extinction is one and the same. The diopsidic augites are intergrown with hornblende. Radial-fibrous chlorite with titanite, lying around ore, may have originated from biotite. Quartz seems to be wanting. - The two rocks can be clearly distinguished from each other because of the qualitative and quantitative differences in the constituting minerals. There is no special transition-zone between them. On the other hand, the rocks border directly on each other and their crystals normally work in with and between each other.

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE GABBROS.

The gabbroic rocks occur in the batholith as darkcoloured massives which seem to present only aberrant phases of the diorite and many of which have small dimensions (see the finding-places and the map). They crop out as big and round blocks (selective weathering) or as acute-angular rocks. Here and there the massives lie on the top of the hills, f.i. of the Seroe Sumpina (N of the Seroe Crystall), of the Seroe Crystall and of hills in N-Aruba. It is very remarkable that the gabbro of the Matividiri locally shows beds, which have a strike N 90 E and a steep dip to the south (the same strike as that of the porphyrite-dikes here!). The massives occur especially in the northern and northeastern regions of the northwestern large batholith outcrop. The most important finding-place is the large gabbro-massive of Sumpina-Matividiri-Bushiribana, bordering partly on the sea. As far as is known, gabbroic rocks are absent in the two southeastern diorite outcrops.

The Matividiri s.str. seems to consist only of hypersthene-gabbro. The gabbros of Bushiribana and the surroundings are mainly augite-gabbros without hypersthene and for the smaller part hypersthene-gabbros. On the Kadiwari, the Seroe Crystall and in the surroundings of Seroe Janchi both kinds of gabbro have been sampled. So, these two gabbros seem to belong to the same geological unit; yet, true transitionrocks have not been found.

As to their geological place in the batholith, Martin (30) considered the gabbroic rocks rocks equivalent with and of the same age as the diorites: (p. 46) ,,Gabbroartige Gesteine treten ebenfalls innerhalb des Dioritmassivs auf, ohne ,,dass ihnen eine geognostische Selbständigkeit zugeschrieben werden dürfte." He mistook the rocks which represent the injected gabbros in the surroundings of Bushiribana for dioritic rocks with gabbroic concretions (compare with his ideas concerning the hooibergite-rocks): (p. 47) ,,Von einer Formationsgrenze ,,zwischen Gabbro und Quarzdiorit, deren Existenz schon auf Grund der beobachteten, gabbroartigen Concretionen in Letzterem unwahrscheinlich ist, vermochte ,,ich nirgends eine Spur zu entdecken." Kloos (25) came to the same conclusion on petrographic bases and considered the gabbro an example ,,von einer lokalen ,,Aenderung des Gesteinscharakters inmitten eines eruptiven Massivs'' (p. 38).

In fact, the diorites and the gabbros are, broadly outlined, not so very different and belong both to the same batholith; that is to say, they present differentiates of one and the same original magma, very probably. We have found several rocks, which lie petrologically between the normal quartz-diorite and the hypersthene-augite-gabbro: normal quartz-diorite without augite ⟶ quartz-diorite with a little augite ⟶ quartz-diorite with much augite ⟶ quartz-gabbro with much augite ⟶ quartz-gabbro with much augite and a little hypersthene ⟶ quartz-gabbro with much augite and much hypersthene. All these rocks contain hornblende and some of them also biotite; quartz may be wanting here and there. A transition between quartz-hornblende-diorite and hornblende-augite-diorite can be seen in the rock A 32—D 11944, described on p. 58; these two rocks seem to be of the same age; at least, no contact-phenomena are present here.

Hence, we can conclude that the dioritic and gabbroic rocks are closely related and that they belong to the same batholith. We cannot accept, however, that the diorites and the gabbros are of the same age, for the gabbros of the Sumpina- Matividiri- Bushiribana- massive have been injected by diorite magma and have been metamorphosed by this magma. So, there must be a difference in age, probably a small one. The gabbros must have consolidated before the diorites, so that the diorite magma could attack the former rocks.

There is a strong geological resemblance between these gabbros and the hooibergite-rocks. In accordance with the latter and with DALY (12) we can consider the gabbros a chilled roof-phase (contact-phase) in the batholithic chamber. This agrees with the occurrence in the batholith outcrop. The gabbros have chiefly been found in the northern and northeastern parts of the outcrop, that is to say, in the highest parts of the batholith. Yet, they border but here and there on the older formation, f.i. in the Matividiri and in the Seroe Crystall (compare with the occurrence of the hooibergite-rocks).

CONTACT-PHENOMENA IN THE GABBROS.

The gabbros and the gabbro-diorites of the Bushiribana-Matividiri-Sumpina-massive can be clearly distinguished from the dioritic rocks, which lie on the south- and west-side of this massive. The diorite magma and its differentiates intruded into the older gabbroic rocks, which must not have been quite consolidated at that time (transition-rocks between the gabbro and the diorite came into being here and there). Yet, the intruding magma consolidated in many cases as true dikes in the gabbro-massive; these dikes are not so very sharply bordered on the invaded rocks. In many places fragments of the gabbroic rocks have been taken up by the intrusive magmas.

The intruding magmas caused a certain exomorphic contactmetamorphism in the gabbro-rocks. Here and there the contactzone is rather wide because of a strong injection with dioritic material. In other places the width only seems to be very great thanks to the low dip of the contact-plane; the diorite here underlies the gabbro-massive.

Contactrocks of the Contactzone between the Matividiri-Bushiribana-gabbros and the Diorite (northwest-foot of the Matividiri): The contactzone here has a great width and its contactplane probably lies about horizontally, so that it cannot be said which of the two kinds of gabbro (the hypersthene-augite-gabbro or the augite-gabbro) has come into contact with the diorite magma. The gabbros have strongly been altered into uralite-gabbros or into transition-rocks between the latter and the diorites.

A 455—D 12531 probably is a contactmetamorphic uralite-gabbro. It has a gabbroic texture and consists of plagioclase and hornblende, in about the same amount. The plagioclases are prismatic albites. The hornblende is green; only a few crystals look undivided and have one and the same extinction, at least for their greater part (primary hornblende). Far the greater part of the hornblende occurs as diverse-granular and -fibrous aggregates, which show a crystal-shape and which probably represent paramorphisms of hornblende after pyroxene. The individuals of the hornblende aggregates here and there are intergrown and contain many quartz-bubbles. Others, however, are small and idiomorphic crystals with a normal hornblende-cleavage; the latter very probably are new-made crystals. Magnetite especially occurs together with chlorite. A few yellow, primary-looking epidote crystals especially occur near and with ore.

A 456—D 12532 is a mediumgrained, contactmetamorphic uralite-gabbro with a dike of quartz-biotite-diorite (or biotite-diorite-aplite). The gabbro is more hypidiomorphic-granulose than gabbroic, and consists of plagioclase, hornblende and quartz. The average composition of the plagioclases is andesine. The hornblende occurs in the same way as in D 12531. Biotite has been almost totally changed. The quartz does not contain fluid-inclusions in a narrow peripheric zone. Although this gabbro is not sharply bordered on the dike-rock, the transition is "abrupt". The dike-rock is a quartz-biotite-diorite or a biotite-diorite-aplite; it has an almost aplitic texture and consists mainly of quartz and plagioclase (oligoclase-andesine to albite), less of altered biotite and hornblende. Hornblende is rare in the section and seems to have been taken up from the gabbro; macroscopically we see more crystals.

A 457—D 12533 presents a dike of quartz-hornblende-biotite-diorite in strongly altered gabbro. The sample consists of two parts; a part, rich in quartz and poor in hornblende, and another, poor in quartz and rich in hornblende. Under the microscope we see the same parts; the former is the dike-rock, the latter is the altered gabbro which contains more plagioclase. For the rest, the two parts are about the same and merge gradually. The texture is hypidiomorphic-granulose. The plagioclases have been totally albitized. The hornblendes of the dioritic part are normal. Those of the gabbroic part are irregularly prismatic to granular and especially arranged in groups; many individuals contain numerous quartz-bubbles; here and there also new-made crystals occur. Biotite has been totally changed. The fluid-inclusions of the gabbro quartzes occur in the centre and not in a narrow peripheric zone. Magnetite, here and there leucoxenic (titanomagnetite), occurs more in the gabbro than in the diorite.

The rock 135*, sampled by Martin near Bushiribana, presents a hornblende-augite-gabbro in contact with quartz-hornblende-biotite-diorite; the crystals of the two rocks work in with and between each other. Contact-phenomena are the rather strong uralitization and chloritization of the pyroxene; here and there small, new-made hornblende crystals occur in the uralite aggregates. The plagioclases in the neighbourhood of the hornblende have been almost totally epidotized.

Hence, as well as the contactmetamorphic uralite-diabases these contactmetamorphic gabbros contain new-made hornblende crystals. Their plagioclases and biotites have more or less been altered, while the pyroxenes (orthorhombic and/or monoclinic) do no more occur as such. The gabbros of the two latter rocks may have been enriched with quartz.

Many of the normal, non-metamorphic gabbro (-diorites) have been sampled near the contact. So probably, the beginning alteration of the pyroxene has come into being under the influence of the contactmetamorphism. Gabbro-diorites still containing augite material have also been found in contact with intruded diorite-aplite.

Further Details about the Contact in the Field: Many of the smaller massives of gabbro do not show clear contacts with contact-phenomena, and seem to merge gradually into the surrounding diorite here and there. Only the large massive Sumpina-Matividiri-Bushiribana has a fine contactzone, although locally the gabbro borders on the diorite without visible contact-phenomena. In by far the most places of the contactzone, however, the gabbro has been very strongly injected by diorite, diorite-aplite and quartz. Here and there it is hybrid and impregnated by numberless dikes and veins. The dikes have various widths, from about 10 cm to about 1 meter; here and there they contain rounded-off or non-resorbed gabbro fragments. These dikes do not only occur in the contactzone but can also be found here and there in the massive, f.i. on the top of the Matividiri. The porphyrite- and lamprophyric dikes, which occur everywhere in the massive (see map) cannot be considered as contact-dikes.

GRANO-DIORITES

(Hornblende-Granodiorites).

Some of the diorites contain a rather large amount of potashfeldspar, so that they must bear the name granodiorites. In general, however, they show the same properties as the common quartz-diorites.

These granodiorites are rare, and they gradually merge into the normal quartz-diorites. They do not form distinct massives in the batholith, as far as we can see.

fig. 14 // nicols 27 X

fig. 15 // nicols 27X

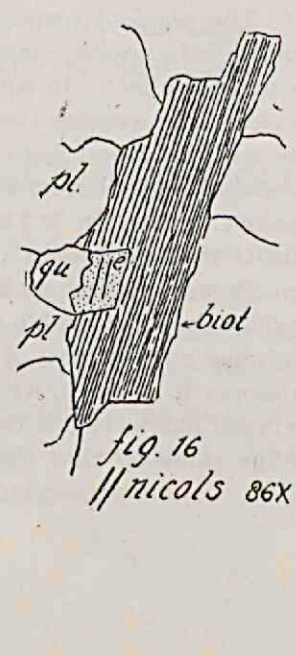

fig. 16 // nicols 86X

In A 70—D 11982 (Seroe di Poos di Noord) the orthoclase and ?microcline occur as allotriomorphic crystals, in which many plagioclases lie enclosed; some of these plagioclases look partly resorbed. The plagioclases which are zonal oligoclase-andesines to andesines and many hornblendes show a good idiomorphism. The great number of idiomorphic and rounded-off plagioclases in the hornblendes is remarkable (fig. 14).

D 6175 (hills N of Savaneta) contains much quartz; and its potashfeldspar is orthoclase. The plagioclases are non-zonal albites to albite-oligoclases. Moreover, there occur some masses of fibrous chlorite with epidote and leucoxenic strings, and a group of titanomagnetite with apatite, chlorite and epidote.

GRANITES.

(Biotite-granites) (plate II, fig. 9).

Some of the rocks which are to be described in this chapter present types intermediate between biotite-granodiorites and biotite-granites, dependent on the proportion of the amount of lime-soda-feldspar and of potashfeldspar. Since however, these intermediate rocktypes contain biotite as dark mineral, and since the above-described granodiorites contain hornblende, it seems better to put the intermediate rocktypes in the group of the biotite-granites. Only in one rock (D 11980), belonging to those intermediate rocktypes, a very little hornblende as non-idiomorphic crystals occurs as a second dark mineral.

Samples: A 63—D 11975; A 64—D 11976; A 65—D 11977; A 66—D 11978; A 67—D 11979; A 68—D 11980; A 69—D 11981; A 71—D 11983.

Macroscopically the granites are lightcoloured rocks, finegrained, rarely fine- to mediumgrained. Their quartzes have a brown or yellow colour; their feldspars are white, and the biotite occurs as black and lustrous plates. A 63 shows an orbicular structure.

Microscopic description: The texture is holocrystalline, hypidiomorphic-granulose. The main constituent minerals are potashfeldspar, plagioclase, quartz and biotite. The amount of feldspar is about the same as that of quartz. The amount of biotite is rather small, and in some rocks very small. In most of the granites the amount of lime-soda-feldspar is greater than that of the potashfeldspar, or both amounts are about the same. In a few rocks the amount of plagioclase is smaller than that of potashfeldspar.

The plagioclases are more or less idiomorphic, and some of them possess resorptionholes filled up with quartz or potashfeldspar. Most of them have a zonal building, often with recurrence-effects. In some rocks the resorption-effect as described in D 11963 (see diorites) is clear. The average composition is oligoclase; the most basic cores are oligoclase-andesine; the most acid peripheric zones are albite-oligoclase. A few myrmekitic intergrowths occur; most of them are bordered by potashfeldspar, but a single plagioclase in D 11978 is myrmekitic against quartz. In D 11980 and D 11981 sub-granophyric intergrowths of plagioclase and quartz may be due to a strong resorption-action of quartz-liquid in plagioclase.

Potashfeldspar occurs as dusty and allotriomorphic crystals, which wholly or partly enclose the idiomorphic or hypidiomorphic plagioclases. Here and there the extinction is an undulose one. In most of the granites the potashfeldspar is microcline, orthoclase, microcline-microperthite and microperthite. In D 11983 the transition of microperthite into normal, twinned plagioclase is very clear, and shows that the lime-soda-feldspar in the microperthite is the same as that outside the microperthite (fig. 15).

The quartz is partly present as allotriomorphic individuals between the more or less idiomorphic plagioclases and the non-idiomorphic potashfeldspar, partly as more or less idiomorphic crystals in the allotriomorphic potashfeldspar. The allotriomorphic quartz must be younger than the plagioclase and must have crystallized at about the same time as the potashfeldspar (in D 11981 there may be a sub-micrographic intergrowth between quartz and orthoclase). The idiomorphic quartz must have crystallized before the potashfeldspar, and shows here and there resorption-holes, filled with potashfeldspar. Some quartz crystals even show idiomorphism with regard to plagioclase in D 11979. The idiomorphic quartzes are wanting in a few rocks (f.i. D 11976 and D 11977). In D 11975 and D 11976 the quartz especially occurs as rather small grains along the borders of the potashfeldspar individuals. The "Streifen" of an idiomorphic quartz in D 11983 show a difference in refraction. Limonite occurs along fissures and moreover as very small and yellow films.

The shape of the biotite crystals commonly is tabular; they are idiomorphic or not. Here and there plagioclases occur as idiomorphic crystals in the biotite. The biotite crystals are rather big or small ones. They partly occur in crystal-groups. The very small crystals occur accumulated in aggregates. — Muscovite is present in a very small amount or it is wanting. Part of the plates occur (as primary minerals) enclosed in the plagioclase, in D 11977 especially along the borders of the biotite.

Apatite occurs as very small prisms in the quartz, the feldspar and the biotite. — A very few crystals of zircon lie enclosed in biotite and quartz (D 11977, D 11983). — Titanite has been found only in D 11980 in the close neighbourhood of biotite (secondary or primary?). — Magnetite is a common mineral, and can be found in the close neighbourhood of biotite, partly in it; or it occurs independently of this mineral, but then together with epidote. The magnetite may be titanomagnetite when accompanied by ?leucoxene.

Some epidote crystals, lying enclosed in biotite, may be primary epidotes (D 11977, D 11978, D 11979, D 11981). In D 11977 and D 11979 (fig. 16) this epidote occurs as follows: wholly or partly enclosed by biotite; idiomorphic, prism-shaped; with or without a good cleavage; slightly pleochroitic from colourless to yellowish, yellowish-green or lightgreen; high interference-colours (abnormal or not); extinction according to the cleavage-planes 0° (in D 11979 this epidote shows ?resorption-holes against quartz). – Chlorite: D 11983 contains some vermicular chlorite. — Calcite occurs as very small and narrow veins in D 11975.

The granites occur here and there in the batholith and seem to merge gradually into the quartz-diorite. So, they do not form distinct massives like the gabbros f.i. and are very probably of the same age as the diorite. They crop out here and there as ,,Felsenmeere", f.i. the granite of the large outcrop just W of the Hooiberg (see the map). Several granites have been collected and observed W of the Hooiberg; moreover, they have been found near Santa Cruz, S of Kudawecha, W of Seroe di Poos di Noord, near Seroe Compa and SW of Rincon (SE-Aruba).

CONTEMPORANEOUS DIKE-ROCKS, OCCURRING IN THE BATHOLITH.

The dike-rocks which will be described here have about the same composition as the plutonic rocks in which they intruded, although they are younger. They are different types of dike-diorites, dike-granodiorites and dike-granites. In fact, the latter two kinds of rock are no true contemporaneous dike-rocks where they occur in the diorite, but still all of their representatives can be reckoned among this group. Those rocks have been added as well, which occur as dikes in the older differentiates of the batholith, f.i. in the hooibergite-rocks.

DIKE-DIORITES

Quartz-hornblende-diorite (A 282—D 12293; A 285—D 12296; A 324—D 12315, D 12316; A 326—D 12318; A 327—D 12319; A 357—D 12335; A 359—D 12337; A 372—D 12341; P 81—D 6546; P 99—D 6178; P 69—D 6180): Macroscopically these rocks are fine- to mediumgrained, and light- or darkcoloured. Some of them look more lamprophyric than dioritic. The diorite-dike of A 326 shows a flow-structure, the hornblende crystals lying roughly parallel to the dike-borders.

Microscopic description: The texture is more or less hypidiomorphic-granulose, hypidiomorphic- to allotriomorphic-granulose, or pan-allotriomorphic-granulose. Hence, a sequence of crystallization cannot be recognized in all the rocks. In those rocks where it is wanting more or less, the quick cooling of the dike-magma may be the cause. The main constituent minerals are plagioclase, hornblende and quartz. The plagioclase takes up more room than or about as much room as the hornblende. Quartz is quantitatively the second or the third mineral.

In the rocks with a hypidiomorphic-granulose texture not all the plagioclases are quite idiomorphic (contemporary crystallization or partial resorption?). The composition of the plagioclase is oligoclase-andesine, rarely oligoclase or albite. In D 12315(16) some albites possess colourless, isotropic spots with a higher refraction than the surrounding plagioclase material. The crystals in D 12296 and D 12319 are long-prismatic to lath-shaped.

The hornblende commonly is regularly distributed but it occurs in groups as well. It is the normal green hornblende; several of the crystals in D 12335 have darkgreen cores. The crystals are prisms, partly idiomorphic with regard to quartz and plagioclase. Quartz-bubbles occur in some of them.

Quartz is allotriomorphic. Locally, narrow and irregular strokes of an albitic feldspar occur in some quartzes of D 12315 (16): filling of fissures by albitic material; the plagioclases have been totally albitized in this rock.

Apatite, grains of titanite, here and there especially tied to hornblende and ore, magnetite and titanomagnetite are accessory.

These rocks have been found as dikes in the diorite batholith and in the hooibergite-massives.

Dike-quartz-hornblende-diorite invaded by another dike-quartz-hornblende-diorite (A 283—D 12294; S of Santa Cruz): The sample shows a darkcoloured, finegrained rock, with a narrow dike, about 3 mm. wide, of a normally dioritic rock.

The darkcoloured rock mainly is a plagioclase-hornblende-rock with locally some quartz. Plagioclase (oligoclase-andesine to andesine) and hornblende, green to brownish-green, constitute a pan-idiomorphic-granulose texture.

The dioritic rock, occurring as a narrow dike in the dike-diorite described above, is mainly a plagioclase-quartz-rock, with some hornblende crystals, and coarser grained than the described rock. Its texture is rather hypidiomorphic-granulose, and the oligoclase-andesines show a prismatic development. Quartz is abundant. It is remarkable that apatites only occur along the borders of the dike.

Hence, the distinction between the darkcoloured diorite and the lightcoloured one is clear. Nevertheless, the rocks do not sharply border on each other; the crystals on both sides normally work in with and between each other.

Quartz-bearing hornblende-diorite dike with an inclosed fragment of quartz-hornblende-diorite (A 286—D 12297; N of Spaansch Lagoen): The enclosed fragment is an orthoclase-bearing diorite. Its plagioclases have been strongly altered; there is a clear connection between the albitization and the polysynthetic twinning. The original composition probably was oligoclase-andesine. The hornblende too is little altered.

The dike-diorite mainly consists of plagioclase and hornblende; quartz is of a minor importance. Plagioclase and hornblende constitute a pan-idiomorphic or pan-allotriomorphic-granulose texture. The plagioclases are albite-oligoclases (albitized?), only a little altered.

The difference between the two rocks is clear, especially the difference in alteration. The crystals on both sides normally work in with and between each other, so that the invaded diorite cannot have been quite consolidated at the time of the intrusion. A certain magmatic solution of the invaded diorite by the dike magma may have occurred too.

QUARTZ-HORNBLENDE-DIORITE, VERY RICH IN QUARTZ AND VERY POOR IN HORNBLENDE. (P 103—D 6562, dike in hooibergite of the Hooiberg): The texture, being about hypidiomorphic-granulose, points to a dioritic rock, but the richness in quartz and the very small amount of hornblende point to a diorite-aplitic rock. The plagioclases are oligoclases and oligoclase-andesines. Beside some small individuals no fresh hornblende is present. Some epidote masses, irregularly or more or less prism-shaped, may have originated from hornblende.

QUARTZ-HORNBLENDE-DIORITE, A LITTLE ABERRANT (A 287—D 12298; N of Seroe Compa): The sample is a finegrained feldspar-hornblende-rock, here and there with quartz globules, feldspar and hornblende "phenocrysts"; globular inclusions of a lightcoloured, aplitic-looking rock can be distinguished as well.

In the slide the normal, darkcoloured rock and a part of a lightcoloured globule can be seen. The rocks merge gradually. The difference is quite clear, thanks to the difference in the quantity of hornblende. In the darkcoloured rock a small quartz globule occurs, with fluid-inclusions in planes and without a special rim. The normal darkcoloured diorite is pan-idiomorphic-granulose and consists of plagioclase, hornblende and rather much quartz. The lightcoloured diorite, occurring as a globule in the darkcoloured diorite, contains less hornblende and much more quartz. The texture is pan-idiomorphic to hypidiomorphic-granulose, the plagioclases being more lath-shaped. Plagioclase (oligoclase-andesine, as in the darkcoloured diorite), quartz and hornblende (as small prisms) are the main constituent minerals. Titanite and small groups of epidote are present here, but are wanting in the darkcoloured diorite.

HORNBLENDE-DIORITE (A 358—D 12336; dike in the hooibergite of Seroe Tres Kabees): A plagioclase-hornblende-rock without quartz, strongly altered, with albitized plagioclases and lightgreen hornblende. An epidote vein is not sharply bordered on the diorite; the epidotization of the latter is most important along the vein.

QUARTZ-HORNBLENDE-BIOTITE-DIORITE (A 74—D 12042; just NW of the Hooiberg): The rock is hypidiomorphic-granulose and consists of oligoclase to oligoclase-andesine, in the second place of hornblende and quartz, in the third place of almost wholly altered biotite.

QUARTZ-HORNBLENDE-BIOTITE-DIORITE (A 288—D 12299; Kamai): The sample shows a darkcoloured, finegrained hornblende-feldspar-rock as a dike in a lightcoloured, coarser grained diorite. The latter is a normal quartz-hornblende-biotite-diorite with totally changed biotite; its plagioclases are oligoclase to oligoclase-andesine. The dike-diorite, rich in hornblende, has a hypidiomorphic-granulose texture as well; its plagioclases show a tendency towards the lathshape, and vary in composition from oligoclase-andesine to labrador. Some potashfeldspar is present. Several hornblendes contain quartz-bubbles. The biotite has been almost completely altered. The difference between the two rocks is clear, thanks to the difference in size of the crystals and in quantity and distribution of the hornblende. The rocks do not sharply border on each other.

QUARTZ-BIOTITE-HORNBLENDE-DIORITE (A 356—D 12334; dike in hooibergite of Seroe Bientoe): It is a more or less hypidiomorphic-granulose diorite, which consists mainly of plagioclase, quartz, biotite and (as a second ferromagnesian mineral) hornblende. The plagioclases are oligoclase-andesines.

Hornblende-biotite-diorite (A 284—D 12295; Sabana Grandi): The texture is pan-allotriomorphic- to pan-idiomorphic-granulose. It consists of oligoclase-andesine, many small hornblende prisms with here and there quartz-bubbles and some biotite.

DIKE-GRANODIORITES.

Hornblende-granodiorite (A 352—D 12330, A 353—D 12331; dikes in hooibergite of the Seroe Bientoe): The texture is hypidiomorphic- to allotriomorphic-granulose. In D 12330 the texture, being on the whole hypidiomorphic-granulose, is pan-allotriomorphic-granulose and finer grained near an enclosed hooibergite fragment. The plagioclases are oligoclase-andesines. Potashfeldspar occurs less than plagioclase, and is allotriomorphic; the boundary between plagioclase and potashfeldspar is not quite straight everywhere (resorption and/or contemporary crystallization). The potashfeldspar occurs in D 12331 as narrow rims around and between the plagioclases. In D 12330 it is only microcline; in D 12331 orthoclase, microcline and microcline-microperthite. It is very remarkable, that the potashfeldspar in D 12330 does not occur in the aplitic part near the countryrock (see above); possibly the potashfeldspar could not crystallize here because of the very quick cooling. Hence, this part of the rock has the composition and the texture of a dioritic aplite. Hornblende only occurs as a few and small prisms. Quartz is the second mineral. Some crystals in D 12331 are idiomorphic with regard to potashfeldspar. Apatite, rare magnetite and several idiomorphic titanite crystals and grains are accessory.

Biotite-granodiorite (A 77—D 12045; near Seroe Plat): This rock very nearly approaches the dike-granites. The texture is hypidiomorphic- to allotriomorphic-granulose. Potashfeldspar occurs in about the same quantity as plagioclase; it is represented by dusty crystals of orthoclase, microperthite, microcline and microcline-microperthite. Many of the oligoclase-andesines are idiomorphic with regard to quartz and potashfeldspar. Some of the quartzes are idiomorphic with regard to the potashfeldspar. Several granophyric intergrowths of plagioclase and quartz can be found. The biotite is brown and green. Magnetite, apatite.

DIKE-GRANITES

Biotite-granite (A 78—D 12046, N of Salinja Cerka; A 79—D 12047, Seroe Tres Kabees): The rocks are finegrained, and hypidiomorphic-granulose. The potashfeldspar occurs as orthoclase, microcline, microperthite, microcline-microperthite. They are big, allotriomorphic crystals which enclose in a poikilitic way earlier crystallized and idiomorphic plagioclases, quartzes and also biotites; partly these enclosed plagioclase and quartz crystals have resorption-holes. The composition of the plagioclase core is oligoclase-andesine, that of the peripheric zones albite-oligoclase to oligoclase. Quartz occurs as idiomorphic crystals in the potashfeldspar and as allotriomorphic individuals between the plagioclases. Hence, there are two different kinds of quartz, that did not crystallize at the same time. The biotite occurs as separate plates or in groups and streaks; the latter locally lie around idiomorphic plagioclases. Magnetite and apatite are common. Some epidotes, enclosed in biotite, may be primary. D 12047 contains moreover some titanite grains and zircons. In D 12046 some grains of spinel are tied to the biotite.

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE CONTEMPORANEOUS DIKE-ROCKS.

The dikes have not been indicated in the geological map. They occur as normal dikes, not very long and with a width, which is not greater than 3 meters, generally, and which is here and there but a few dm. N of Salinja Cerka a long, granitic dike occurs, locally more than 3 meters wide and cropping out as small, roundish blocks; the dike, N 70 E, has been faulted in two places, so that the eastern parts have been removed a few meters towards the north with regard to the western part.

The strikes are varying; several dikes strike N 100 E and N 140 E. The dips are vertical or very steep, rarely less steep.

This kind of dikes is not so widespread as the leucocratic dikes. Besides in the contactzones between diorite, hooibergites and gabbros the contemporaneous dikes have only been observed in the batholith outcrop in the northwestern half of the island. On an average, the dikes occur regularly distributed in this outcrop. It is remarkable, however, that most of the dioritic dikes have been observed in the southwestern zone of this outcrop, whereas most of the granitic dikes occur in the northern and northeastern parts.

PORPHYRITIC DIKE-ROCKS BELONGING TO THE BATHOLITH.

Younger representatives of the magmatic sequence in the diorite batholith are, amongst others, those dike-rocks, which have a composition, not so very different from that of the plutonic rocks of the batholith: the porphyrites and the vintlites. As will be shown here below, transitional rock-phases between diorite and porphyrite and between porphyrite and vintlite have been found too, and these rocks prove that the different rock-types are all products of one and the same magma.

The porphyrites and the vintlites occur as dikes in the diorite, but also in a great number in the older rock-system; the latter must have their source in the batholith, which lies in the underground of these older rocks. The dikes also cross the contactzones between the older rocks and the diorite. Especially the gabbro-massive of Matividiri contains many dikes.

The rocks occur in the landscape as distinct dikes, a great number of which are very long and wide; the dikes can be clearly distinguished from the rocks in which they intruded, because of their shape and colour; in general, the dikes do not occur as elevations.

PORPHYRITES.

By far the most of these rocks are diorite-porphyrites. These diorite-porphyrites can be divided into two groups: quartz-hornblende-diorite-porphyrites (constituting the bigger group) and hornblende-diorite-porphyrites (the smaller group), dependent on the occurrence of quartz and/or hornblende phenocrysts. However on the whole, there is no great difference between these two groups. Moreover, two aberrant porphyrites (A 228—D 12248; and D 860) and one rock, being transitional between porphyritic quartz-hornblende-diorite and quartz-hornblende-diorite-porphyrite (A 220—D 12240) have been found.

The groundmass of the porphyrites is finegrained to aphanitic. The maximum size of the plagioclase phenocrysts is about 7 mm, that of the hornblendes about 15 mm, that of the quartzes 5 mm.

THE TRANSITION-ROCK BETWEEN DIORITE AND PORPHYRITE (A 220—D 12240) is a dike-rock, transitional between porphyritic quartz-hornblende-diorite and quartz-hornblende-diorite-porphyrite (north-foot of Matividiri). The rock is a dioritic one, in which some feldspars have a more or less phenocrystic appearance. Properly speaking, only some plagioclases have developed as phenocrysts with a rather good idiomorphism, zonally built and partly with recurrence-resorption; oligoclase-andesine. These phenocrystic plagioclases lie in a hypidiomorphic-granulose-textured, dioritic "groundmass" of zonal plagioclase, hornblende, quartz, magnetite and apatite. Here and there quartz and plagioclase occur in granophyric intergrowth.

Quartz-hornblende-diorite-porphyrites (A 221—D 12241; A 222—D 12242; A 224—D 12244; A 225—D 12245; A 226—D 12246; A 227—D 12247; A 231—D 12251; A 232—D 12252; A 233—D 12253; A 235—D 12255; A 238—D 12258; P 83—D 6172 and D 6548; P 84—D 6173): In some of these porphyrites hornblende phenocrysts can no more be found having been changed into several secondary alteration-products. In one rock even (P 84—D 6173) hornblende as well as its alteration-products are totally absent. Still, it seems admissible to put these rocks into the quartz-hornblende-diorite-porphyrite group.

Macroscopically many of the rocks show a green to grayish-darkgrayish (to black) groundmass, with feldspar, quartz and hornblende phenocrysts. Other rocks look more fine-grained-granitic and dioritic than porphyritic, and do not show the phenocrysts so clearly.

Microscopic description: In a great part of the rocks the groundmass takes up more room than the phenocrysts; in other rocks they are about equivalent. And even in one rock (D 12255) there are more phenocrysts than groundmass. The phenocrysts are plagioclases, hornblendes and quartzes. In most of the rocks the plagioclase phenocrysts take up more room than the hornblende phenocrysts; in others the amount of both is about the same. In some rocks the amount of plagioclase phenocrysts is about the same as that of quartz phenocrysts; in most of the porphyrites, however, the plagioclase phenocrysts are more frequent, and in many of these rocks the quartzes are only present as a few or a very few crystals. In general, quartz occurs in a smaller amount than hornblende. The above-mentioned variations in the frequency of phenocrysts do not show any regularity. D 12258 and D 12242 show hornblende and plagioclase phenocrysts, that drifted together.

Plagioclase phenocrysts: The plagioclases show a partial, seldom total alteration, especially the cores. Calcite rarely occurs. The plagioclases of a part of the porphyrites have been totally albitized. In some of the plagioclases of D 12253 more or less brownish-dusty spots are to be seen, isotropic and with a refraction, less than about 1,535: opal. The phenocrysts are idiomorphic or not. The latter are for the smaller part fragmentary crystals (crystalsplinters), for the greater part rounded-off phenocrysts. These rounded-off (in a few cases also partly resorbed) crystals owe their shape to the magmatic resorption after the crystallization of the phenocrysts and before that of the groundmass-magma. In D 12242 some plagioclases have drifted together and are grown together. In D 12247, D 12253 and D 12255 the phenocrysts are not sharply bordered on the groundmass, that is to say, the crystals of the groundmass (especially the quartzes) work in with the phenocrysts; hence, these phenocrysts probably continued to crystallize during the consolidation of the groundmass. The plagioclases more basic than albite are in general zonally built, often with recurrence-zones (repeated recurrence with resorption-effects, in most cases). The average composition of the unaltered plagioclases ranges from oligoclase to andesine, rarely to labrador. In D 12241 many very small plagioclase phenocrysts (zonal laths) occur beside bigger ones. Probably, the former represent a second generation of phenocrysts.

Hornblende phenocrysts: They are prisms of normal green hornblende. The crystals are more or less idiomorphic; rarely fragmentary, frayed, or rounded-off and partly resorbed. In D 12244 most of the hornblendes show a paramorphism into fibrous secondary hornblende. As a particularity it must be mentioned that most of the phenocrysts in D 6172 and D 12247 are surrounded by a rim of small biotite plates, which probably are primary. In accordance with the total albitization of the plagioclase phenocrysts of D 12242, D 12245, D 12251, D 12255, the hornblende phenocrysts have been totally altered, whereby the prism-shape has been more or less preserved.

Quartz phenocrysts: Some phenocrysts are still idiomorphic; most of the quartzes are strongly rounded-off and partly resorbed. D 12247 shows plagioclase and hornblende phenocrysts in a groundmass, the latter being enclosed itself in a resorption-hole of a quartz. Fragmentary phenocrysts rarely occur. By far the most of the quartzes in D 12247, D 12253 and D 12255 are not sharply bordered on the groundmass (nor the plagioclase phenocrysts in these rocks either, see above!), the crystals of the groundmass (especially the quartzes) working in with them. Probably also these phenocrysts continued to crystallize during the consolidation of the groundmass. D 12253 contains some big quartzes, which are no true phenocrysts and which enclose some plagioclases in a dioritic way; plagioclase phenocrysts probably have been enclosed here in very big quartz phenocrysts. – In D 12252 and D 12241 irregularly shaped quartz occurs enclosed in the core of a hornblende phenocryst; moreover, quartz grains can be found in the core of a plagioclase phenocryst in D 12252.

The groundmass is holocrystalline. Two kinds of groundmass-texture can be distinguished: the allotriomorphic-granulose one (here and there with affinities to the micro-granitic texture) and the pseudo-spherolitic texture.

The following types of groundmass have been observed: –D 12253: allotriomorphic-granulose groundmass of quartz and plagioclase (probably oligoclase). -D 12245: as in D 12253; the plagioclases, however, are albitic. –D 12255: as in D 12245; moreover, some chlorite probably originated from small biotite plates. –D 12252: as in D 12253; moreover small biotite plates. –D 12244: as in D 12253; moreover very small hornblende prisms (vintlitic quartz-hornblende-diorite-porphyrite). – D 6173: as in D 12253; moreover, very small biotite and chlorite plates ; ?hornblende is very rare. –D 12241: about as in D 12253; however, the one part of the groundmass, an aggregate of grainy oligoclase with a very little quartz, merges into a finer grained part which seems to consist only of dusty oligoclase; moreover, numerous very small chlorite scales occur. –D 6172, D 12247: as in D 12253; many of the plagioclases are zonal and more or less idiomorphic; nevertheless, the texture is more allotriomorphic-granulose than microgranitic. Moreover, small biotite plates. –D 12242: the groundmass is for the smaller part as that of D 12245, and consists for the greater part of radiant pseudo-spherolites (H. Rosenbusch (37) p. 353); the latter are sectors of globules, and consist alternately of fresh quartz radia and dusty albite radia; these radia branch out in an irregular way or like feathers; moreover, these pseudo-spherolites merge into granophyric intergrowths here and there. They are especially attached to quartz phenocrysts. – D 12246: as in D 12242; the pseudo-spherolites seem to be eutectic-granophyric intergrowths. -D 12251 D 12258: as in D 12242; the pseudo-spherolites are more (true pseudo-spherolites) or less (granophyric textures) regularly built.

Accessory minerals: Apatite occurs in phenocrysts and groundmass. Magnetite occurs in a varying amount. In D 12241 and D 12244 there are rather big grains, and very small ones in the groundmass; the big grains may constitute the first crystallization-phase ("phenocrysts"), and the small ones the second crystallization-phase of the magnetite material ("groundmass"). Titanomagnetite, titanite, zircon, ?primary epidote and biotite rarely can be found.

In several rocks secondary chlorite is widespread.

Hornblende-diorite-porphyrites (A 223—D 12243; A 229—D 12249; A 230—D 12250; A 234—D 12254; A 236—D 12256; A 237—D 12257; A 239—D 12259): On the whole these rocks are similar to the porphyrites with quartz phenocrysts.

The phenocrysts are plagioclases and hornblendes. In D 12250 and D 12259 the plagioclase phenocrysts are not sharply bordered on the groundmass as in some of the quartz-diorite-porphyrites.

Hornblende phenocrysts: In D 12254 a single hornblende has a rim of small biotite plates. Hence, where chlorite lies as a rim around other hornblendes or hornblende cores, it may have – at any rate partly– originated from biotite, that surrounded the hornblende. In D 12243 the phenocrysts are brownish-green, well-idiomorphic hornblendes with an ill-developed cleavage. D 12249 only contains a single, ill-preserved hornblende. In D 12257 the phenocrysts have been altered for the greater part, partly with preservation of the prism-shape. In D 12250 and D 12259 prism-shaped, irregularly shaped masses and zones of epidote and chlorite (with titanite) probably originated from hornblende phenocrysts. The chlorite is radiant-fibrous with steelblue or greenish-brownish interference-colours. There is a connection between this alteration and the alteration and the distortion-phenomena in the plagioclases of these rocks.

Groundmass: Three kinds of groundmass can be distinguished: the allotriomorphic-granulose-textured, the micro-granitic, and the pseudo-spherolitic quartz-plagioclase-groundmass.

D 12259: allotriomorphic-granulose; quartz and albitic plagioclase. —D 12256: as in D 12259, plus very small scales of chlorite. —D 12243: as in D 12259, plus numerous and very small scales of ?chlorite and ?titanite. —D 12250: the groundmass is partly as that of D 12256, and consists partly of radiant pseudo-spherolites as in the quartz-hornblende-dioriteporphyrites; these pseudo-spherolites are especially attached to plagioclase phenocrysts. —D 12257: microgranitic; more or less lath-shaped albites and allotriomorphic quartz; the former, however, are not everywhere idiomorphic with regard to the quartz- —D 12249: as in D 12257; green biotite is a common mineral, partly chloritized. —D 12254: the groundmass is partly like that of D 12249; the plagioclases, however, are probably oligoclases. Many radiant and globular pseudo-spherolites occur scattered in it; they are here and there attached to phenocrysts.

Pyrite can be found in D 12243 and D 12256.

The main difference with the above-described porphyrite-group is the lack of quartz phenocrysts. Probably, the quartz phenocrysts have been present in the magmatic phase, but could not remain as such and have been assimilated again by the liquid. At all events, quartz is abundant in the groundmass. [1])

The two ABERRANT PORPHYRITIC ROCKS are the following: D 860 presents a spherolitic quartz-porphyrite with a reddish-brown groundmass. The latter contains quartz and oligoclase phenocrysts. In one place a curious intergrowth of both kinds of phenocrysts can be seen (fig. 17). The groundmass consists of small chalcedony-spherolites, working in with each other, between which lamelled laths of acid plagioclase occur [2]). Groundmass and plagioclase phenocrysts have been strongly infiltrated by limonite.

A 228—D 12248 presents a strongly altered porphyrite, without hornblende, found just N of Santa Lucia. Sericite, epidote and chlorite occur in large masses and as irregular zones through the whole rock. The small quartz crystals of the groundmass work in with the albite phenocrysts.

VINTLITES.

Petrogenetically these rocks are transition-rocks between the diorite-porphyrites and the lamprophyric rocks.

The Aruba vintlites distinguish themselves from the Aruba diorite-porphyrites, mainly, by the smaller amount of quartz in the groundmass, by the greater development of lath-shaped plagioclases in the groundmass, and by the richness in dark minerals (especially hornblende) in the groundmass. The relation, however,

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[1]) J. H. KLOOS (25) described several (quartz-) hornblende-dioriteporphyrites, sampled by MARTIN. KLOOS abusively described the totally epidotized and chloritized hornblende phenocrysts in 117b as augite phenocrysts (p. 64); orthoclase is wanting (compare with the rock A 222—D 12242; both rocks have been sampled in the same place near Fontein).

[2]) According to H. ROSENBUSCH (37) p. 356: "Bei Verkieselung von Quarzporphyren "und Lipariten füllen sich die Grundmassen oft mit radialstrahligen Chalcedonkugeln", the original groundmass of this porphyrite seems to have been partly silicified.

between the quantities of plagioclase and hornblende phenocrysts is generally about the same in both porphyritic rocks.

The vintlites can be divided into several groups: the vintlites with plagioclase, hornblende and quartz phenocrysts; those with plagioclase and hornblende phenocrysts; those with plagioclase, hornblende and pyroxene phenocrysts; moreover, there have been found a single vintlite with plagioclase, hornblende, pyroxene and quartz phenocrysts, and a single one with hornblende, altered-pyroxene and quartz phenocrysts. – A rock will be described as well which is a transition-rock between quartz-hornblende-dioriteporphyrite and vintlite.

The groundmass of the vintlites is finegrained to aphanitic. The plagioclase phenocrysts reach a maximum size of about 15 mm, the hornblendes 19 mm, and the quartzes 7 mm.

Transition-rock between quartz-hornblende-dioriteporphyrite and vintlite (A 265—D 12264; W of Andicouri in the gabbro massive): The phenocrysts are plagioclases (andesine to labrador), less hornblendes and a very few quartzes. Here and there they have drifted together, while also flow-structures can be seen. The quartz phenocrysts are totally rounded-off. Fig. 18 shows a phenocryst with a round-bordered quartz-centre, around which the form of a slightly visible and fragmentary crystal can be distinguished. The part of this fragmentary crystal outside the round quartz-centre is mainly composed of quartz, with the same extinction as the centre; however, beside this quartz, this part contains small plagioclase laths and (less) small biotite plates, both of the groundmass, and moreover pseudo-spherolite-like parts here and there. As to this quartz crystal we can probably conclude, that the original phenocryst has been partly resorbed (unto the round central part), and that afterwards the quartz of the groundmass crystallized (together with the other groundmass components) around and with the same orientation as the quartz of the resorbed phenocryst, thus creating the fragmentary limitation in the surrounding groundmass.

fig. 17
// nicols, 27x

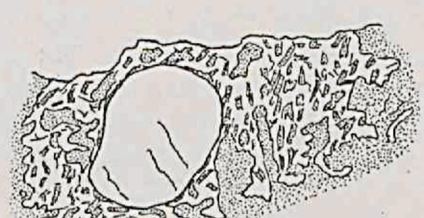
fig. 18
+ nicols, 27x


fig. 19
// nicols, 27x

The groundmass consists of small laths of plagioclase (lamelled; zonal; probably about oligoclase-andesine), very small plates of green biotite (no hornblende prisms, as in the normal vintlites!), and allotriomorphic quartz. Here and there, in the place of this quartz, the groundmass looks pseudo-spherolitic. [1]

[1] Other kinds of such transition-rocks have been described by J. H. Kloos (25). The rock (105) on p. 42 is a quartz-dioriteporphyrite, showing transitions to vintlite, found as a dike in the diorite of Seroe Colorado (SE-point of the island); beside the small biotite plates many small hornblende crystals are present in the groundmass, which is microgranitic and allotriomorphic-granulose. A similar rock (120a) has been described on p. 63, sampled by Martin near Shete; the groundmass contains plagioclase laths, hornblende (chlorite) needles and quartz.

Hornblende-quartz-vintlites (A 261 – D 12260; A 262 – D 12261; A 268 – D 12267; A 270 – D 12269; A 271 – D 12270; A 272 – D 12271; A 273 – D 12272; A 275 – D 12274; A 277 – D 12276; A 278 - D 12277): Macroscopically these rocks are porphyritic ones. In a black-grayish, or darkgrayish to dark-grayish-green groundmass feldspar phenocrysts, hornblende phenocrysts and quartz phenocrysts can be distinguished. A very thin, greenish rim can be seen around the quartzes in A 261. A small diorite fragment occurs enclosed in A 278. — Pl. III. fig. 4.

Microscopic description: The groundmass takes up much more room than the phenocrysts. In general, the relative quantity of the different phenocryst-minerals is the same as that in the quartz-dioriteporphyrites. There seems to be the following order concerning the relations between the different phenocrysts but it is of a questionable value: the more room is taken up by the phenocrysts with regard to the groundmass, the more quartz phenocrysts seem to be present with regard to plagioclase phenocrysts, in general. In D 12271 the hornblende phenocrysts can be distinguished only with difficulty from the hornblendes of the groundmass, the size of both being only a little different. Flow-structures (in D 12267 and D 12270) especially occur around phenocrysts, and clearly manifest themselves by means of the small hornblendes of the groundmass.

Plagioclase phenocrysts: As to alteration, albitization, shape, resorption, zonal structures and composition the plagioclases generally agree with those of the quartz-hornblende-dioriteporphyrites; the composition may be somewhat more basic, the original average running from oligoclase to labrador. A very few plagioclases of D 12270 contain numerous microlites in their cores. The strongly rounded-off crystals in D 12269 possess dusty rims (resorption effect). The more acid peripheric zones of the phenocrysts in D 12270 are not sharply bordered on the groundmass; the hornblendes of the latter stick in these zones.

Hornblende phenocrysts: In so far as not altered, the hornblende is the common green one; some of the crystals in D 12269 possess a periphery, which is a little darker green than the central part; yet, the whole crystal has one and the same extinction. The phenocrysts are idiomorphic prisms, rarely rounded-off. Those in D 12277 are not sharply bordered on the groundmass. In D 12267 and D 12272 phenocrysts occur with a rim of small groundmass hornblendes, and with many epidote grains in the close neighbourhood.

Hornblendes in several rocks have been partly or totally altered into chlorite, fibrous secondary hornblende (in D 12277 together with numerous quartz-bubbles) and epidote. Many of them show a composed alteration. There is a connection between the alteration of the hornblendes and that of the plagioclase phenocrysts. The possibility remains, that – at any rate partly – the secondary hornblende originated from (is pseudomorphic after) pyroxene and can be called uralite. This possibility, however, is very small, taking into consideration the total absence of fresh pyroxene and the hornblende-shape of the altered crystals.

Quartz phenocrysts. D 12260, D 12261, D 12267, D 12269, D 12271, D 12274, D 12276: The quartzes are for the greater part rounded-off crystals, for a very small part quite round or roundish ones; some even show resorption-holes. A small, idiomorphic hornblende (?phenocryst) seems to be enclosed in the quartz of D 12276.

Reaction-rims: *a*) D 12267, D 12269, D 12271 and D 12274 show narrow hornblende reactionrims around the quartzes. In the DD with more than one quartz, only part of the quartzes have such a rim. The rims are composed of bundles of very small and thin hornblende needles; these bundles lie in the quartz substance or stick partly in it. A single quartz in D 12269 possesses a rim of chlorite, which may be altered hornblende. – *b*) D 12260, D 12261 and D 12276. D 12276: a single quartz with a reactionrim (fig. 19), composed of epidote grains, with here and there a little chlorite. D 12260, D 12261: the rims around the quartzes are composed of small prisms and needles of monoclinic pyroxene (also of epidote or of hornblende?) in bundles and sheaves. Some chlorite (and calcite in D 12260) is present as well. The crystals of pyroxene lie in the peripheric part of the quartz, or stick in the quartz substance.

In D 12270, D 12272, D 12277 the quartzes are non-idiomorphic, round, or rounded-off and semi-resorbed, and consist of several small quartz individuals. Fluid-inclusions in planes occur in several of them. The quartzes of D 12277 are not round, and rims are wanting; the crystals are not sharply bordered on the groundmass (see also its hornblendes). No true reactionrim can be found in D 12270 and D 12272; the small hornblende crystals of the groundmass, however, more or less occur as a rim around the quartzes. The rim is wanting around some quartzes in D 12270; there, the crystals of the groundmass stick in the quartz with their free ends.

The groundmass consists of small laths of plagioclase, of small prisms of green hornblende, between which more or less allotriomorphic quartz occurs. In most of the rocks the plagioclases are lamelled and simply zonal. Their original composition varies from oligoclase to andesine. Part of the hornblendes are twinned, in so far as not altered. The groundmass in D 12277 is very rich in quartz . Quartz seems to be wanting in the groundmass of D 12261. In that of D 12270, beside the hornblendes, many very small biotite plates occur, partly chloritized. Many small grains of epidote occur scattered in the groundmass of several rocks. In the groundmass of D 12260 and D 12261 monoclinic pyroxenes also are present (compare with the pyroxene rims around the quartzes!).

Accessory minerals: Apatite especially occurs in the groundmass. The magnetite generally occurs as a few bigger grains and as many diminutive ones (compare respectively with phenocrysts and second generation); here and there the grains have a narrow rim of epidote. Titanite rarely occurs, as grains or in strings.

Secondary chlorite, together with epidote or not, occurs in some rocks.

The hornblende-quartz-vintlites, described here, have been found exclusively in the diorite batholith.

Hornblende-vintlites (A 263—D 12262; A 264—D 12263; A 269—D 12268; A 276—D 12275): On the whole, these vintlites are similar to the hornblende-quartz-vintlites, except in the lack of quartz phenocrysts. The original, average composition of the plagioclase phenocrysts is more basic than that of the quartz-hornblende-dioriteporphyrite plagioclases and runs from oligoclase to labrador. In D 12263 the phenocrysts are not sharply bordered on the groundmass. – The hornblende phenocrysts in D 12263 have been altered into chlorite, in which many small plates of browngreen biotite occur. Some in D 12262 and D 12263 contain in their cores a diopsidic pyroxene; the latter may be strongly limonitized and may be partly twinned. Hornblende and pyroxene seem to be in intergrowth here. – The groundmass of D 12263 contains among the normal constituents small epidote grains and, here and there, small browngreen biotite plates (see also above). – D 12262 contains a very few grains of pyrite. — Pl. III. fig. 3.

The vintlites described here are limited to the very northern part of the island. It is noteworthy that A 263—D 12262 (Seroe Grandi) and A 264—D 12263 (near Druif), both with a small amount of diopsidic augite, occur in basic diorites and gabbroic rocks. A 269—D 12268 sampled in the amphibolites at the foot of Annaboei does not contain any pyroxene. A 276—D 12275 has been found NE of Salinja Cerka. – A non-described hornblende-vintlite A 427—D 12512 has been sampled in the older rocks S of Andicouri.

As in the hornblende-dioriteporphyrites quartz phenocrysts could not continue to exist in these vintlites; at least, if they did come into existence in a beginning-phase of the magma crystallization.

Hornblende-augite-vintlites (A 274—D 12273; A 279—D 12278; A 280—D 12279; A 281—D 12280): These rocks show similar properties as the hornblende-quartz-vintlites. – The groundmass takes up more room than or as much room as the phenocrysts. The latter are plagioclases, hornblendes and pyroxenes. The quantities of plagioclase and hornblende-pyroxene are about the same; or more ferromagnesian phenocrysts occur than plagioclase phenocrysts; the latter, however, are the bigger crystals, the former the smaller ones.

The plagioclase phenocrysts have the same shape and zonal structure as those of the quartz-hornblende-dioriteporphyrites. The crystals of D 12279, however, are lath-shaped. The original composition is more basic than that of the porphyrite plagioclases, and runs from andesine to labrador-bytownite.

Pyroxene phenocrysts are present in about the same amount as the hornblende phenocrysts, in D 12278. They are partly idiomorphic (short prisms), partly rounded-off (resorbed), here and there fragmentary. The pyroxenes are very palegreen to nearly colourless diopsidic augites, some of which are twinned. Quite-unaltered pyroxenes are wanting in D 12279.

Pyroxene and secondary hornblende. D 12273, D 12278, D 12279: Several pyroxenes possess a more or less regular rim of hornblende and are "intergrown" with hornblende. Probably these pyroxenes are partly uralitized, the hornblende material occurring along the fissures of the pyroxene and being not sharply bordered on it. However, some pyroxene-hornblende crystals may be primary intergrowths. The hornblende (secondary or primary) in and around the pyroxene is here and there chloritized. In D 12273 some crystals with chloritized hornblende in the pyroxene and still-preserved hornblende around it are present. - D 12273, D 12279, D 12280: Part of the pyroxenes have been quite uralitized, whereby the prism-shape has been preserved; the secondary hornblende is fibrous, and is partly chloritized. There is, however, a possibility, that some of these secondary hornblendes have originated from primary hornblendes, taking into consideration the forms and the presence of this secondary hornblende next to fresh pyroxenes. In D 12273 there can also be found irregular masses of hornblende fibres, chlorite, some calcite and epidote, which masses probably owe their existence to pyroxenes.

The groundmass is on the whole similar to that of the hornblende-quartz-vintlites, but is poor in quartz. Small pyroxene prisms occur in D 12280, perhaps also in D 12273. Orthoclase may be present in the groundmass of D 12280. Moreover, in that of D 12273, D 12278 and D 12279 small calcite plates and epidote grains occur. Magnetite is accessory.

These hornblende-augite-vintlites (without quartz phenocrysts) only have been found in the diabase-schist formation in the central part of the island, and especially in a region W of Boca Prins; A 281—D 12280 has been found near and W of Boca Prins, the other three rocks occur about 2 km. W of this Boca.

A 279, hornblende-augite-vintlite, has been collected as a "Salband" sample of a quartz-hornblende-dioriteporphyrite (A 238—D 12258) dike. The fact that the pyroxene phenocrysts only are present in the "Salband" of this dioriteporphyrite-vintlite dike, is interesting in connection with an observation of v. Foullon with regard to the pyroxene-vintlites, quoted by H. Rosenbusch (36) p. 561: "Interessant ist die Beobachtung v. Foullon's, dass "in den pyroxenführenden Gängen die Diopside nach den Salbändern hin sich anreichern". - A 280, hornblende-augite-vintlite, too occurs as a "Salband" of a dioriteporphyrite dike in the diabase (very finegrained uralitized diabase) which has been invaded by narrow veins.

The following rock A 428—D 12513, occurring on the Seroe Kabaai, must probably be reckoned among this hornblende-augite-vintlite group, although it does no more show pyroxene as such. The hornblende-pyroxene phenocrysts, in about the same amount as the albitized plagioclases, have been quite changed into an aggregate of green, cleaved hornblende. The prism-shape has been preserved, and some of the original crystals have conformed to the plagioclases. In several of these phenocrysts a narrow hornblende rim is undivided and has one and the same extinction, so that these phenocrysts may have represented hornblendes, which were intergrown with pyroxene in the core; this pyroxene must have been altered into secondary hornblende. The granular groundmass consists of albite, hornblende, biotite and quartz.

A similar rock has been abusively described as an uralite-diabase by J. H. Kloos (25) on p. 59. This rock 120c, sampled by Martin near Shete, shows plagioclase and hornblende phenocrysts in a groundmass of small plagioclase laths, hornblende prisms and needles, allotriomorphic quartz and ore. Some of the hornblende phenocrysts are undivided, frayed and contain small quartz-bubbles; many of them are prism-shaped hornblende aggregates with small quartz-bubbles.

Hornblende-augite-quartz-vintlite (A267—D12266): The normally vintlitic groundmass contains many phenocrysts, which are plagioclases, hornblendes, a few pyroxenes and a few quartzes. The plagioclase phenocrysts are andesine to labrador ; a single one must be labrador-bytownite. The hornblende phenocrysts are partly or wholly altered. The pyroxene phenocrysts are small diopsidic ones with a narrow rim of hornblende. The pyroxenes and the groundmass in the close neighbourhood are rather strongly limonitized. The quartz phenocrysts are round or rounded-off quartzes. A single one of them possesses arim of small hornblende prisms, which are grouped more or less sheaf-like, and which stick in the quartz substance with their free ends (reactionrim).

This vintlite, containing both pyroxene and quartz phenocrysts, has been found about a kilometer S of Andicouri, in the diabase-schist formation, but not so very far from the contact with the diorite batholith.

HORNBLENDE-PYROXENE-QUARTZ-VINTLITE, WITHOUT TRUE PLAGIOCLASE PHENOCRYSTS (A 429—D 12514): The phenocrysts are hornblendes, secondary hornblendes (altered pyroxene) and quartzes. Plagioclase phenocrysts, if present, cannot be distinguished from the groundmass plagioclases. The hornblende phenocrysts are for the smaller part normal, lightgreen hornblendes. Most of them however are composed of secondary hornblende, which is very probably pseudomorphic after pyroxene; this secondary hornblende occurs in idiomorphic or idiomorphic-rounded-off crystals, and is very lightgreen (at the very peripheric border darker green) and diverse-fibrous. This secondary hornblende is partly chloritized. Where this hornblende and the hornblendes of the groundmass border on each other, it is very difficult to distinguish them from each other. In several of these pseudomorphic hornblendes grains of titanite and magnetite occur, which probably have to do something with the pyroxene alteration. Quartz phenocrysts occur many times as round or rounded-off crystals. No reactionrims occur, but the hornblendes of the groundmass here and there conformed to and around the quartzes; some of these hornblende needles even stick in the quartz substance. The groundmass is normally vintlitic.

This vintlite containing altered-pyroxene and quartz phenocrysts occurs in the gabbro-massive of the Matividiri, on the southern slope of this mountain.

CONSIDERATION ON THE NATURE OF THE QUARTZ PHENOCRYSTS IN THE VINTLITIC ROCKS.

Many of the quartz phenocrysts in the vintlites possess remarkable reactionrims of hornblende (or pyroxene), whereas the quartz crystals of the porphyrites do not show such rims. Moreover, the quartzes in the vintlites are strongly rounded-off.

H. ROSENBUSCH (36) writes about vintlite quartzes on p. 560: ,,Wo Quarz ,,einsprenglingsartig sich noch findet, zeigt er die Form von gerundeten Körnern, ,,die sich oft durch Kränze von Amphibol oder Pyroxen als Fremdlinge aus- ,,weisen . . .". G. J. H. MOLENGRAAFF (31) has found in some of the vintlite-rocks of Curaçao similar quartz crystals with hornblende-rims. He too considers these crystals xenocrysts (enclosures), which do not belong to the vintlite magma and have been taken up from elsewhere: (p. 45) ,,In navolging van H. ROSENBUSCH ,,neem ik aan, dat deze kwartskristallen niet uit het magma afkomstig zijn. De ,,kwarts is door het magma opgenomen."

However, the above-mentioned statements about the xenocrystic nature of the big vintlite quartzes do not seem to hold good with regard to the quartz-vintlites of Aruba nor with regard to those of Curaçao either.

The quartz phenocrysts of the quartz-diorite-porphyrites are idiomorphic or have been more or less rounded-off and resorbed by magmatic resorption-action. The quartzes of the quartz-vintlites are all rounded-off crystals or roundish grains. – Many of the quartzes in the porphyrites contain fluid-inclusions, arranged along planes. Also several quartzes of the vintlites contain such fluid-inclusions. – Undulose extinction can be seen in part of the quartzes of both kinds of rock. – The quartzes in both rocks are rather irregularly distributed in one and the same rock and also in the different rocks. – The quartzes of the diorite-porphyrites are sharply bordered on the groundmass or not, but do not possess reactionrims. Many quartzes of the vintlites have well- or ill-developed reactionrims of hornblende (pyroxene, epidote, chlorite).

So, if we compare the quartzes in both kinds of rock, we see distinct similarities and also differences; the vintlites have a lack of idiomorphic crystals, the porphyrites have no crystals with reactionrims. On these differences ROSENBUSCH and with him G. J. H. MOLENGRAAFF have founded their opinion that the vintlite quartzes are xenocrysts. – However, why should only special vintlite magmas take up exogenic quartz crystals, whereas other vintlites and diorite-porphyrites, closely related to them and occurring in the same places, do not possess those xenocrysts?! If we accept that the quartzes in the vintlites are of an exogenic nature, we must also accept that, at least some of the quartzes of the diorite-porphyrites are equally exogenic. However, if we accept – and this may be done with reason – that the quartz-diorite magma produced dike-magmas of the composition of quartz-dioriteporphyrites and quartz-vintlites, and of dioriteporphyrites and vintlites (without quartz developing into phenocrysts), there is no reason why the quartz-vintlites could not have true quartz phenocrysts. – The lamprophyric dike-rocks, which have the same occurrence as the vintlites, and which are also closely related to them, do not contain big quartz crystals (but for a single exception). If the vintlite quartzes were xenocrysts, why should not the lamprophyric rocks contain such xenocrysts too?!

Hence, we come to the conclusion that the big and undivided quartz crystals of the vintlites are true phenocrysts as in the dioriteporphyrites. The reason that they have been more resorbed than the porphyrite-quartzes and that many of them possess reactionrims must be sought in the difference of magmatic action in the more acid groundmass-liquid of the porphyrites and the less acid groundmass-liquid of the vintlites. Concerning the genesis of the reactionrim, see f.i. F. BECKE (4) and O. H. ERDMANNSDÖRFFER (18) [1].

Many of the vintlite quartzes have well-developed reactionrims of hornblende-material, rarely of pyroxene, epidote or chlorite. Others are more or less surrounded by the small hornblende crystals of the groundmass. Also quartzes occur without rims (see also the strange quartz phenocryst in the transition-rock A 265—D 12264, on p. 71). Moreover, it is very peculiar that hornblende pheno-

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[1]) p. 273 (Relikte): "Wo ein Mineral an sich noch im Bereiche seines Existenzfeldes "liegt, aber in seiner Paragenese mit benachbarten Mineralien ein instabiles System darstellt, "kann es gleichwohl als "instabiles Relikt" in die neue Paragenese hinübergerettet werden. "Dies geschieht durch die Entwickelung eines Reaktionssaumes, der die "nichtkongressiblen" "(d.h. in direkter Berührung nicht bestandfähigen) Phasen trennt, aber selbst mit dem um-"schlossenen Relikt und den es umschliessenden Mineralien im Gleichgewicht steht ("Ge-"panzerte Relikte" im Sinne von ESKOLA)".

crysts of the hornblende-quartz-vintlites D 12267 and D 12272 possess a rim of small hornblende crystals of the groundmass (see p. 72).

As to the rounded-off quartzes of the hornblende-quartz-vintlites D 12270, D 12272 and D 12277, which consist of several small quartz individuals and which in D 12270 and D 12272 have a kind of rim of small groundmass hornblendes (see p. 72), we may better accept that these quartzes have been taken up as xenocrysts (from the diorite!?) and have been resorbed and corroded by the vintlite magma. At least, it seems difficult to recognize these composed quartz individuals as phenocrystic elements.

The sample A 219, found near Alto Vista, is a dioriteporphyrite, which contains a very big, rounded-off quartz fragment; it may be considered as an exogenic inclusion, taken up from the country-rock (diorite!?).

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE PORPHYRITIC ROCKS.

The very long and large dikes can be seen in the geological map; many dikes, however, have not been indicated.

As has been mentioned above, the bulk of the porphyritic rocks occur as common dikes with nearly or quite parallel walls and with a length which is considerably greater than the width. However, also dikes occur which have more neck- or pipe-shape; the latter present themselves here and there as accumulations of big blocks (monoliths; compare with the diorite), in consequence of selective weathering. – Here and there the contact between the diorite and the porphyritic rocks is very clear; some dikes even enclose fragments of this plutonic rock

Some of the dikes in the older formation are clearly dioritic in the centre and become more porphyritic in the ,,Salband". Such forms have not been found in the diorites; they are due to the quickness of magma-cooling, which must have been greater in the older rocks than in the batholith itself.

SE of Seroe di Poos di Noord a hornblende-quartz-vintlite dike ends against a quartz-hornblende-dioriteporphyrite dike of 18m. wide; so here the dioriteporphyrite dike is probably the older one. N of Salinja Cerka a vintlite dike cuts through a granite dike and must be younger.

Some dikes have the length of about 1 km. or more, others have the length of some hundred meters (see the map) and many are less than 100 m. to only a few meters long. The width is also very different. The long dikes are rather wide. Widths of 20—40 meters could be measured at dikes near, E and N of Alto Vista. Many dikes have a width of about 10m. or more than 10m; such dikes especially occur in the gabbro-massive of the Matividiri. Also many dikes have a width of 1—10 m, whereas only a few of them are less than 1m. wide (the narrowest dike which has been measured has a width of 3—4 dm.).

The dikes have different strikes, although strikes which do not differ so much from the E—W direction prevail (see the map and diagram fig. 20). The bulk of the dikes are vertical or almost vertical. Some of the dikes are less steep and their dips could be measured; most of the dips lie between 45° and 90°, only a few

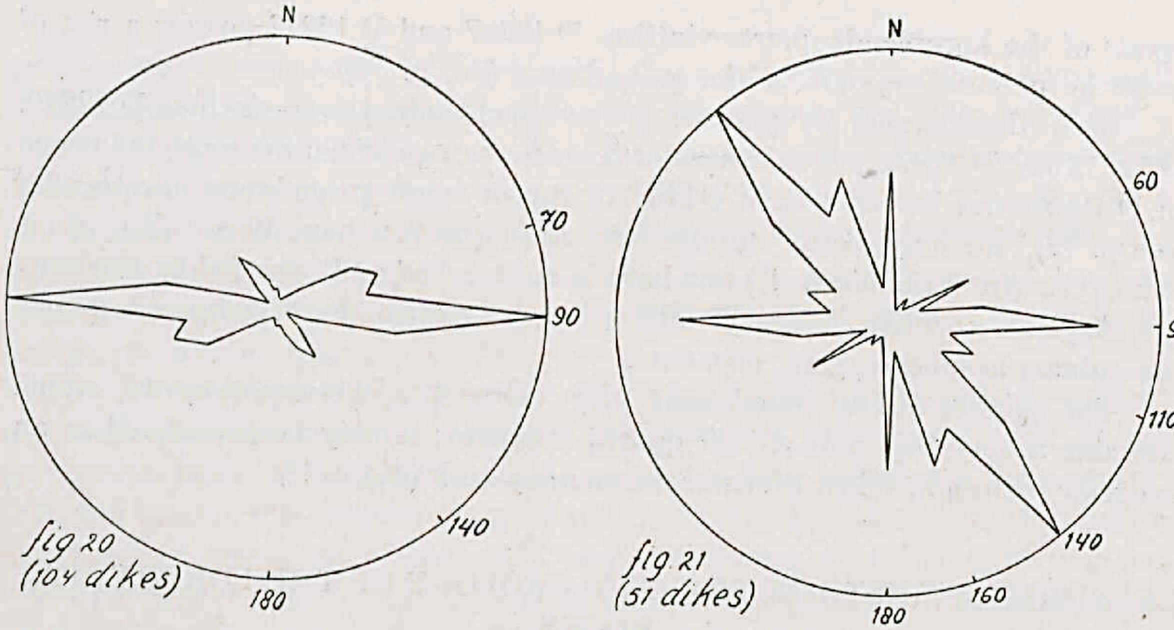

fig 20 (104 dikes)

fig 21 (51 dikes)

of them are less (f.i. 20°). – A few dikes in the hornblende-schists (metamorphic tuffs) of the upper-course of Rooi Prins (near Juditi) lie quite conformably in these schists.

Some of the dikes have been faulted after their consolidation. F.i. the enormous porphyrite dike, E of Alto Vista and N 150 E, has been cut through by a hornblende-dioriteporphyrite dike (N 70 E) and has been removed 10 meters south-west-ward. The hornblende-vintlite dike, SE of Druif (N-Aruba, see map), has been faulted in two places. Hence, not only the diorites but also the porphyrites have been submitted to orogenic movements after their consolidation (compare with the undulose quartz phenocrysts and other minerals).

It is a very remarkable fact that the bulk of the porphyrites and vintlites occur in a zone along the N- (NE-) coast, 2—3 km. wide (see map). This zone is bordered to the S and the SW about by a line which can be drawn from NW to SE across Malmok – Salinja Cerka – Turibana – Jaburibari – Zumbo – Seroe Pretoe – Arikok – Juditi – Butucoe – Rincon. Still, dioriteporphyrites and vintlites have been found in a small number S and SW of this line. Most of these dikes do even occur not so very far from this line, that is to say, they occur in the NW—SE central zone of the island and especially in the central part of this zone. It is remarkable that porphyritic rocks are lacking in the large diorite outcrop N of Savaneta, as far as is known. In the easternmost, large diorite outcrop only two porphyritic rocks have been found, that is to say, a hornblende-diorite-porphyrite 1,5 km. W of Boca Grandi and an ?epidotized porphyrite NW of Seroe Grandi. The southern- and southwesternmost porphyritic rocks, as far as is known, are a vintlite NE of Spaansch Lagoen, a dioriteporphyrite near Nanki (near Seroe Colorado) and a quartz-dioriteporphyrite, transitional into vintlite, on the Seroe Colorado (Martin 105).

Probably, this special distribution has something to do with the situation in the batholith; the highest parts in the batholith probably contain the greatest number of porphyritic dike-rocks, and these highest parts probably occur along the N- and NE-coast and under the older rock mountains. – As far as can be seen, there is a connection between the presence of pyroxene in the vintlites and the occurrence of these vintlites in the older diabasic series or in the gabbroic rocks of the batholith; the composition of the dike-magmas may have been a little altered by addition of material out of the latter rocks.

LAMPROPHYRIC DIKE-ROCKS.

This kind of rocks occurs as dikes, mainly in the batholith and rarely in the older rocks. They can be considered as differentiates of the dioritic magma, which are younger than the porphyritic dike-rocks and which differ much more from the diorite than these porphyritic rocks do. Yet, transitional rock-phases have been found, that is to say, between the vintlites and the malchites; some malchites even have a somewhat dioritic character. Beside malchites, a few spessartites and odinites have been found.

In the field these rocks can be clearly distinguished from the invaded batholithic rocks, on account of the shape in which they occur and on account of their colour and granularity. It is, however, rather difficult to detect them in the rocks of the older formation.

MALCHITES.

Most of the malchites, described here, are normal malchites. Besides, there will be described a malchite in contact with diorite, three aberrant malchite-rocks (one of them in contact with diorite), a dioritic malchite, a biotite-malchite, a pyroxene-malchite without quartz, a vintlitic pyroxene-malchite, and an epidotized and chloritized ?malchite.

Normal Malchites (A 293—D 12302; A 295—D 12304; A 296—D 12305; A 383—D 12342; A 384—D 12343; A 431—D 12516; A 432—D 12517; A 433—D 12518; P 74—D 6169; P 75—D 6170; P 105—D 6179; P 105a—D 6179; P 71—D 6541): Macroscopically they are aphanitic to finegrained, generally darkcoloured (black-grayish or dark-grayish; rarely greenish). Bigger crystals of hornblende can be distinguished here and there. Small diorite fragments occur enclosed in A 295 and A 296.

Microscopic description: The rock consists mainly of plagioclase, hornblende and quartz. In most of the rocks the plagioclase takes up about as much room as or a little more room than the hornblende; it must be mentioned, that in most of these rocks (an exception is D 12343) much or rather much quartz occurs. In a few rocks (D 12304, D 12516, D 12517), however, the hornblende takes up more room than the plagioclase; it is striking, that these rocks contain only a little or very little quartz. A few plagioclase phenocrysts can be seen in DD 6179. Hornblende phenocrysts in D 12304, scattered or in groups, are idiomorphic with regard to the "groundmass" or not; some of them contain epidote and have partly been altered into a fibrous chlorite. D 12342 contains several phenocrystic hornblendes and plagioclases. Flow-structures, particularly manifested by the small hornblende crystals, can be seen in D 6541 and in D 12342. In some rocks the distribution of the hornblendes is not quite a regular one, and in others the hornblendes occur in small groups here and there. In D 12517 a streak, composed of small fibrous hornblende prisms which lie roughly parallel, is very curious.

Plagioclase: It is particularly striking, that in the rocks with much or rather much quartz the plagioclases are not idiomorphic with regard to the quartz. On the other hand, the plagioclases of the rocks with only a little quartz (D 12304, D 12516, D 12343; labrador-bytownite to oligoclase-andesine) are idiomorphic with regard to the quartz; these plagioclases are small laths or short prismatic crystals. As to D 12517, its quartz only occurs in nests; its oligoclases occur as very small grains between the numerous accumulated hornblende crystals. D 12305, D 12342, DD 6179, D 6169, D 6170: the plagioclases are lath-shaped or prismatic bytownites to labrador-bytownites; nevertheless they are not quite idiomorphic with regard to the quartz; plagioclase-border and quartz work in with each other. Especially in D 12305 the plagioclase-borders and the quartzes very intensively work in with each other, so that here and there "drops" of plagioclase seem to occur enclosed in the quartz, close to the plagioclase crystals. Probably, the plagioclase began to crystallize; after that the quartz; these minerals must have stopped their growth against each other at the same time; the final crystallization must have had a more or less eutectic character. – D 12302, D 6541: the plagioclases are more isometric-granulose than lath-shaped labrador-bytownites, and work in with the quartzes; D 12302 shows plagioclase "drops" in the quartz. The albite-oligoclases in D 12518 are but here and there prismatic, and particularly occur in granophyric-micrographic intergrowth with quartz. Only plagioclases in D 12304, D 12516 and D 12343 (rocks with a little quartz!) are simply zonal. Most of the rocks contain many grains of epidote, zoisite and titanite, scattered in and around the plagioclases.

The hornblende is on the whole the common green one; it is rarely brownish-green. In D 12302 and D 12304 hornblendes occur with darkergreen and brown-green cores. The hornblendes are prism-shaped, but do not show a good idiomorphism; they often have a frayed habit (especially terminally frayed). The prisms are short or long and slender, even needle-shaped. Concerning the relation between hornblende and plagioclase, they border on each other in an irregular way. However, the small hornblende prisms in D 12305 are rather idiomorphic with regard to the plagioclase, whereas on the contrary, many small plagioclase laths in D 12304 are idiomorphic with regard to the hornblende (sub-ophitic). As to the relation of hornblende to quartz, the crystallization of the two minerals in the malchites with much or rather much quartz must have occurred, in general, at about the same time (compare with the relation plagioclase-quartz and plagioclase-hornblende). In D 12305 the hornblendes are rather idiomorphic with regard to both plagioclase and quartz. In D 12516 and D 12343 (with a little quartz) both plagioclase and hornblende are idiomorphic with regard to the quartz. In D 12304 (with a little quartz), however, plagioclase is idiomorphic with regard to both hornblende and quartz. Some hornblendes are fibrously altered. Some of the hornblendes in D 12302 and D 6179—P 105 include small quartz-bubbles.

Quartz: As to the occurrence of the quartz in the different malchites, see the relations between plagioclase and quartz, and between hornblende and quartz. The quartz in D 12517 only occurs in roundish or eggshaped nests, not sharply bordered and consisting of granular quartz or of quartz and plagioclase. There occur in D 6541 some bigger, eggshaped quartz crystals, surrounded by small hornblende crystals: exogenic inclusions?

Accessory minerals: Except in a few rocks apatite occurs as small needles. Magnetite can be found as rare and diminutive grains; as a few grains, bigger and smaller ones; and as many diminutive grains. Titanite occurs as small grains or crystals in many rocks. In D 6179—P 105 many epidote grains and a few pyrite grains (with a limonite rim) occur along limonite fissures.

A 751—D 13058 is a biotite-bearing malchite, occurring near Seroe Janchi. The bigger hornblendes lie mostly in groups, between which the smaller ones are scattered. Biotite, of minor importance, occurs as small greenbrown plates. The composition of the plagioclase is about oligoclase-andesine.

The malchites described here occur by far the greatest part as dikes in the diorite batholith (W of the diabase-schist-region). Some rocks occur as dikes in hooibergite-massives: P 105 and P 105*a* in the Hooiberg-massive, A 383 in the Turibana-massive and A 384 in the Seroe

Pretoe-massive (E of Hooiberg). Only one rock has been found in the older formation near Spaansch Lagoen.

Malchite in contact with normal quartz-hornblende-diorite (A 291—D 12300; 0,5 km. W of Seroe di Poos di Noord): The malchite-rock is sharply bordered on the diorite. There is no transition between the diorite and the malchite; on the other hand, the plagioclases of the diorite have a dead end against the malchite dike, and have partly been resorbed by the malchite magma, so that these plagioclases are irregularly bordered on the dike-rock. Small apophyses of the malchite occur between the crystals of the diorite. A very fine flow-structure is manifested by many small and lath-shaped phenocrysts, that lie parallel. Flow-structures in miniature occur around the diorite plagioclases, at the border of the dike. The malchite is porphyritic; its groundmass takes up more room than the phenocrysts. The latter are plagioclases and hornblendes, both probably in the same quantity. – Pl. III. fig. 5.

The plagioclase phenocrysts are lath-shaped, here and there slightly zonal labrador-bytownites. The hornblende phenocrysts are long, lightgreen prisms. Moreover there occur some bigger and more isometric plagioclases and hornblendes, that are quite idiomorphic, and, on the whole, do not show resorption-holes. These crystals may be assimilated crystals of the diorite, but probably they belong to the normal phenocrysts of the malchite.

A zone of the groundmass along the border of the dike, about 1,5 mm broad, is almost aphanitic, and merges into the somewhat more grainy, normal malchite, farther from the diorite-contact. The groundmass of the "Salband" looks grayish-brown and glassy, and merges into the crystalline groundmass of the central parts. The latter consists of a felt-like mass of very small hornblende needles, in which also occurs some ?plagioclase and ?quartz. Magnetite occurs as numerous diminutive grains, scattered in the groundmass; the "Salband" is very rich in ore.

Secondary minerals: a narrow vein mainly consists of chlorite, and also contains a little ore; it is a remarkable fact, that some hornblende phenocrysts bridge over this vein, and also groundmass-hornblendes occur in and between the chlorite. Hence, this vein seems to be no true vein, but a zone of infiltration.

An aberrant malchite (A 292—D 12301) has been sampled near Unja Unja, in the diorite outcrop N of Savaneta. The main components are oligoclase-andesine, hornblende and quartz; the latter occurs but in a small amount. The small laths of plagioclase are idiomorphic with regard to the quartz and are especially composed to sheaf-like groups; some of the plagioclases are zonal. Brownish-green hornblendes, some of which with darker cores or with darker peripheric zones, are more or less idiomorphic prisms; a single hornblende shows a zonal extinction. Non-idiomorphic plates of chlorite seem to have originated from ?biotite, but are of a minor importance. A little calcite must be secondary. – This malchite is mainly aberrant in the occurrence of the plagioclases and in the character of the hornblende.

The aberrant malchite A 294—D 12303, sampled S of Seroe Tres Kabees, is very rich in hornblende, and contains more hornblende than plagioclase. In connection herewith the quartz is very rare and occurs in nests. The plagioclase crystals, albites, albite-oligoclases, occur as granular individuals between the many hornblendes. The hornblende occurs in the first place as small, brownish-green prisms, which are rather idiomorphic; and, secondly, as bigger, green and fibrous crystals, non-idiomorphic. Small hornblende needles (secondary hornblende), lying in sheaf-like bundles, radiate into veins of epidote. – This malchite is aberrant because of its richness in hornblende and because of the special occurrence of this mineral.

A 324—D 12316 is an aberrant malchite, as a dike in quartz-hornblende-diorite on the Seroe Pretoe, E of the Hooiberg; the latter rock forms a dike in hooibergite-rock. Microscopically the crystals of the diorite and the malchite normally work in with and between each other, so that the intrusion must have taken place at a time when the diorite was not yet quite consolidated. – Quartz is only present in a very small amount and rather locally.

The plagioclase is most important and occurs as grainy crystals of albite-oligoclase showing a tendency to the lath-shape. The hornblende occurs: 1. as long and slender prisms, not everywhere quite idiomorphic, and especially arranged in several star-shaped aggregates; 2. as some aggregates, composed of more isometric, non-idiomorphic crystals. Small brown and green biotite plates and some chlorite are present here and there. Numberless diminutive apatite needles and rods lie in the plagioclase. Some rather big grains of titanite are allotriomorphic with regard to plagioclase laths. Small cubes of magnetite. – This malchite is mainly aberrant in the relation plagioclase-quartz, in the occurrence of the hornblende and in the presence of biotite.

The DIORITIC MALCHITE A 300—D 12309 has been found S of Kudawecha, and contains an inclusion of quartz-hornblende-diorite. This malchite has partly a hypidiomorphic-granulose texture, and consists of plagioclase, hornblende and quartz. The plagioclases, labrador-bytownites to bytownites, show a lath-shaped development, and are partly idiomorphic with regard to the quartz; many plagioclases, however, work in with the quartz at their borders; here and there very intensively, so that the plagioclase occurs as small "drops" in the quartz (no resorption-effects). The hornblende is the normal one; some crystals possess a periphery, which is darkergreen than the core. The crystals are non-idiomorphic and especially occur in groups. Some hornblendes contain quartz-bubbles. The quartz contains fluid-inclusions in planes. Many small apatites can be seen, especially in the quartz. Titanite, magnetite and a single pyrite crystal are accessory. – The dioritic character of this malchite can be seen in the texture, in the rather great richness in quartz and in the occurrence of fluid-inclusions in the quartz.

A 297—D 12306, W of the Hooiberg, is a BIOTITE-MALCHITE. It mainly consists of plagioclase, hornblende and biotite; quartz is of a minor importance; moreover, epidote is very abundant as small grains. Flow-structures. Both plagioclase and hornblende have partly developed as phenocrysts. The plagioclase phenocrysts have been almost wholly changed, amongst others into a yellowish, almost isotropic substance, and are idiomorphic and prismatic. The hornblende phenocrysts are small and short prisms. The small plagioclases are laths and prisms, especially zonal oligoclase-andesines to andesines. Small prism-shaped hornblendes are only a little different from the phenocrysts. Very small and brown biotite plates occur as separate crystals or in strings; part of the hornblendes join these strings. Probably, the biotite material takes up more room than the hornblende material. It is not probable that the biotite is secondary.

A PYROXENE-MALCHITE, WITHOUT QUARTZ (A 299—D 12308), N of the Jaburibari, consists of hornblende (the most important mineral), plagioclase, and pyroxene (a little). The plagioclase crystals occur more or less as laths between the hornblendes (sub-ophitic texture). They are slightly zonal labrador-bytownites; a single one even shows recurrence. The hornblendes are bigger or smaller crystals. The latter are, firstly, brown-green with a green rim (some of which even possess a zonal extinction) and with a rather good idiomorphism; secondly, lightgreen, more fibrous (secondary hornblende? !); both kinds of hornblende merge (!). The bigger crystals, which are no true phenocrysts, are non-idiomorphic, very lightgreen; some of them contain a diopsidic augite in their core. Part of the lightgreen hornblendes may be uralite after pyroxene.

N of Alto Vista a dike-rock has been found, which probably represents one of the transitional rocks between the vintlites and the malchites: VINTLITIC PYROXENE- MALCHITE (A 298—D 12307). The groundmass takes up more room than the phenocrysts; the latter mainly are hornblendes, less altered-?plagioclases and a few pyroxenes (in groups). ?Plagioclase phenocrysts have quite changed into epidote, with preservation of the original, non-idiomorphic shape. The hornblende phenocrysts are idiomorphic or rounded-off. Some of them are fibrous. A single one contains pyroxene in its core (partly uralitized pyroxene?). The pyroxene phenocrysts are non-idiomorphic diopsidic augites. Groundmass: A felt-like mass of small hornblende prisms, needles and fibres, with lath-shaped oligoclase-andesines to andesines and quartz. Here and there more or less eggshaped quartz nests can be found, not sharply bordered ont the groundmass.

A strongly altered lamprophyric rock, N of Salinja Cerka, is an EPIDOTIZED AND CHLORITIZED ?MALCHITE (A 301—D 12310). Plagioclase and quartz have been preserved; the ferromagnesian minerals do no more exist as such. The plagioclases (albite, oligoclase) are more or less idiomorphic laths. The dark minerals have been wholly changed into epidote and chlorite, both scattered through the rock; the epidote is grainy or prism-shaped; the chlorite masses are irregularly bordered, and are composed of small spherolites, with greenish-brown interference-colours.

OTHER LAMPROPHYRES.

Beside the malchite dike-rocks a few other lamprophyres have been found on the island: three kinds of spessartite and one odinite-rock.

THE SPESSARTITE, WITHOUT QUARTZ (A 303—D 12312) occurs in Rooi Santoe (N-Aruba) as a finegrained, blackgrayish, porphyritic rock, with phenocrystic and greenish pyroxene crystals. Beside pyroxene, hornblende and plagioclase are the main constituent minerals. Pyroxene and hornblende together take up more room than the plagioclase. The groundmass takes up much more room than the phenocrysts; the latter occur in several places in groups (drifted together!?). The pyroxene occurs in the first place as phenocrysts, secondly as smaller crystals in the "groundmass". The almost colourless diopsidic augites are generally idiomorphic prisms, part of which are twinned. All of the pyroxenes possess a very narrow rim of hornblende or are in a transitional phase to uralite; the process of uralitizing proceeded from the periphery to the central parts. The hornblende is green, partly fibrous and then probably uralite after the pyroxene. The crystals are short prisms, idiomorphic or frayed ones. It seems even to be questionable, whether primary hornblende is or has been present in this rock. The plagioclases are laths of andesine to ?labrador, partly idiomorphic with regard to the hornblende; some also zonal. Magnetite. Numerous diminutive grains of ?leucoxene.

A 302—D 12311, a darkgreenish (AUGITE-) SPESSARTITE POOR IN PLAGIOCLASE, on the Seroe di Poos di Noord, is a pan-idiomorphic-granulose and sub-porphyritic rock, which consists of pyroxenes (in the first place), hornblende (in the second place) and of plagioclase and quartz (both of a minor importance). Some big and idiomorphic pyroxenes are no true phenocrysts, probably. The pyroxene is diopsidic augite, colourless to very palegreen, either idiomorphic or granular, and partly twinned. The hornblendes are brown-green prisms, smaller than the pyroxene crystals and rather idiomorphic. Some of the hornblendes are intergrown with pyroxene (no partly uralitized pyroxenes!). Between these pyroxenes and hornblendes some grainy plagioclase (?oligoclase) and rare quartz occur; these two minerals can be distinguished only with difficulty, because of the great quantities of epidote and chlorite. Apatite needles. Magnetite occurs as a very few and small grains, with a rim of epidote and of ?leucoxene. Secondary minerals are several masses of chlorite and of epidote. Some pseudomorphisms of ?crystals to a yellowish pinite-like mass (?epidote) are very curious; in one of them augite occurs as a kind of core, so that probably the original crystals are pyroxenes.

The SPESSARTITE A 752—D 13059, sampled just W of Jaburibari, is not so very much different from A 302—D 12311, except that it is richer in plagioclase, hornblende and quartz, and poorer in augite. The pyroxenes have been uralitized along fissures and borders, but also seem to be intergrown with hornblende here and there (hornblende-rim). As in D 12311 prism-shaped masses of very finegrained epidote are present. The hornblende is green (partly uralite). The plagioclases are albite prisms, not idiomorphic with regard to and here and there in granophyric intergrowth with quartz. Many epidote grains.

On the Seroe di Poos di Noord a diorite has been sampled with a narrow dike of AUGITE-ODINITE (A 304—D 12313).

Sample: Normal quartz-hornblende-(biotite-)diorite with a dike of an aphanitic and darkgrayish rock, in which greenish-weathered phenocrysts can be seen. The boundary between diorite and odinite is not quite straight, but sharp.

Microscopic description: The odinite dike-rock is sharply bordered on the diorite; plagioclase and hornblende crystals of the diorite have been cut off and partly somewhat resorbed by the intruding odinite magma. Small apophyses of the dike occur between the crystals of the diorite. – The rock is porphyritic; its groundmass takes up more room than the phenocrysts. The latter are pyroxenes, and lie closer together in the "Salband" than they do in the central parts.

The pyroxene phenocrysts are colourless diopsidic augites, idiomorphic or rounded-off, partly resorbed and fragmentary. A very few are twinned. Masses of a yellowish uralitic mineral and of a yellowish chlorite are pseudomorphic after pyroxene or plagioclase phenocrysts.

Groundmass: The "Salband", about 1—1,5 mm. wide, is almost aphanitic, brownish-coloured and glassy, and merges into the groundmass of the central parts of the dike; the latter is composed of a felt-like mass of small hornblende needles, with some ?plagioclase, ?quartz, ?chlorite and ?glass. In the felty groundmass numerous very small ore grains can be seen, part of which are limonitized. In the groundmass of the "Salband" some bigger magnetite grains occur; moreover many diminutive, green-grayish spots, which may be ore-remnants (?leucoxene).

It can be mentioned that the original composition of the lamprophyre-plagioclases is more basic than that of the plagioclase phenocrysts of the diorite-porphyrites. The difference in composition, however, between these minerals in lamprophyres and vintlites is very small, whereas the basic augite-vintlites have plagioclase phenocrysts which have about the same composition as the plagioclase of the lamprophyres.

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE LAMPROPHYRIC DIKE-ROCKS.

The lamprophyric dike-rocks, in general, do not occur in such large dikes as the porphyritic ones and have, therefore, not been indicated in the geological map. They present themselves in normal dikes, not in pipes. Here and there they crop out as round blocks (monoliths) in consequence of the selective weathering, f.i. N and E of Alto Vista and on the Jaburibari (reddish-brown blocks). Near Alto Vista and on the Urataka complexes of lamprophyric dikes occur. Several dikes contain fragments of the diorite. No ,,Salband"-textures could be distinguished in the field, only under the microscope.

The relation in age between the lamprophyres and the dike-granites and porphyritic rocks can be studied f.i. in Rooi Santoe just N of Salinja Cerka, where a malchite-dike cuts through a granite- and a vintlite-dike; it is clear that the malchite must be of a younger age than the two other rocks.

As has been said, the dikes are generally of a small length and width. The length is mostly but a few meters; the width is in general no more than 1 meter. Yet, there have been found some dikes with a width varying from a few meters to 10 meters, especially in the northern parts of the batholith.

Varying strikes have been found (see diagram fig. 21, p. 78). Most of the dips are vertical or almost vertical; a few dikes are less steep, dips of about 60° and 25° having been found. — N of Jaburibari a dike runs N 150 E; its western part has been removed a few meters to the north, with regard to the eastern part (orogenic movements).

There is no such strong difference concerning the distribution between a zone along the north(-east)-coast, 2—3 km. wide, and the other part of the batholith, as in the porphyritic rocks (see there). The lamprophyres are widespread in the whole northern and western outcrop of the batholith; still, it is remarkable, that in this outcrop the number of dikes increases from SW to NE (respectively, from the deeper to the higher parts of the batholith), so that in general the same order holds good with regard to both porphyritic and lamprophyric dikes. – Only one rock has been found in the batholith outcrop N of Savaneta (near Unja Unja), whereas in the easternmost outcrop not one could be observed. – Some dikes run through the contactzone between gabbro and diorite, near Bushiribana, Matividiri and Sumpina, and must have intruded after the contactprocesses had finished. A single dike occurs in the gabbro-massive. – As has been mentioned above, the lamprophyres are almost wanting in the older rocks. Only one dike (N 135 E) has been found in the southern mountains, S of Seroe Blanco; it cuts unconformably through the hornblende-schists. The poorness in lamprophyric dikes here may be understood if we take into consideration that the dikes are generally very small and narrow; the amount of lamprophyric magma must have been too small for it to break through the batholith-roof, but for a single exception. The difficulty, however, to distinguish lamprophyric dike-rocks from the diabases and metamorphic tuffs is certainly one of the causes that lamprophyres have hardly been observed. The poorness in lamprophyres in the older rocks must be very probably ascribed to both these influences.

LEUCOCRATIC DIKE-ROCKS.

These dike-rocks are very probably the youngest differentiates in the batholith. They belong partly to the magmatic period of crystallization (dioritic aplites, granodioritic aplites, granitic aplites, gabbro-aplites, quartz-albitites, granitic pegmatites), partly to the epimagmatic period (pegmatites, quartz-rocks, quartz-epidote-rocks, epidote-quartz-rocks, epidote-rocks; metalliferous quartz-rocks); the rocks of the latter group must be of an aqueo-igneous or of hydrothermal origin.

They form dikes and veins in the batholithic rocks and also in the diabase-schist formation, as well as in the contactzone of the latter.

The dikes can be clearly distinguished from the invaded rocks because of their shape and colour, the latter being a very light one. The dikes, in general, do not appear as elevations in the landscape.

APLITES.

Dioritic Aplites (Hornblende-diorite-aplites): P 102—D 6561; A 325—D 12317; A 332—D 12325; A 336—D 12329 (dikes in hooibergite-rocks).

Macroscopically these rocks are mostly mediumgrained; they consist mainly of feldspar and quartz; the dark mineral is hornblende, which occurs as a few and small crystals.

Microscopic description: The texture is mainly pan-allotriomorphic-granulose (aplitic). In these rocks quartz and plagioclase are, quantitatively, about equivalent. D 12317 is more dioritic in the central parts of the dike, more hornblende crystals being present here.

Some of the plagioclase crystals show a remarkable tendency to idiomorphism (with regard to quartz; seldom with regard to hornblende, f.i. in D 6561). The composition is rarely oligoclase, mostly oligoclase-andesine. In D 12329 there is a clear connection between the strong albitization and the polysynthetic twinning (see fig. 22).

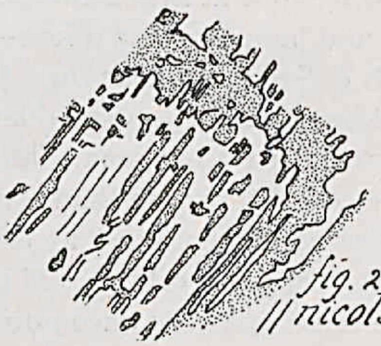

fig. 22. // nicols 92 X

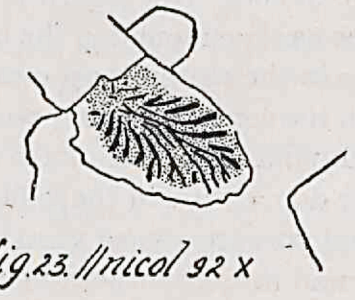

fig. 23. // nicol 92 X

Quartz: It is a remarkable fact, that the quartz individuals in D 12329 are stretched about parallel to the dike-borders, and that the undulose extinction and the lines of fluid-inclusions show a certain parallellism to the dike-borders as well.

The hornblendes are here and there idiomorphic with regard to quartz and plagioclase. So, the sequence of crystallization is not entirely wanting; a consolidation-residuum may even have attacked former more idiomorphic hornblende crystals.

Accessory minerals are apatite, magnetite, titanite, zircon (D 12329; a single crystal in hornblende), ?sillimanite (D 6561; small needles). — D 6561 contains a mass of chlorite with epidote and titanite strings.

Dioritic Aplites (Hornblende-diorite-aplites): A 80—D 12048; A 81—D 12049. (dikes in diorite). Some rocksamples consist of both the quartz-hornblende-diorite and the dioritic aplite dike. Hence, the transition and the difference between the plutonic rock and the dike-rock could be studied. The difference is very clear on account of the smaller quantity of the hornblende in the aplite; in connection herewith the quantity of quartz is greater. The crystals of both rocks work in with and between each other, and a true "Salband" is wanting. According to this transition, and also to the more or less plutonic texture of the dike-rock we can assume that the dike-intrusion took place during the last stages of the diorite consolidation. Thus, an interchange of material may have occurred.

In sample A 80 the hornblendes lie about parallel to the border of the dike, indicating a flow-structure. The texture is mainly hypidiomorphic-granulose, perhaps partly pan-allotriomorphic-granulose. There may be more quartz than feldspar, or the other way about, possibly depending on the degree of interchange with the dioritic rock.

Plagioclase is sometimes idiomorphic with regard to the quartz. Sometimes it is hypidiomorphic or allotriomorphic, which may be caused by a resorption-action by the late stage quartz-fluid or by simultaneous crystallization with the quartz. In D 12049 the crystals are the less dusty the farther away they occur from the diorite. In general, they are the same as the plagioclases of the diorite and have a composition of oligoclase to oligoclase-andesine.

Quartz is in general the youngest constituent part. In D 12049 the quartz amount increases from the dike-border to the centre. Hornblende is here and there idiomorphic. Apatite, magnetite and titanite; zircon seems to occur in D 12049.

Granodioritic Aplites (Biotite-granodiorite-aplites): A 82—D 12050; A 83—D 12051; A 84—D 12052; A 168—D 12239.

These aplites contain no hornblende but biotite as dark mineral. They are mainly finegrained rocks with gray, yellow or orange-brown quartzes, white feldspars and few black biotites. The texture is pan-allotriomorphic-granulose. Generally, plagioclase constitutes the majority with regard to the potashfeldspar. Biotite is of a minor importance.

Some of the plagioclase crystals are partly idiomorphic with regard to the other minerals. Oligoclase to oligoclase-andesine. D 12050 shows myrmekitic intergrowths bordering on potashfeldspar. In D 12052 (granophyric granodiorite-aplite) a great part of the plagioclase is in granophyric intergrowth with quartz, partly with radial appearance. Very clearly there can be seen the transition of plagioclase and quartz into the granophyric intergrowth, while even the twinning partly is present in the granophyric plagioclase. – Potashfeldspar is present as dusty orthoclase, microcline, microcline-microperthite and microperthite. – In D 12051 the quartz partly occurs in cataclastic zones between the feldspars. In D 12050 a single quartz is idiomorphic.

Biotite is present as scattered plates. Especially D 12050 contains socalled "streaks" of small biotite crystals, that have probably drifted together. In this case it is evident that the biotite crystallized before the other minerals. In the same rock small muscovite plates have been found, chiefly in the neighbourhood of the biotite groups. Whether the muscovite is wholly or partly secondary or primary remains uncertain. Also in D 12239 muscovite is met with.

Magnetite, apatite and titanite are accessory. In D 12052 and D 12239 very small rods, scattered through the rock, may be sillimanite needles. D 12239 possesses a biotite with an enclosed ?primary epidote.

GRANITIC APLITES. (BIOTITE-GRANITE-APLITES): A 85—D 12053; A 86—D 12054; A 87—D 12055; A 88—D 12056; A 89—D 12057; A 90—D 12058; A 91—D 12059; A 92—D 12060; A 93—D 12061; A 360—D 12338; A 361—D 12339; P 72—D 6542.

They look like the granodioritic aplites. The texture is normally aplitic, and the crystals are especially equigranular. The main constituent minerals are potashfeldspar, quartz and plagioclase; biotite and muscovite are of a minor importance. Part of the rocks look very cataclastic: narrow zones of fine-cataclastic quartz occur between the feldspar crystals, especially between the potashfeldspars; the quartz grains work in with them.

Four kinds of potashfeldspar, that is to say orthoclase, microperthite, microcline and microcline-microperthite, occur in different quantities. D 12060 shows an irregular intergrowth of potashfeldspar and quartz. In D 12053 some of the potashfeldspars show a poikilitic habit, enclosing idiomorphic quartz and plagioclase crystals. The potashfeldspar is very dusty; in D 12056 dust-lines occur along the layers of albite in the perthitic potashfeldspars. In some of the crystals of D 12059 irregularly shaped and narrow zones of albite, probably represent no perthitic layers but lines of albitization (phase of youngest alteration).

Plagioclase generally occurs in a smaller amount than potashfeldspar. In many rocks plagioclases occur with a simply zonal structure, that is to say, in far the most cases with a core and one more acid zone. Core and zone are distinctly separated or pass gradually into each other. In the former cases the zone may be "resorptive" with regard to the core; by way of exception more zones may occur, partly being recurrence-zones. The average composition is oligoclase, hence more acid than in the granodioritic aplites; some crystals have an oligoclase core and an albite-oligoclase zone. The plagioclases of D 12338 are albites; those of D 12339 oligoclase-andesines. Most of the plagioclases are allotriomorphic; nevertheless, some crystals show a tendency towards idiomorphism (with regard to the quartz and the potashfeldspar). In D 12053 and D 12060 many myrmekitic intergrowths of plagioclase and quartz border on potashfeldspar; especially in D 12060 many of them have a feather-shape (fig. 23). In the latter rock myrmekites with core and zone occur (zonal plagioclase). Most of the plagioclases in D 12061 occur in very fine, radial, granophyric intergrowths with quartz (granophyric granitic aplite); these plagioclases are in general not lamelled. There are transitions of quartz and of twinned plagioclase into such granophyric intergrowths.

Quartz: A few quartzes show a tendency towards idiomorphism or are idiomorphic with regard to the potashfeldspar.

Small biotite plates occur as independent crystals, or in streaks and aggregates. Many epidote grains can be seen in the close neighbourhood of the biotites. Frequently also very few and small muscovite plates are present, less than biotite. It is difficult in some cases to distinguish them from the secondary sericite in the feldspar.

Magnetite is rare or is present in a small amount. Part of the grains have a rim of epidote. In other aplites a great part of the ore is tied to the biotite. In D 12057 the ore occurs in curious groups of grains and of crystals, between and around which epidote-like and chlorite-like substances can be seen. – A few apatites. – In D 12059 and D 12339 rare titanite occurs next to magnetite or biotite: primary or secondary? – Zircon seems to occur in D 12053 and D 12058. – In D 12053, D 12055(?), D 12057, D 12061 and D 12339 small needles and prisms, for a part brownish, may be sillimanite. – D 12054, D 12056, D 12060 and D 12338 may contain primary epidote as idiomorphic crystals, wholly or partly enclosed in biotite.

These granitic aplites occur as dikes in the diorite batholith or in hooibergite-rocks [1]).

Gabbro-Aplite (A 100—D 12067): Only one sample of this rock-type has been found, SE of Canashito. It is a finegrained, grayish, siliceous-looking, aplitic rock, in which small black spots can be seen: the dark minerals.

Microscopic description: The texture is allotriomorphic-granulose, although many plagioclases show, it is true an irregularly bordered, lath-shape. The rock mainly consists of quartz and plagioclase, less of hornblende and mica. Locally, there are granophyric intergrowths of quartz and plagioclase. The occurrence of small plagioclase "drops" included in the quartz, just outside of the plagioclase crystals (see plate III fig. 6), is very common: the extinction of all these plagioclase inclusions is the same as that of the big plagioclase crystal to which they apparently belong. Probably, the plagioclase began to crystallize before the quartz. The remaining quartz-plagioclase-liquid crystallized afterwards more or less granophyrically, possibly after having partly resorbed the already formed plagioclases. The new-crystallized plagioclase got the same crystallographic orientation as that of the neighbouring and older crystals. – Plagioclases locally lie in groups between the quartz individuals: labrador bytownites. – The quartz contains rare fluid-inclusions.

Hornblende occurs a little more than biotite, and partly as separate, more or less skeleton-shaped crystals, that may owe their shape to resorption-effects. The hornblende, however, is chiefly present in groups of small, non-idiomorphic crystals, together with biotites, magnetites and apatites. A great number of quartz-bubbles occur in the hornblendes. Moreover resorption-holes in some hornblende crystals due to the reaction-effects of the quartz-liquid (compare with the relation between plagioclase and quartz) are present; a connection between the occurrence of the many quartz-bubbles and the resorption-action of the quartz-fluid seems to be obvious in this rock (see also p. 96). – Biotite plates are scattered through the rock, or occur near and between the hornblendes. Muscovite is present as a few small plates. – Many apatites occur together with magnetite and titanite near and between the dark minerals. The amount of magnetite is rather big; a single grain of pyrite is present. Titanite is especially to be found around the magnetite, and may be of a secondary genesis. – In the neighbourhood of the dark minerals large masses of epidote occur.

QUARTZ-ALBITITES

A 94—D 12062; A 95—D 12063; A 96—D 12064; A 97—D 12065; A 182—D 12507; A 745—D 13053.

The rocks are fine- to mediumgrained, and have an aplitic texture. The plagioclases,

[1]) J. H. Kloos (25) p. 43 called a similar rock (93*) microcline-granite and saw in the sample "kleine hellrothe Granate" (?). According to him, the bending and the flexion of the twinlamels "lassen sich leicht erklären durch den Druck, den der nachträglich auskrystallisi-"rende Quarz bei seiner Festwerdung auf die bereits vorhandenen Mineralien ausübte und "ist es unwahrscheinlich, dass hierbei andere mechanische Vorgänge mitgewirkt haben "sollten." – The quartz itself shows effects of stress as well. In comparison with the other rocks of the batholith and with the general orogenic relations the conclusion seems to be more reasonable that the distortion-phenomena in the feldspars and quartzes are due to slight orogenic movements during and after the magma-consolidation.

mostly albites, can be idiomorphic with regard to quartz, allotriomorphic with regard to idiomorphic quartz, or these two minerals can occur in micrographic-granophyric intergrowth. The rocks show clear effects of stress; amongst others, fine-cataclastic quartz zones between the bigger minerals, and "Schachbrett" albites. A few biotite plates, chloritized or not, especially occur in streaks. Chlorite may also be newly added, f.i. in the quartz zones of D 12507. D 13053 contains several fibrous muscovites with leucoxenic flocks. The epidote partly lies in strings through the rock. Apatites, magnetites, titanites and rare zircons are accessory. Moreover, D 12065 contains very small, partly brownish, needles and prisms, which may be sillimanites. A single epidote here is pleochroitic from grayish-brown to colourless and has the interference-colour of zoisite; a few others are idiomorphic. In D 12063 apatite needles are very abundant in the quartz, and occur less in the plagioclase. The presence of many zoisite prisms, which occur only in the quartz, is very curious; here and there these prisms are arranged to sheaf-like aggregates. According to WEINSCHENK (51) p. 151 and p. 152 these zoisite crystals may be primary α-zoisite.

A rock which shows affinities to the quartz-albitites is A 746—D 13054, found about 1 km. W of the Hooiberg. It is a parallel-structured, white-grayish aplitic rock, which under the microscope shows a clear parallel structure as well. It consists of layers of finer and coarser grained, undulose or strongly cataclastic quartz. Several broken or bent albites lie in these layers, and the quartz zones curve around them. Some layers are very rich in epidote; the latter mineral also occurs in masses, with here and there a little fibrous chlorite. – It is clear that this rock must have been submitted to a great pressure, which caused the parallel structure. May be, the original rock had the composition of a quartz-albitite.

GRANITIC PEGMATITES

A 99 possesses a beautiful, macrographic texture. Big quartz "letters" occur between feldspar; the latter takes up more room than the quartz. The quartz is white. The feldspar has a white or ,,beige" colour, and its crystals, orthoclase and albite, are very dusty.

A 98—D 12066 is a coarsegrained feldspar-quartz-rock, principally composed of big microcline crystals with a beautiful cross-hatching. The intergrowth of the feldspar and the quartz is not a graphic one, but an irregularly granophyric one. The irregularly shaped quartz strings in the microcline cause a rather curious appearance of this feldspar. The spotted aspect of the microcline may be due to irregular twinning or to an intergrowth of this feldspar with other potashfeldspars or with acid plagioclase. Some twinned plagioclase individuals are also present in the microcline. – Epidote occurs as grains. A big nest of epidote, present in this rock, will be described under epidote-rocks.

QUARTZ-, EPIDOTE-, CHLORITE- AND TALC- DIKE- AND VEIN-ROCKS

QUARTZ-DIKEROCKS: P 67 is composed of milkwhite quartz crystals. Under the microscope the rock shows allotriomorphic quartz crystals, which work in with each other in an irregular way. Between those bigger crystals "nests" of smaller ones occur here and there. The quartz is very dusty. Its gas- or fluid-inclusions occur in a kind of network.

The rock A 101—D 12068 (belonging to the very long dike N of Spaansch Lagoen) is a siliceous one with beautiful, reddishbrown and bright-green colours, alternately. It is a quartz aggregate, with here and there bigger individuals. Limonite strings and "veins" cause a parallel structure. Bright-green malachite occurs in strings and grains. The ore has been partly altered into limonite. A little ore, reddishbrown in reflected light and possibly cuprite, is still present, here and there enfolded by malachite. May be, the limonite originated from magnetite, the latter, however, no more being present.

A 747—D 13055, sampled on the Seroe Crystall, presents a quartz-dike which gradually merges into a dark dioritic rock. – The rock shows several zones or layers which merge. The zone farthest from the diorite consists only of quartz. Narrow "veins" or zones of very small quartz grains occur between and through rather big individuals, which show but here and there idiomorphism. The quartz is filled allover with fluid-inclusions, partly arranged in planes. The second zone consists of an aggregate of finer grained quartz and a little chlorite, in which bigger, more or less idiomorphic or fragmentary quartzes and some sericitized, lamelled albites lie. The third zone nearest the diorite consists of big quartzes, here and there idiomorphic, between which finer grained quartz occurs, and moreover of sericitized albites and masses of chlorite. Ore is present in a few semi-limonitized magnetite grains. – The albites and the chlorite must be altered diorite minerals, between which the quartz-liquid must have penetrated and which must have been taken up in the quartz-dike. The albitization and chloritization of the plagioclases and hornblendes are very probably due to the same quartz-liquid injection and flooding.

Quartz-epidote-, epidote-quartz- and epidote-dike- and vein-rocks (A 72—DD 12039, 12040; A 98—D 12066; A 102—D 12069; A 103—D 12070; A 104—D 12071; A 105—D 12072; A 106—D 12073; A 107—D 12074; A 109—D 12076; A 110—D 12077; A 111—D 12078): Macroscopically these rocks are greenish, greenish-gray, yellow-greenish-gray or brownish, more or less siliceous-looking ones, in some of which narrow quartz veins clearly can be seen.

The rocks consist of varying quantities of quartz and epidote, irregularly distributed in most of them. Where the epidotes are prisms or columns, they sometimes lie in a radial way. In one place of D 12071 filiform microlites diverge from the epidote aggregate into one of the quartzes. In D 12069, D 12071 and D 12073 both minerals occur in a banded structure. Some chlorite here and there occurs between the epidotes; rarely sericite (D 12077). –Several other minerals can be found which probably have been taken up from the country-rock: distorted albites in D 12069; remnants of biotite, transformed into chlorite and titanite or not, in D 12073 and D 12076; magnetites, apatites, titanites.

A 72 is a quartz-biotite-diorite with a fissure, in which green, filiform or needle-shaped crystals clearly can be seen. In the DD the epidote-quartz-vein is bounded by the diorite in a rather sharp way, except in the places where the quartzes of the two rocks touch each other and seem to have fused.

D 12066 is a granite-pegmatite with a nest of epidote. Between the epidote individuals some quartzes occur, which enclose irregularly shaped pieces of potashfeldspar. Epidote crystals stick in the microcline of the pegmatite.

Quartz-talc-epidote dike-rock (A 434—D 12519): This rock is a dirty-grayish-green-, brownish- and blackish-looking, schisty rock. It is composed of a finegrained quartz aggregate, with epidote and talc, irregularly distributed. The epidote is grainy, and here and there arranged in strings. The talc is present as stretched scales and plates. Moreover there occur several enclosed plagioclase crystals, roundish and strongly-pressed, and a few limonitic grains of magnetite.

It is a dike-rock in diorite of the Hooiberg. Both talc and epidote may have originated from the Ca- and Al-bearing ferromagnesian minerals of the hooibergite. The enclosed plagioclases may have been taken up from the hooibergite or from the diorite. – The dike strikes N 30 E and dips 45 NW.

Chlorite-epidote-rock: The rock A 753—D 13060 probably occurs as a dike in the diorite S of Kudawecha and can be described in addition to the epidote-dike-rocks. It is a greenish rock with lustrous, greenish-black plates. The main mineral is slightly pleochroitic, lightgreen, platy or radial-fibrous chlorite, undulose or broken (angle between the optic axes 0°; optically positive; main zone negative; velvet-like, greenish-gray interference-colours). Brownish, leucoxenic spots lie parallel or radial in these big chlorites, between which a kind of groundmass of small epidote prisms and similar chlorite occurs. Moreover, some quartz, a little calcite and brownish ?leucoxene are present.

GENESIS OF THE LEUCOCRATIC DIKE-ROCKS.

The leucocratic rocktypes cannot be rigorously separated from each other. Transition-rocks prove that they are differentiates of one and the same magma, in so far as they are true magmatic rocktypes.

The aplitic and albititic rocks are normal, leucocratic differentiates of a dioritic magma and are of an igneous nature. As to the pegmatitic and quartzose rocks we probably cannot consider them differentiates of a merely igneous nature. They belong to the epimagmatic period of consolidation of the batholithic magmas.

According to J. E. SPURR (43) p. 70 we can call the pegmatite, quartz and metalliferous quartz dikes and veins ,,veindikes", the magma of these rocks being intrusive, but differing from that typical of the usual igneous rocks; the magma approaches the solutions from which veins are deposited, and represents an extreme differentiate (an aqueo-igneous end-stage consolidation product) [1]. The most important metal in the quartzose veindikes is free gold; most of these auriferous quartz-rocks occur in tabular vein form, some of them in more lens-shaped forms. According to SPURR (43) p. 85 these veindikes must not have been formed at a great depth. According to W. LINDGREN (28, pp. 546—549) the goldbearing quartz-dikes belong probably to the group ,,Metalliferous deposits at intermediate depths by ascending thermal waters and in genetic connection with intrusive rocks." Here and there also a little pyrite, chalcopyrite and malachite have been found. — It is questionable whether the quartz-epidote-, epidote-quartz- and epidote-dikes and -veins are also ,,veindikes" or are more hydrothermal veins. Probably, there is a transition, so that the epidote-rocks rich in quartz originated from a liquid thinner and more aqueous than the true veindike magmas, whereas the epidote-rocks poor in quartz or without quartz are hydrothermal. In addition herewith it must be mentioned, that most of the batholithic rocks contain very narrow and small veins of epidote or of epidote and quartz, obviously of hydrothermal origin and impregnated along fractures and fissures. These rocks have been generally epidotized in the neighbourhood of these veins. The solutions of the bigger epidote- and epidote-quartz-dikes too attacked the country-rocks, whether belonging to the older formation or to the batholith. This can be clearly seen f.i. in the rock A 747—D 13055, which presents a dioritic rock gradually merging into a quartz-dike-rock (p. 89).

OCCURRENCE, DISTRIBUTION AND GEOLOGY OF THE LEUCOCRATIC DIKE-ROCKS.

The leucocratic rocks, being widespread and occurring generally in dikes of small dimensions, have not been indicated in the geological map.

On the whole, they present themselves in normal dikes and veins; rarely in pipe-shaped dikes, which have been preserved here and there by selective erosion and which occur in the landscape as small tops and hills. Locally, a dike-

[1] Also R. J. COLONY (11) considers the magmas of these rocks acid, aqueo-igneous differentiates of a more basic magma. On the other hand, ERDMANNSDÖRFFER (18) p. 225 and BOWEN (7) p. 131 believe the (metalliferous) quartz-veins to be formed from highly aqueous residuums, hence under hydrothermal conditions. According to BOWEN ,,Such ,,liquids are in no sense magmas as the term is ordinarily used, for this usage implies a ,,liquid which, by a single act of injection into a fissure, with subsequent congelation, is ,,capable of filling the fissure with a solid rock. Quartz veins are plainly not formed from ,,any such liquids."

or a pipe-shape cannot be distinguished, the leucocratic rock occurring as a small massive in the diorite (f. i. an aplite massive just E of Zumbo). The aplitic dikes rarely crop out as big, roundish blocks like the diorite. ,,Salband"-textures could not be found.

The leucocratic dike-rocks are very probably the youngest in the batholith. They mainly occur in the diorite. In a few places they cross diorite-dikes. North of Du Chef quartz-dikes seem to branch out from a porphyrite-dike.

The bulk of the dikes and veins have small dimensions. Yet, some very long dikes have been found; f. i. a leucocratic dike of more than 200 meters long in the gabbro-massive of the Matividiri, an 80 meters long granite-aplite dike NNW of Arikok in the diabase near the contact with diorite, a leucocratic dike more than 200 meters long S of Santa Cruz, a quartz-dike of about 1400 meters long in the diorite N of Spaansch Lagoen; on the Arikok also a rather long quartz-dike occurs. — The width is generally small, and varies from a few cm. to about 3 meters; the long dikes are rather wide (aplitic and quartz-dikes). The long quartz-dike N of Spaansch Lagoen wedges out to the east. The gabbro-aplite dike SE of Canashito, is more than 5 meters wide; and a granite-aplite outcrop 800 m. E of Seroe Blanco (SE-Aruba) has a length of about 100 meters and a width of about 40 meters (E-W stretched).

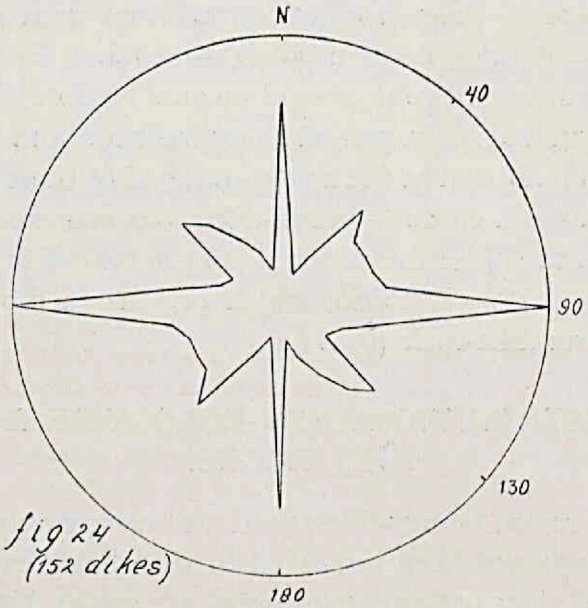

fig 24
(152 dikes)

Varying strikes have been found (see diagram, fig. 24). Most of the dips are vertical or almost vertical; some dikes are less steep, the dips lying for the greater part between 45° and 90°; a single dike is about horizontal. — Some dikes in the southern part of the older formation lie conformably in the schists there; a dike in the contactzone of NW-Aruba too shows the same strike as the amphibolites. — A dike near Druif (NW-Aruba) has been faulted once (orogenic movements).

The leucocratic dike-rocks are widespread in the batholith. It can be mentioned that the number of dikes found in the batholith is much greater than that in the older formation; whereas the latter seem to be almost wanting in the eastern parts (region of Dos Playa, Fontein, lower course of Rooi Prins), that is to say, in those parts of the older formation which lie far from the batholith. In distinction to the distribution of the porphyritic and lamprophyric rocks the leucocratic dike-rocks are regularly distributed and their number does not increase from SW to NE. The easternmost batholith outcrop contains several dikes, but the outcrop N of Savaneta contains only very few. Numerous dikes and veins especially occur in the contactzones between diorite and the older formation and between diorite and hooibergite-rocks or gabbros.

RESORPTION PHENOMENA. AUTOMETAMORPHISM.

The resorption phenomenon described on p. 40 where a more acid shell of plagioclase shows a resorptive character with respect to the more basic core, can be compared with the relation between the hypersthene and hornblende of the gabbroic rocks. In both cases the remaining liquid must have reacted with and must have partly resorbed the already crystallized substances during a phase of slow cooling. These plagioclases do not form a true continuous reaction series but can also be considered as a kind of discontinuous reaction series. The more acid plagioclase shell has crystallized during a phase of rapid cooling, either from a residual liquid originated on the spot, or from a residual liquid newly added. In the latter case, there must have been a relative motion of liquid and crystals. According to Bowen (7, p. 276) the total composition of this liquid is changed but little by the partial solution of the older crystals. — Although the genesis of the hornblende shell and that of the acid plagioclase shell in the hypersthene-gabbros have the same character, the hornblende must have been formed in an earlier period than this plagioclase and at about the same time as the more basic plagioclase.

As to these resorption phenomena also O. H. Erdmannsdörffer (18, pp. 238—239) gives as his opinion that the resorption took place during the normal course of magma consolidation in consequence of the failing of equilibrium between the already crystallized minerals and the remaining liquid. Besides however, he remarks that resorption can be caused by „äussere Eingriffe" as well: „Auch Wärmezufuhr, Druck- oder Konzentrationswechsel, z.B. durch Extrusion „oder plötzliche Entgasung, kann zu Gleichgewichtsverschiebungen mit ähn- „lichen Ergebnissen (resorption) führen, ebenso Aufhebung von Uebersättigung „und Ähnliches. Beispiele liefern die stark verrundeten Quarzdihexaeder in „liparitischen Gesteinen, die zerfressenen Formen der früh ausgeschiedenen Kerne „zonargeschichteter Mischkristalle, z.B. Plagioklase in dioritischen Gesteinen."— In order to understand the limitation of the resorption of the older cores, see Bowen (7, pp. 275—276).

Since the recognition of this plagioclase resorption phenomenon greatly depends on the situation of the section it is very difficult to form an idea of its quantitative occurrence. Possibly all the plagioclases show the phenomenon, partly beside their normal zonal character; the latter must have come into existence in an earlier period during a rather quick cooling. Such a general occurrence could be very well understood. On the other hand, it is also possible that only locally in the batholith this resorption took place.

Considering now the later resorption of plagioclase and hornblende by a SiO_2-rich liquid, resulting in the occurrence of quartz in peripheric holes of these older minerals, such a resorption must be due to the action of the end-stage residual liquid, very rich in SiO_2, alkali and volatiles, and with a great corrosive power. In part and beside quartz also potashfeldspar must have crystallized from this liquid, as found in some of the dioritic rocks. The residual liquid may be newly added instead of a differentiation from the spot. Probably it had about the properties of an eutectic mixture; at all events, it has been consolidated here and there as granophyric or micropegmatitic, interstitial material.

In connection with this resorption and in general with the final consolidation phenomena R. J. COLONY (11) remarks that pyrogenetic effects produced within the igneous rock itself are partly the result of "reactions due to adjustments of "equilibrium between the extreme end-stage, highly concentrated "mother-"liquor" which, by selective freezing, has been enriched with the more volatile "gases usually termed "mineralizers", among which water plays an important "part, and the now almost wholly consolidated rock. These equilibrium ad-"justments, and the changes produced by chemical attack, may be thought of "as an extension of the reaction effects described by BOWEN. At this stage much "of the quartz and some of the alkalies, especially soda in such a form as to "appear ultimately as albite, seem to be concentrated in the form of a liquid "consolidation-residuum, which, from such evidence as is presented in the rocks "themselves, must possess an extremely low viscosity, great penetrating power, "and considerable chemical activity. During the consolidation of plutonic "rocks especially, the mineralizers operate to effect changes in some of the already "formed minerals, and in some cases cause profound changes in the rock itself". The changes of equilibrium occur on account of the different conditions of temperature and concentration, f.i. on account of the abolishment of undercooling (see also the remarks of ERDMANNSDÖRFFER as referred to above). Such changes occur in many of the igneous rocks of Aruba and are in general the albitization, sericitization and epidotization of plagioclase, the chloritization of hornblende, the chloritization, titanitization and epidotization of biotite, the uralitization of pyroxene (as far as not the contact uralitization), the zeolitization, the silicification. Probably this alteration may be considered in part as a result of hydrothermal action, the latter being the continuation of the end-stage magmatic processes.

The same end-stage liquid (aqueo-igneous matters) which attacked the older minerals in the igneous rocks also acted on the country-rock which, according to COLONY (p. 177), "may be so flooded with quartz, or quartz and feldspar from "igneous sources, as to profoundly change the character of the invaded rocks." In fact, where on Aruba younger dike-rocks are in contact with older rocks and where the diorite borders on the older formation, these phenomena can be clearly seen. The extent of this metasomatic alteration of the country-rock depends upon the character of the latter and upon the quantity and quality of the emanation products themselves.

The younger crystallization products, chiefly the quartzes, show an undulose or cataclastic character. Therefore, mechanical stresses must have acted during or after the final consolidation.

In conclusion, there must have been several resorption phases in the consolidation of the Aruba batholithic rocks: 1. that before the crystallization of hornblende around the hypersthene of the gabbros, 2. that resulting in the reversal of normal order of zoning with resorption effects of the plagioclases (see BOWEN (7) pp. 274, 275), 3. that before the crystallization of more acid shells in some of the plagioclases, and 4. that before the final consolidation. The resorption of (3) is different from that of (4), for the plagioclase shell is more basic than albite and is older than the quartz.

As to the occurrence of small quartz-bubbles in some of the hornblendes of the batholithic igneous rocks, reference can be made to B. ASKLUND (3), who on p. 35 described the hornblende of certain quartz-diorites as follows: "The horn- "blende usually presents a poecilitic character and contains small grains of quartz. "It differs from common hornblende in its brownish-green colour." An equal texture has been found by ASKLUND in hornblende-bearing derivatives of noritic gabbro (he calls it a "metamorphic" phase, an "amphibolite"): (p. 22) "The "hornblende individuals are mainly studded with small quartz-grains or small "vermicular quartz aggregates, often very thin. This intergrowing structure "clearly recalls myrmekite ("hornblende-myrmekite")". — In fact there is a striking resemblance between this "hornblende-myrmekite" and the textures found in some of the Aruba hornblendes; the genesis, however, of the former texture, as assumed by ASKLUND, cannot be taken for that of the latter, the hornblende-myrmekite of Stavsjö being defined by the setting free of SiO_2 through the reaction hypersthene + plagioclase $\longrightarrow$ hornblende + SiO_2, or pyroxenes + anorthite (-albite) $\longrightarrow$ hornblende + SiO_2; these reactions may have occurred after the complete consolidation of the noritic gabbro.

In the diorites the formation of hornblende took place during the magmatic stage and resulted in the setting free of quartz, this being (after BOWEN (7) p. 90) "a plain inference from the very basic nature of hornblende". And according to the same writer "the hornblende of the diorites has a tendency to include "some of the quartz as small grains". In this way one may understand the genesis of the Aruba "hornblende-myrmekite". — There seems to be a connection, however not a very clear one, between the occurrence of this "hornblende-myrmekite" and a small amount of quartz in the diorite; that is to say, the quartz inclusions especially occur in the hornblendes of diorites, more or less poor in or with a normal quantity of quartz substance; whereas the diorites with rather much to very much quartz do not show quartz inclusions in the hornblendes. Perhaps one can understand this, in taking into consideration that, when part of the diorite-magma-SiO_2 has been included in the hornblende during earlier crystallization, less SiO_2 is able to consolidate as younger quartz. However, the youngest

SiO_2 residual consolidation liquid may have originated, in some cases, not from the spot itself (being no true differentiation liquid); in that case, on account of the newly added quartz material, the younger quartz may occur in a greater amount, even when much quartz is included in the hornblende.

Nevertheless, a better explanation of the "hornblende-myrmekite" puts the occurrence of quartz-bubbles in hornblende with the autometamorphism in the diorite magma (see above). That is to say, the residual consolidation liquid, rich in SiO_2, assimilated parts of the already crystallized hornblende and, at the same time, impregnated some of the hornblendes with quartz, so that vermicular, myrmekite-like textures came into existence. In some rocks this connection between hornblende resorption and the quartz-bubbles is very striking; see f.i. the gabbroic quartz-hornblende-diorites A 423—D 12508 and A 448—D 12524. Similar textures occur in contactzones, being there the result of contact-metamorphic action (see the hornblendes of transformed hooibergites, gabbros, diabases; compare with the reaction formulas on p. 95).

It must be mentioned, that in the described quartz-hornblende-biotite-diorites with "hornblende-myrmekite" no orthoclase was found.

CONSIDERATIONS ON THE BATHOLITH.

The batholith on Aruba is a differentiated and composite one, which consists of typical quartz-rich, calci-alkalic rocks. As DALY (12) writes (p. 413), "the Tertiary "eruptives associated with the very extensive regions of normal faulting and" "subsidence, in the West Indies, are chiefly or wholly of subalkaline, "Pacific types".

The richness in quartz of the igneous rocks, especially of the diorite, must be the result of fractional crystallization during the consolidation of the magma. As BOWEN (7) has pointed out, f.i. in Chapter VI, separation of early crystals from liquid (of hornblende, pp. 85, 90; of biotite, pp. 81, 83; or through relative movement of liquid and crystals) will be the cause of continual lowering of the temperature of final consolidation and offsetting in the composition of the remaining liquid, f.i. towards free silica. Since the batholith may have more or less a laccolith shape and since the examined rocks have been formed near the chamber roof, we can accept that the magma has been submitted to a rather quick cooling and crystallization. This quick cooling and also the orogenic, deformative forces in the batholith (intrusion during the orogenesis of the older formation!) must have strongly promoted the mentioned fractional crystallization, visible now in the zoning of plagioclases and the richness in quartz. As to the deformative forces, they acted during or after the late crystallization and caused the undulose and cataclastic nature of the crystals, especially of the quartzes, and also the faulting of some dikes.

Beside quartz, hornblende is a very important mineral in the Aruba diorites. The fact that the latter rocks are true hornblende-rocks, whereas the gabbros and hooibergites contain much pyroxene, agrees very well with the fact that hornblende minerals are genetically related to higher temperatures and pressures, and monoclinic pyroxene to lower temperatures and pressures, the gabbros and hooibergites being roof-crystallizations.

It is a remarkable fact that the peripheric parts of the batholith do not show a diorite-porphyritic texture, no more an aberrant marginal texture. The process of crystallization here was similar to that in the more central parts. The strong contactmetamorphism of the older rocks also speaks in favour of a considerable supply of heat to the country-rocks. — The dikes in the batholith which do not differ so much from the plutonic rocks, have no sharp borders or ,,Salbänder", and prove that the invasion took place at a time when these plutonic rocks were still warm and semifluide; in some cases these dikes even show a hypidiomorphic-granulose texture.

The sequence in intrusion and consolidation of the various differentiates of the primary batholithic magma can be clearly distinguished in Aruba: the hooibergites, the gabbroid rocks and the older dioritic rocks intruded and crystallized before the diorites, the granodiorites and the granites. — The primary batholithic magma, which was probably a basaltic magma shows a rather great differentiation, probably because of an ascending of the magma up to a high level (wide range in temperature and pressures).

According to Bowen (7) pp. 85—91, the quartzdiorite and the granite might be the product of a fractional crystallization of a noritic gabbro magma (originally, of primary basaltic magma). — The ideas of Daly (12) concerning the genesis of norite, hornblende-gabbro, diorite, granodiorite, and granite, being syntectics of primary basaltic magma and acid country-rock, or the differentiate of such a syntectic (see f. i. p. 312), do clearly not hold good with regard to the Aruba plutonic rocks, for the assimilated surface country-rocks present here are no acid ones (diabases, diabase-tuffs). Probably however, these acid country-rocks in the sense of Daly's theory are present under the rocks of the older formation and can be compared with the gneissose rocks of the Venezuelan coastrange. — The value of the conception, that the quartzdiorite is a syntectic of granite magma with diabase, or with gabbro magma, is also doubtful. — Very probably, the granite can be considered as a differentiate from dioritic magma; as Daly writes (p. 361) "Very commonly, diorite, quartz diorite, "granodiorite passes insensibly into granite in such a way as to suggest that the "granitic magma was a late differentiate from the other magma". — About the genesis of the hooibergites and gabbroic rocks, see the chapters in question. Certainly the crystallization of these basic roof-phases must have influenced the composition of the younger intrusive units.

The dike-rocks must be considered as solid dike-phases of magmas similar to or differentiated from dioritic magma, that is to say, they bear an aschistic or a diaschistic relation to the plutonic rocks. Referring to the idea of Daly (p. 384) it would seem that the basic dike magmas, the melanocratic ones, are direct differentiates from the primary basaltic magma. In this connection, see also Iddings (21, pp. 292—295) "Complementary Rocks".

The predominant E-W strike of the dikes in the batholith rocks – which can also be seen in the dikes occurring in the older formation – is connected with the fact that the batholith intruded during the orogenesis of the older formation, the strike of the axis of folding of the latter being E-W (in this connection, see the wrong conclusion of Martin (30) p. 63).

CONTACT ROCKS.

Since the diorite batholith is younger than the diabase-tuff formation, the latter has been metamorphosed at its border by the intruding magma. It has been discussed already before that the uralitization of the diabases and the hornblendization of the tuffs was closely connected with this intrusion. This kind of contactmetamorphism must have acted over a distance of about 2 km from the visible contact. We have also seen that the uralite-diabases near or in the true contactzone show more distinct contact-phenomena than the rocks farther from the contact: contactmetamorphic uralite-diabases. In several places the diabasic rocks do not border directly on the diorite, but amphibolitic contactrocks (amphibolites, amphibole-plagioclase-rocks), which have originated from the diabasic rocks in consequence of the process of contactmetamorphism, lie here between the two former rocks. The schistose tuff-rocks too can show strong contact-phenomena where they lie in the contactzone: contactmetamorphic hornblende-schists. In other places in the contactzone these rocks only have been strongly invaded. — Beside exomorphic contactmetamorphism, in some places also endomorphic contactmetamorphism could be distinguished, and rocks transitional between diorite and amphibolitic rocks have been found as well. Many of the contactrocks have a hybrid character, that is to say, they have been strongly invaded by dioritic material.

In order to prevent the forming of a wrong idea concerning the names contactmetamorphic uralite-diabase and contactmetamorphic hornblende-schist it must be mentioned once again that the strongly contactmetamorphic rocks in the true contactzone and the slightly contactmetamorphic rocks farther from the contact (to about 2 km from the contact) have undergone one and the same process of contactmetamorphism at one and the same time.

CONTACT QUARTZDIORITE AND DIABASE

A series of contactrocks has been sampled in the contactzone NW of Shete: A 554, A 555—D 12581, A 556—D 12582, A 557—D 12583, A 558—D 12584, A 559—D 12585, with mutual distances of 5 to 10 m. (total length about 30 m). The latter four rocks are contactmetamorphic uralite-diabases, described above. The rocks A 554 and A 555—D 12581 are normal, orthoclase-bearing quartz-hornblende-biotite-diorites; the many times repeated recurrence of the plagioclases and the local intergrowth of plagioclase and potashfeldspar in D 12581 may be connected with the neighbourbood of the batholith roof. - In this contact diorite and diabase border directly on each other, other contactrocks not having been found here. It is also remarkable that in most of these contact-diabases pyroxene is still present. -If we compare the four diabases, the rock D 12585, farthermost from the visible diorite,seems to be most contactmetamorphic (see the deteriorated texture and the non-fibrous character of all the hornblende). Yet, it still contains pyroxene, which may have been preserved in consequence of a quick metamorphism; the latter however must have acted so strongly that a part of the pyroxene could alter into non-fibrous hornblende. The alteration of D12585 being strongest, proves that the contact plane is not vertical and that the diorite is also present under the diabase. Therefore, no regular changing of properties in the contact series occurs here.

CONTACTMETAMORPHIC HORNBLENDE-SCHISTS, OCCURRING IN THE CONTACTZONE QUARTZDIORITE-HORNBLENDESCHISTS (plate II, fig. 4)

These rocks occur in the contactzone Baranca Corra-Shidaharaka, in the schist-massives E of Spaansch Lagoen, in the neighbourhood of the diorite-contact near Seroe Boonchi, and near Andicouri.

Macroscopically these rocks are grayish, finegrained and partly schisty. In several of the samples many small hornblendes can be distinguished.

Microscopic description: The rocks consist of a very finegrained, plagioclase-rich hornblende aggregate, with many bigger hornblende crystals. The matrix is composed of a felt of hornblende needles and prisms, in which small plagioclase grains occur, here and there lamelled, and simply zonal. It is remarkable, that, in contrast with the normal metamorphic tuffs, the hornblende aggregate in the DD perpendicular to the cleavage-planes of the schisty rocks is diverse and not parallel. – Beside a more or less regular distribution of hornblende and plagioclase, the rocks D 12639, D 12652, D 12662, D 12670 and D 12676 show an irregular alternation of both minerals, the plagioclase occurring as an aggregate in veins, or in more or less parallel "lenses" (magmatic invasion). The transition between plagioclase mass and hornblende felt is rather abrupt or gradual. At all events, many hornblende needles stick and lie in the plagioclase aggregate. The latter moreover contains in D 12652 some chlorite and epidote, in D 12662 big ?epidote flocks. The composition of the plagioclase is about oligoclase-andesine to andesine. Beside the plagioclase D 12649 locally contains some quartz. Ore is abundant in most of the rocks: magnetite and titanomagnetite. Some rocks contain nests of epidote

A few tuff relic-crystals of andesine occur in the matrix of D 12639, D 12649, D 12662, D 12663 and D 12676. They are partly idiomorphic, here and there twinned or zonal and rarely altered (?opalized in D 12663). The hornblende needles of the matrix stick in many of them. If we compare these rocks with the normal metamorphic tuffs, we see that in the former the number of plagioclase relic-crystals is smaller than in the latter, and also that the plagioclases of the former have been more hornblendized than those of the latter. So it seems, that a number of relic-crystals in the contactmetamorphic rocks have quite disappeared during the strong contactmetamorphism. In D 12639 a few roundish parts are greener than the rest of the matrix and consist of a coarser hornblende felt plus ore. May be, these parts originated from rock inclusions.

The clear exomorphic contact-phenomenon in these rocks is the occurrence of many rather big, new-made hornblende crystals, which are generally idiomorphic prisms and needles, with the normal hornblende-cleavage. Yet, many of the prisms and needles show frayed ends. The hornblendes are light-greenishbrown, light-brownishgreen to almost colourless in D 12652 and D 12663; green to lightgreen in the other rocks. Part of the crystals show twinning. Some of them contain ?quartz-bubbles. The arrangement of the hornblendes in D 12662 is here and there as in amphibolites. The hornblende felt takes up more room than these hornblende crystals. Generally, the quantity of the hornblende crystals decreases with increasing distance from the contact. – The big hornblendes occur in too large a number for them to have originated from pyroxene crystals of the original, tuffoid rocks. At the utmost, only a few of them originated from such pyroxenes. The greater number of them is new-made, perhaps totally out of tuff material, perhaps also by supply of magmatic material out of the diorite magma (compare with the invasion of plagioclase material). – Hence, may be this contactmetamorphism is not only a thermal one but also a hydrothermal-pneumatolytic and injection metamorphism.

As to the invasion of plagioclase material, these rocks must have been invaded and soaked with magmatic or hydrothermal solutions during the intrusion of the diorite batholith; these solutions must have intruded along fissures, formed by orogenesis, and must have resorbed the rocks locally. The fact that hornblende needles lie in the plagioclase veins means – as we have seen already above – that the process of hornblendization proceeded still after the intrusion of the veins.

Findingplaces:

A 652—D 12652: E of Baranca Corra; A 662—D 12662: just N of Baranca Corra; A 663 —D 12663: between Baranca Corra and Shidaharaka; A 670—D 12670: just N of Shidaharaka; A 639—D 12639: E of Spaansch Lagoen, W of Shidaharaka; A 649—D 12649: Seroe Boonchi; A 676—D 12676: Andicouri.

Professor J. A. Grutterink sampled a pebble in Rooi Taki, E of Spaansch Lagoen, which proved to be a contactmetamorphic, variolitic hornblende-schist (metamorphic variolitic tuff). This rock (no. 3285—D 2337) is a normal contactmetamorphic hornblende-schist, the variolitic character of which manifests itself because of the fact that the number of new-made, secondary-idiomorphic hornblende crystals is much smaller in the varioles than in the interjacent mass. So, there must have been a primary difference between the composition or texture of the varioles and that of the interjacent mass.

SOME CONTACTROCKS BETWEEN QUARTZ-DIORITE AND HORNBLENDE-SCHISTS (METAMORPHIC TUFFS)

A series of rocks has been sampled in the contactzone N of Seroe Blanco (near Spaansch Lagoen), where diorite and metamorphic tuffs border on each other: The samples have been taken in a direction perpendicular to the contact line, over a distance of about 40 me

A 717—D 12685 is a normal quartz-hornblende-biotite-diorite with a many times repeated recurrence in the plagioclases and with normal alteration and distortion of the minerals.

A 718—D 12686 is an altered quartz-diorite. Macroscopically the rock looks strongly altered; the dark minerals occur more as stretched masses than as crystals. Under the microscope it shows a slightly parallel structure, and an oppressed hypidiomorphic-granulose texture. Its dark minerals have been totally chloritized. The plagioclases intensively work in with quartz in several places, and are strongly bent or undulose. They are quite albitized, strongly epidotized and less sericitized. The quartz is present as bigger grains, strongly undulose to cataclastic, and as finegrained aggregates as well; narrow chlorite layers are woven between the stretched grains of these aggregates. The chlorite occurs with epidote and titanite as more or less stretched masses, and has velvet-like greenishbrown and steelblue interference-colours, or is isotropic. It originated partly, perhaps wholly, from hornblende (hornblende-cleavage); may be, part of it originated from biotite (chlorite together with titanite).

It is questionable whether the above-described alteration is due to contactmetamorphism. In fact, other diorites, sampled far from the contact, show the same alteration minerals and also, to a certain extent, effects of stress. On the other hand, the distortion in this contact-diorite is so strong that it seems to have had its origin in the "collision" between the optrusive and intrusive diorite and the solid tuff (and diabase) mass.

A 719—D 12687, A 722 and A 723 are quartz-plagioclase-epidote-chlorite-rocks; greeny, schisty and breccious. D 12687 shows a kind of banded structure, that is to say, plicated layers of epidote with some quartz lie between breccious layers, of unequal thickness, of plagioclase and quartz. These breccious layers contain many fragments of strongly squeezed, undulose and bent albites; narrow layers of strongly undulose, stretched quartz grains are woven between these plagioclase fragments. The latter lie in an any-given way with regard to the parallel structure of the rock. The narrow quartz layers contain epidote and chlorite, the latter with greenishbrown interference-colours and occurring as stretched, fibrous masses, which follow the curves of the quartz layers. Magnetite is rare. – These rocks represent no compressed and altered diorites, but probably are the product of solutions (quartz-epidote) which took up diorite plagioclases and crystallized under pressure to a banded-structured rock.

A 720—D 12688 is a quartz-epidote-vein-rock with a kind of banded structure: layers of undulose and dusty quartz alternate with quartz-epidote and epidote-quartz layers. The epidote is brownyellow. Locally, bundles and felt-like aggregates of tiny hornblende needles occur enclosed in the quartz aggregates. – This rock is also a magmatic or hydrothermal product, crystallized under pressure to a banded-structured quartz-epidote-rock.

A 721—D 12689 is an invaded hornblende-schist (metamorphic tuff) with a kind of banded structure; lenses and layers of albite-oligoclase, with many hornblende needles, occur between plicated layers of parallel-structured hornblende aggregate. The latter curves around the hornblende relic-crystals. Beside these relic-crystals which are short-prismatic, a very few hornblendes occur which are long- and thin-prismatic, non-fibrous and cleaved; the latter can probably be considered as bigger crystals, new-made under the influence of a strong contactmetamorphism. Parallel strings of epidote and titanite are also present. – This rock is about the same as the rocks described on p. 23, which have been sampled farther from the contact. It is very remarkable that this rock, which occurs so near the diorite, does not show the typical contact-phenomenon as it has been described in the contactmetamorphic hornblende-schists on p. 99; that is to say, the bigger new-made hornblendes, so abundant in the above-mentioned rocks, are present in but a very small number here.

The veinmaterial in the latter five rocks must be connected with the diorite intrusion. It must have intruded even during the process of folding and must have consolidated under pressure (see the structure). The hornblende needles, chloritized or not, which occur in the veins, may have come into existence in consequence of the hornblendization process which was not yet finished at the time of the vein intrusion, or may have loosened from the hornblende matrix of the invaded metamorphic tuff-rock and enclosed in the veinmaterial; in the latter case the veinmaterial must have intruded after the process of hornblendization had finished (see also the discussion on p. 100).

Hence, this series of contactrocks does not show strong contact-phenomena. At best, the contactmetamorphism was an endomorphic (?) and exomorphic, pneumatolytic-hydrothermal contactmetamorphism, whereby the original tuff-rocks were partly replaced by magmatic or hydrothermal material. As has been manifested above, even the hornblende-schist A 721—D 12689 shows no strong contact-phenomena.

In connection with the above-described contactrocks, some other contactrocks will be described.

1. From a spot on the SW-foot of the Jamanota, where hornblende-schists (originally tuffoid rocks) have been metamorphosed by a quartz intrusion. A 673—D 12673 occurs farthermost from the quartz dike and is a hornblende-epidote-schist (metamorphic tuff). A 672—D 12672 is a quartz-epidote-rock with enclosed parts of hornblende-schist, and lies about 30 cm. from the dike. A 174 is an epidote-bearing quartz-rock and lies between the quartz dike and A 672. The rocks merge gradually into each other. – D 12673 consists mainly of a parallel-structured hornblende aggregate with a minute folding around many epidote grains, epidote aggregates and some hornblende and oligoclase relic-crystals. The rock is somewhat banded-structured because of some layers and lenses of undulose quartz with some chlorite and hornblende fibres enclosed. – D 12672 shows a kind of banded structure of brownish epidote and undulose, parallel-granular quartz. The epidote layers locally contain a parallel-structured hornblende aggregate and also bigger hornblendes.

2. A chlorite-epidote-hornblende-schist A 628—D 12628, sampled near the contact and N of Spaansch Lagoen. Quartz dikes occur in a great number here. The structure of this schisty rock is a little banded. Spherolitic chlorite with brownishgreen, rarely steelblue,

interference-colours and grainy epidote occur alternately (banded) or mixed. Moreover, small prismatic hornblendes, locally in a great number, some quartz and rare magnetite are present. — In the close neighbourhood of these rocks also invaded chlorite-epidote-schists (A 686) and invaded hornblende-schists (A 685) occur.

3. A quartz-chlorite-schist A 675—D 12675 has been sampled as the country-rock of gold-quartz-dikes on the Mira la Mar, near the diorite contact. The rock feels fat and is lustrous, schisty and green; it shows a minute folding. It is a finegrained quartz mass with much chlorite and calcite, which occur as "flames" through the rock (in the sample the darkgreen spots). Moreover some magnetite and brownish leucoxene are present; the rock has been invaded by quartz-calcite.

4. In a place NNE of Spaansch Lagoen too contactrocks have been sampled; A 180 and A 181 are strongly altered diorites which merge gradually via quartz-albite-chlorite-epidote-rocks (A 185, A 186) into invaded hornblende-schists.

5. From the contactzone WNW of Mira la Mar two rocks are known which occur but a few m. from each other: A 709 is an altered quartz-hornblende-diorite, A 708 a chloritized hornblende-schist.

6. In the diorite NNW and N of Spaansch Lagoen rocks transitional between diorite and hornblende-schists have been found in several places. These rocks have different strikes f.i. N 65 E, N 85 E, N 120 E and have a very steep dip. They are quartz-albite-chlorite-epidote-rocks (A 173, A 183, A 724, A 725) and border on diorite or on quartz dikes. This diorite is altered in the close neighbourhood of the schisty rocks and is greeny there.

ROCKS TRANSITIONAL BETWEEN DIABASE AND AMPHIBOLITIC CONTACT-ROCKS

1. Rocks transitional between contactmetamorphic uralite-diabase and amphibole-plagioclase-rock.

Contactmetamorphic uralite-diabases have been described before. In connection herewith two rocks will be described from the hill E of Malmok (NW-Aruba) which are still more metamorphic: A 486—D 12550 and 3394—D 2444 (Delft collection). The rocks consist for the greater part of hornblende. An ophitic texture can be recognized but here and there, although the bulk of the laths do no more exist as such and are composed of a grainy anorthite aggregate. These plagioclase aggregates lie also as irregularly shaped masses between the hornblendes and contain big flocks of ?epidote. The hornblende is mainly developed as rather big, irregularly shaped crystals, non-fibrous and partly cleaved or twinned. The crystals are frayed, and numberless diminutive hornblende needles and prisms occur in the bigger crystals and in the plagioclase aggregates. A few small hornblendes are secondary, idiomorphic and occur especially in the bigger crystals. The common accessory minerals are present.

In A 778—D 13076 (Mira la Mar) we see quartz-hornblende-biotite-diorite with an inclusion of strongly contactmetamorphic uralite-diabase, transitional into amphibole-plagioclase-rock. The diorite forms a dike in diabase and partly resorbed the inclusion. Microscopically the rocks are not sharply bordered. In the diabase an ophitic texture can be recognized with difficulty. The plagioclases have been totally albitized (the diorite plagioclases are also albite!) and strongly sericitized and epidotized. The many new-made hornblendes lie locally so close together that the diabase has an amphibolitic character in such places. The hornblende is here and there chloritized. Titanomagnetite is present in grainy groups. Some quartz and totally chloritized biotite may be diorite material.

No. 3376—D 2426 (Delft collection), sampled on the beach between Bushiribana and Rooi Fluit, probably at Andicouri, is an amphibole-plagioclase-rock, transitional between diabase and amphibolite. It is a massive, granoblastic rock with hornblende and plagioclase in about the same amount, regularly distributed. The hornblende occurs, alternating, as well-cleaved amphibolitic hornblende and as lightgreen, fibrous and partly chloritized hornblende. The basic plagioclase, locally simply zonal, is granular or more lath-shaped, and is in many places diablastically intergrown with the hornblende. The texture has still here and there an ophitic character. Diminutive hornblende needles lie in the plagioclase. Magnetite and titanite are accessory.

So, in this series of rocks the texture changes gradually from a diabasic into an amphibolitic one; here and there together with an increase in hornblende amount.

2. Rocks transitional between contactmetamorphic uralite-diabase and amphibole-diopside-plagioclase-rock.

Some of the contactmetamorphic uralite-diabases, described together with the uralite-diabases, still contain remnants of pyroxene. The contactmetamorphic uralite-diabase 3229—D 2290 (Delft collection; NW of Rincon) also contains pyroxene, however in a secondary phase. The rock has been somewhat invaded by quartz-plagioclase-material and shows an almost totally deteriorated ophitic texture. There is less plagioclase than hornblende. The plagioclase is present for a small part as laths, and mainly as a finegrained aggregate between the short hornblende prisms, many of which are secondary-idiomorphic and many of which contain bubbles of ?Several limonitic grains of colourless diopsidic pyroxene and much ore lie scattered in this rock. -The texture and the occurrence of pyroxene grains stamp this rock as a type transitional between diabase and a pyroxene-bearing amphibolitic rock.

No 3380—D 2430 (Delft collection), found on the beach between Bushiribana and Rooi Fluit, probably at Andicouri, is an amphibole-diopside-plagioclase-rock with diabase relic-features. The structure is massive to slightly parallel. Hornblende and plagioclase occur in the same way as in 3376—D 2426 (see above). The diopsidic pyroxene is the third mineral and occurs more locally as almost colourless grains. Apatite, magnetite and titanite are accessory; also a little quartz is present.

AMPHIBOLITES (AMPHIBOLE-PLAGIOCLASE-ROCKS) (plate II, fig. 2—3).

The amphibolites are no normal amphibolites as have been described f i by GRUBENMANN (19), but – as we shall see below – must be considered as contactmetamorphic rocks. It is better therefore to add the name amphibole-plagioclase-rocks, some of the here-described rocks being rather different from true amphibolites and looking more like real contactmetamorphic rocks. Although the rocks show certain points of distinction, they can, nevertheless, be brought together in this chapter.

Samples: A 550—D 12577; A 566—D 12589; A 576—D 12595; A 586—D 12600; A 587—D 12601; A 588—D 12602; A 589—D 12603; A 590—D 12604; A 591—D 12605; A 592—D 12606; A 603—D 12607; A 604—D 12608; A 605—D 12609; A 606—D 12610; A 611—D 12613; A 615—D 12615; A 616—D 12616; A 617—D 12617; A 618—D 12618; A 625—D 12625; A 626—D 12626; A 627—D 12627; P 79—D 6545.

Macroscopic description: The amphibolitic rocks are finegrained to very finegrained; generally darkcoloured (grayish, greenish, brownish). The colour depends in general on the degree of alteration ("imbibition"). Most of the samples show a more or less schisty habit. The rocks A 550, A 566, A 576, A 589, A 590, A 592 and A 618, however, are massive-granular. The rock A 587 shows moreover a banded and also spotted structure. A 617 has a spotted structure; small black spots are lenses of "unaltered" amphibolite, and lie in a grayish to brownish "altered" amphibolite.

Microscopic description: The structure is parallel in most of the rocks; the parallellism, however, differs for each of them. The hornblende crystals lie roughly parallel, in most cases; D 12600 and D 12608 show a rather good parallellism. A kind of banded structure can be seen in D 12601 and D 12605. That in D 12601 is characterized by an alternation of nodular to long-lens-shaped, darker and lighter green masses; the darker parts contain more isometric and irregularly granular hornblende, the lighter parts contain more stretched hornblendes; these parts merge. – The structure of the rocks which are not schisty in the sample, is massive.

The texture is crystalloblastic. Moreover, it is granoblastic in most of the rocks (also in the rocks with massive structure). Exceptions are D 12600, D 12601 (granoblastic with a tendency towards nematoblastic), D 12608, D 12625 and D 6545 (granoblastic to nematoblastic).

Main constituent minerals: The amphibolites consist mainly of hornblende and plagioclase. The hornblende takes up more room than, about as much room as and rarely less room than plagioclase. The rocks with very much plagioclase and also those with a certain amount of quartz have been secondary enriched with plagioclase and quartz material, very probably (see p. 105). The crystals are, in general, regularly distributed. The hornblendes in D 12577 are much bigger than the plagioclase crystals. D 12602 and D 12616 contain in a few places groups of bigger hornblendes. D 12617 shows more or less lens-shaped parts, which consist mainly of hornblende; these parts lie in an amphibolitic mass, that contains a little more plagioclase than hornblende and that seems to be enriched. There is no fundamental difference, however, between both kinds of amphibolite, which merge. Ore can be found in by far the most of the rocks.

The hornblende is the common green hornblende. In some rocks this mineral is lightgreen to very lightgreen; brownish-green and almost colourless crystals are not widespread. In most of the rocks the crystals are grainy and short-prismatic. D 12600, D 12608 and D 6545 contain prismoid-granular to columnar crystals (long prisms). Beside the common hornblendes very small hornblende needles are present in some rocks; they lie and stick in the plagioclase. – The prismatic crystals are but for a small part quite idiomorphic. The cleavage of the hornblendes is the normal one and their crystal borders are non-frayed. Several of them show twinning. Many of the hornblendes contain diminutive quartz-bubbles, which seem to be connected with the presence of foreign quartz material in many of these rocks (see p. 105).

The plagioclases are in general fresh. In some rocks they contain some epidote and sericite, in connection with the neighbourhood of narrow epidote veins. The plagioclases are granular, rarely prismatic. They occur between the hornblende crystals and do not show own forms. The plagioclase in D 12589 locally occurs in aggregates. The same rock also contains a few laths. In D 12600, D 12601, D 12602, D 12605 and D 12609 plagioclases are somewhat diablastically intergrown with hornblendes, or show a tendency towards such an intergrowth. This kind of texture may be considered as being connected with the ophitic diabase texture (see also p. 102). Only a few crystals show twins or lamels. A few plagioclases show a zonal extinction. The composition of most of the plagioclases is oligoclase-andesine; others are andesine, andesine to labrador, labrador. The plagioclase of D 12589 is bytownite. D 6545, D 12610 and D 12616 contain albite-oligoclases, D 12595 and D 12618 albites. There is a close connection between the composition of the amphibolite plagioclase and that of the plagioclase of intruded material (see below). – D 12605 and D 12617 contain a few bigger crystals, which may be relic-minerals; those of D 12617 enclose hornblende needles.

In some rocks apatite occurs as small needles, especially in the plagioclase. – Magnetite is of a non-frequent occurrence or of a very minor importance in the greater part of the rocks. Other rocks contain much ore as bigger and as many diminutive grains. The ore rarely contains leucoxene (titanomagnetite).

A few and small plates of biotite can be found in D 12617. Chlorite in D 12605 may be newly added or may have originated from hornblende. – D 12600 shows a curious and narrow "Quetsch"-zone, perpendicular to the parallellism; the hornblende crystals in this zone show a very good cleavage.

These amphibolitic rocks always occur in the neighbourhood of the contact, in the NW-corner of the island, in the surroundings of Andicouri and of the Santa Lucia, and — for a small part – in the Seroe Pretoe, N of Savaneta. A 566 occurs on Mira la Mar, A 550 near Baranca Corra and A 576 NW of Rincon [1]).

[1]) Kloos (25) described some amphibolites. The rock 106* is an amphibole-plagioclase-rock enriched with diorite material. The rock 144 has been abusively called by him a fine-grained diorite variety; it is an invaded and enriched amphibolite.

Except A 550, A 590 and A 617, the above-called amphibolitic rocks have been enriched with quartz and/or have been invaded by dioritic material.

The rocks are more or less strongly invaded by magmatic and hydrothermal veins, which are leucocratic. The veins do not only lie parallel to the schistosity. Some rocks have been invaded very strongly so that lenses and layers of the amphibolite lie enclosed in a mass of invasion material.

Except in the rocks D 12600, D 12603, D 12605, D 12615, D 12618 and D 6545, quartz as non-undulose grains between the amphibolitic minerals is present in a smaller or greater amount. The quartzes of D 12601 are partly intensely intergrown with plagioclase and hornblende; the quartz-bubbles in the hornblende are clearly connected herewith.

Some rocks only contain veins of epidote, with or without quartz and chlorite. Most of the rocks, however, also show aplitic veins (dikes). The latter are not sharply bordered on the amphibolitic rock, but merge gradually or more abruptly into this rock. Hence, there is a difference in composition between the central and peripheric parts of such veins. The veins in the various rocks also show differences in composition. – The plagioclase of the true diorite-aplitic veins (dikes) varies in composition from albite to andesine, and is rarely zonal. The quartz is here and there slightly undulose. The hornblende, if present, is irregularly distributed and looks as if it had been taken up from the amphibolitic rock; if the hornblende really does not belong to the aplitic invasion material, it must have been taken up during the genesis of the amphibolite. It occurs as prisms, needles or grains, many of which contain quartz-bubbles and some of which have been partly chloritized. – The vein of D 12613 contains several very big hornblendes which enclose many small plagioclase and quartz grains (sieve texture), and also contains a diverse-fibrous hornblende aggregate. – The vein in D 12626 shows parallel layers of accumulated hornblende crystals, obviously parts of the amphibolitic rock. Accessory minerals in the veins can be magnetite and apatite, possibly also amphibolitic minerals. – The vein in D 12600 contains the same minerals as the amphibolite, but relatively much more plagioclase; some curious, irregularly shaped apatite grains are also present. – The vein in D 12603 consists of grainy plagioclase which is oligoclase-andesine at the borders of the vein (the same composition as in the amphibolite) and albite-oligoclase in the centre. – The veins in D 12608 are plagioclase veins with some hornblende, green biotite and magnetite. The part of the amphibolite which borders on the vein, contains more and bigger hornblendes than the normal amphibolite farther from the vein; in this part the structure is not so clearly parallel, and the hornblendes contain ?quartz-bubbles. – In D 12618 we can see spots with more plagioclase than in the normal rock, and with small hornblende needles and ore. They form the transition into veins of grainy and dusty albite. – Some hornblendes near and in the quartz veins of D 6545 have been chloritized. – D 12616 contains, amongst others, a quartz vein, part of the grains of which show "Streifen." These "Streifen" and also the planes of fluid-inclusions occur mainly perpendicular or parallel to the vein borders. – The veins here and there manifest faults in the amphibolitic rock, f.i. in D 12605.

STRONGLY ALTERED AND INVADED, PARTLY ABERRANT AMPHIBOLITIC ROCKS (AMPHIBOLE-PLAGIOCLASE-QUARTZ-ROCKS)

Under this title rocks will be described which still show much affinity to the described amphibolites, but which have been strongly enriched and partly have a different texture.

A 624—D 12624 (near Santa Lucia) is a pink rock with darkcoloured, parallel layers of small hornblende crystals and magnetite in a granoblastic mass of plagioclase (oligoclase-andesine) and quartz. The grainy hornblende, green to colourless, with many quartz-bubbles, occurs also outside the mentioned layers and between the other minerals. Apatite. Limonite occurs between the crystals (pink colour).

A 620—D 12620 (just S of Tibusji Goudmijn) is an amphibolite with a hardly parallel structure and which has been strongly enriched with quartz and plagioclase (labrador). In a fine-granoblastic mass of palegreen hornblende, plagioclase, quartz and a few small, partly chloritized biotites many bigger, irregularly shaped, green hornblendes occur, which are more twinned and contain more quartz-bubbles than the smaller ones (see also the dark spots in the sample).

A 548—D 12575 (NW of Annaboei) is a massive-structured, granoblastic rock, rich in ore and enriched with quartz and albite. The hornblende is almost colourless to palegreen and partly limonitized. Small aggregates of brown-green biotite occur in the neighbourhood of the hornblendes. The rock has been invaded by quartz–albite material with some hornblende and magnetite; the latter two minerals probably belong to the amphibolite.

A 623—D 12623 (E-slope of the Santa Lucia) is a massive, granoblastic amphibolite, the hornblende of which is partly normal and partly irregularly shaped, lighter green, fibrous or chloritized. These two kinds of hornblende have the same distribution. The plagioclase (labrador) partly occurs as some bigger, non-idiomorphic, strongly altered crystals.

A 577—D 12596 (between Rincon and Quadirikiri) looks in the sample like a dark diorite; the dark parts are very finegrained amphibolite and hornblende crystals. In the slide we see parts of massive, granoblastic amphibolite which gradually merge into the rest of the rock. The plagioclases of the amphibolite are simply zonal oligoclase-andesines; the hornblendes of the borders of the amphibolitic parts contain small plagioclase grains. For the rest, the rock consists of an aggregate of zonal andesines with many, rather big and irregularly shaped hornblendes, which enclose many plagioclase grains (sieve texture). These hornblendes are light- to browngreen, partly chloritized. Locally, big quartzes occur, which also enclose small plagioclase crystals. Moreover, much ore and a little titanite are accessory.

A 573—D 12592 (NW of Rincon) looks a little dioritic and is locally almost exclusively a coarse hornblende aggregate. A narrow aplitic dike merges into the lightcoloured parts of the rock. In the slide, very big, normal hornblendes enclose numerous small plagioclase grains with a varying orientation (sieve texture). Between these hornblendes a finegrained albite aggregate occurs, with secondary minerals and locally with quartz. On the side of the intrusion the rock looks more dioritic: normal, prismatic hornblende, idiomorphic albites and allotriomorphic quartz. Ore is rather abundant.

ROCKS TRANSITIONAL BETWEEN AMPHIBOLITIC ROCK AND DIORITE.

These rocks must be considered as dioritized amphibolitic rocks, that is to say, these rocks must have been flooded in such a way by magmatic material that they have lost their amphibolitic character.

The rocks A 612—D 12614, A 621—D 12621 (E of Plantage Westpunt), A 619—D 12619 (near Druif, NW Aruba), A 549—D 12576 (NW of Annaboei) are darkcoloured, finegrained rocks, invaded by dioritic material; they are allotriomorphic-granulose. The plagioclase is about the same as diorite-plagioclase, and its composition varies from oligoclase to labrador; some of the crystals are clearly bent. Some plagioclases in D 12614 and D 12619 contain microlitic inclusions in the core. The hornblendes are granular to short-prismatic, rarely idiomorphic, and part of them contain quartz-bubbles. They lie here and there in groups, and as very small crystals in the plagioclase. Except in D 12621, quartz is present in a smaller or greater amount. D 12614 contains a few very small grains of diopsidic pyroxene and a single crystal, which seems to have been uralitized along the borders and fissures. Apatite, magnetite and titanite are accessory. – The rock in D 12621 merges into dioritic dike material of plagioclase, quartz, hornblende and chloritized biotite.

A 607—D 12611 (E of Plantage Westpunt) is an orthoclase-bearing quartz-hornblende-biotite-diorite merging into a finegrained, dioritized amphibolitic rock. The diorite is rather rich in quartz and rather poor in dark minerals; the altered amphibolitic rock is poor in quartz and rich in hornblende and does not contain orthoclase. Both rocks have a hypidiomorphic-granulose texture. The hornblende in the altered amphibolitic rock is partly present in groups of small crystals; quartz "drops" occur in and between the grains of these groups. The same rock also contains a very little biotite.

A 563—D 12586 (Sabanilla Abau, SE of Santa Lucia) shows short plagioclase prisms with microlites and recurrence-zones in a finegrained quartz-plagioclase aggregate. This aggregate also contains irregularly shaped hornblendes and more aggregates of hornblendes with numberless quartz-bubbles. In some of these aggregates pyroxene cores can be seen. Chlorite may have originated from hornblende and from biotite. Ore is rather abundant.

Appendix: A 779—D 13077 is an aberrant amphibolite S of Seroe Boonchi, near the contact. The aberrant characters are 1) nematoblastic texture, 2) richness in ore, 3) acidity of the plagioclase (oligoclase) and 4) the presence of several bigger relic-crystals of strongly altered plagioclase and hornblende, around which the small hornblende crystals curve.

HORNBLENDE-GEDRITE-SCHISTS AND HORNBLENDITE-GEDRITITES

Dependent on the smaller or greater amount of plagioclase, the following rocks belong to the former or to the latter group. The rocks are greenish-gray, finegrained and more or less schisty.

A 754—D 13061 (Salinja Druif) and A 755—D 13062 (near Andicouri) are hornblende-gedrite-schists, massive and nematoblastic. They consist for by far the greatest part of common green hornblende and gedrite, and contain but very little grainy plagioclase and quartz. The amphiboles are palegreen to almost colourless prisms, needles and columns of a varying size, which lie in diverse-fibrous aggregates or in radial bundles. The crystals are sound-bordered or frayed. Some of the common hornblendes are twinned. Chlorite occurs here and there between the amphiboles. Magnetite is present as a few grains and crystals.

A 758, A 757—D 13064 (Salinja Druif) and A 610—D 12612 (E of Plantage Westpunt, NW-Aruba) are rocks, transitional between hornblende-gedrite-schist and hornblendite-gedritite.They are massive and roughly parallel-structured, grano- to nematoblastic, and consist for the greater part of common hornblende and gedrite with a little plagioclase and quartz. The common hornblende is green to lightgreen, granular to prismatic, well-cleaved and partly twinned. The gedrite is almost colourless to very palegreen, long-prismatic to columnar. The amphiboles are sound-bordered and contain many quartz-bubbles. The plagioclase is granular and contains many hornblende needles; it is partly-lamelled oligoclase-andesine (D 13064) and labrador (D 12612). A few small biotite plates and magnetite grains are also present. Quartz is a secondary, added mineral (see also the quartz-bubbles in the hornblende) and occurs in D 13064 as grains, in D 12612 in nests. The latter rock contains vein material, merging into the amphibole aggregate; it is an allotriomorphic-granulose quartz mass with plagioclase, some hornblende and ore.

A 756—D 13063 (near Salinja Druif) is a rock transitional between gedrite-schist and gedritite. It is a roughly parallel- and slightly banded structured, nematoblastic rock with much more gedrite than plagioclase. The gedrites are very palegreen, sound-bordered prisms, columns and needles, with ?quartz-bubbles. The plagioclase grains contain many gedrite needles, and are partly-zonal andesines. Some biotite and magnetite.

AMPHIBOLE-DIOPSIDE-PLAGIOCLASE-ROCKS

These rocks too must be considered as contactrocks, occurring in the contactzone of the diabase.

The rocks A 575—D 12594, A 584—D 12599 and A 622—D 12622 are darkcoloured, finegrained, massive-structured and granoblastic, in general amphibolitic.

D 12594 (NW of Rincon) consists of normally amphibolitic hornblende and plagioclase (oligoclase-andesine), many grains and short prisms of palegreen, diopsidic pyroxene, irregularly distributed and locally accumulated, and a little magnetite. Veins of plagioclase.

D 12622 (Seroe Pretoe, N of Savaneta) contains hornblendes of a varying size, a little plagioclase (labrador-bytownite), apatite and magnetite. The diopsidic pyroxenes have a varying size, and are colourless to very palegreen grains and prisms, rarely twinned. They occur especially in intergrowth with hornblende (partly uralitized?). The rock merges into invasion material which is an aggregate of plagioclase grains (labrador-bytownite), working in with each other; the latter show a "Schachbrett" texture and contain quartz "drops" (sieve texture). Locally, bigger quartzes occur between the plagioclases. Flocky epidote is present. The transition part between the two rocks contains normally grainy plagioclase, small prisms and needles of hornblende and grainy pyroxene.

In D 12599 (NW of Arikok) the amphibolite, consisting of hornblende, less diopsidic pyroxene, plagioclase and a little ore, merges gradually into a grainy pyroxene aggregate with ore. At the same time the size of the grains decreases. The amphibolitic rock contains a little more hornblende and pyroxene than plagioclase (andesine). The two former minerals contain bubbles of ?Veins merge rather abruptly in the described rock and consist of plagioclase with or without epidote, sericite, quartz.

A 574—D 12593 (NW of Rincon) is a reddishbrown weathered, darkcoloured, crystalline rock. Big, green hornblendes, big, colourless to very palegreen, diopsidic pyroxenes and big quartzes contain numerous small grains and crystals of labrador, several of which are simply zonal (sieve texture). In several places the plagioclases occur in aggregates, and also a few bigger prisms are present. Magnetite is abundant. The pyroxene shows limonitization and here and there a fibrous alteration.

The dark part of A 582—D 12597 (SW-foot Seroe Boonchi) contains big hornblendes, with many plagioclase crystals enclosed. The small hornblendes and plagioclases constitute an allotriomorphic-granulose texture. Locally, between and in the hornblendes small diopsidic grains occur, with a narrow hornblende rim. Magnetite is widespread. This rock gradually merges into a quartz-rich, aberrant diorite-rock. The hornblendes of this diorite are big, irregularly shaped and contain many roundish to prismatic plagioclases and a very few grainy quartzes (a single quartz is idiomorphic). This hornblende also contains a little chlorite. A single hornblende in the transitional zone contains quartz-bubbles.

J. H. Kloos (25, p. 28) abusively described the rock 141, sampled by Martin near Arashi (NW-Aruba), as an augite-diorite. It is a quartz-plagioclase-diopside-hornblende-ore-rock with a dike of diorite. The pyroxene is granular. The few hornblendes occur as irregularly shaped individuals and also as grainy crystals.

Appendix: Locally in the contactzone of NW-Aruba aphanitic to finegrained rocks have been sampled, which are very rich in quartz and epidote, but which do not occur as dikes or veins. Probably they must be considered as contactrocks.

J. H. Kloos (25) abusively described on p. 27 the rock 140 (near Arashi) as an augite-diorite. It is a quartz-chlorite-epidote-hornblende-ore-rock with here and there amphibolitic parts. The hornblende occurs as small, idiomorphic or frayed prisms, locally with quartz-bubbles. Many very big ore individuals have a grainy titanite rim. Apatites.

A 108—D 12075 (E of Malmok) is an epidote-quartz-ore-rock with some chlorite, apatites and narrow quartz veins.

Similar rocks have been found, probably as inclusions, in the diorite. A 749—D 13056 (ESE of Turibana) is a quartz-epidote-hornblende-biotite-chlorite-rock with a little ore. In one part of the rock hornblende occurs (as small, frayed prisms), in the other part greenish-brown biotite and yellowish chlorite. A 776—D 13074 (in the "rooi" S of Seroe Sumpina, near Seroe Crystall) is a quartz-epidote-albite-hornblende-rock with magnetite, apatite, titanite, and epidote veins. The albite is here and there intensely intergrown with quartz. The hornblende occurs as many long, twinned prisms, green and cleaved, locally accumulated.

GEOLOGY OF THE CONTACTZONES WITH AMPHIBOLITIC ROCKS.

In several places in the contactzone between diabase and diorite the transition diabase → diorite has been studied. Since the contact plane is not vertical, but in many places slowly dips in the direction of the diabase, and since in consequence hereof the diorite underlies the diabases, which are the roof of the batholith [1]), the contactzone crops out here and there as a very wide zone. So f.i. in NW-Aruba and S of Andicouri the great distribution of amphibolitic rocks proves that not far down there the diorite is present and that the contact plane in general must lie about horizontal. In many places too, the contact plane is very irregular, and the diorite sticks in many big tongues in the diabase. Therefore, many of the contacts do not show a regular transition from diabase to diorite in the samples.

1. Contact amphibolitic rocks and diorite E of Plantage Westpunt, NW-Aruba. The samples have been taken here over a distance of about 285 meters in a direction N 160 E. From N to S: *a* amphibolite (A 603, D) → (30m.) *b* enriched and invaded amphibolite (A 604, D) → (30m) *c* the same (A 605, D) → (30m) *d* the same (A 606, D) → (6m) *e* small outcrop of quartz-hornblende-biotite-diorite with inclusions of dioritized amphibolite (A 607, D; A 608; A 609) → (65m) *f* invaded hornblendite-gedritite (A 610, D) → (30m) *g* strongly invaded amphibolite (A 611, D) → (55m) *h* rock transitional between amphibolite and diorite (A 612, D) → (15m) *i* a leucocratic dike, a few m. wide → (25m) *j* quartz-hornblende-diorite (A 613).

2. Contact diabase and diorite NW of Annaboei, NW-Aruba. The following rocks have been sampled here: *a* contactmetamorphic uralite-diabase (A 547, D); *b* enriched and invaded amphibolite (A 548, D); *c* rock transitional between amphibolite and diorite (A 549, D); *d* strongly altered diorite (A 546—D 12573). The plagioclases of the latter rock work in with the quartz here and there or are granular in groups, and contain ore and numerous quartz "drops". Its hornblende mainly occurs in groups of small crystals with quartz-bubbles and as many needles and grains in the plagioclase.

3. Contact diabase and diorite NW of Arikok: *a* invaded, contactmetamorphic uralite-diabase (A 583, D); *b* invaded amphibole-diopside-plagioclase-rock (A 584, D); *c* dike of quartz-hornblende-diorite in diabase (A 424—D 12509). The alteration, the ophitic texture and the presence of a little, partly uralitized pyroxene in the latter roçk are probably connected with the neighbourhood of the contact.

4. Contact diabase and diorite near Baranca Corra. The samples have been taken over a distance of about 25 m: *a* contactmetamorphic uralite-diabase (A 551, D); *b* ditto, invaded (A 552, D); *c* contactmetamorphic uralite-diabase, rich in quartz and invaded by dioritic aplite (A 560); *d* amphibole-plagioclase-rock (A 550, D); *e* quartz-hornblende-biotite-diorite (A 553—D 12580).

5. The Seroe Pretoe, N of Savaneta, consists for a great part of contact-rocks: contactmetamorphic uralite-gabbrodiabases, amphibole-plagioclase-rocks, amphibole-diopside-plagioclase-rocks, more or less invaded by dioritic material.

6. The samples taken from the contactzone NW of Rincon are the following ones: amphibole-diopside-plagioclase-rocks, with quartz or invaded (A 574, D;

[1]) Martin (30) p. 53 did not consider the diabase the roof of the batholith. From his fieldobservations he concluded, "dass der Diabas das Liegende des Diorits ist, welcher "deckenartig sich über die Gehänge der westlichen Kuppen und Hügel ausbreitete und durch "die Verwitterung weit zerfallen ist, so dass er die unterlagernde Formation nur noch unvoll-"ständig verhüllt."

A 575, D); invaded amphibolitic rocks (f.i. A 576, D); amphibole-plagioclase-quartz-rocks (f.i. A 571; A 573, D; A 577, D; A 578); quartz-hornblende-biotite-diorite, a little altered (A 572—D 12591). The occurrence of aggregates of normal browngreen hornblende, parallel- and radial-fibrous hornblende, chlorite, ore and titanite in the latter rock is connected with the close neighbourhood of the contact.

The amphibolitic rocks merge gradually into the diabasic rocks, and in the field can be distinguished from the latter only with difficulty. Both are strongly invaded. The diorite and the contactrocks, however, can be clearly distinguished. Yet, here and there the dark diorite near the contact merges into the strongly invaded and hybrid amphibolitic rocks (transition rocks). A small amphibolite outcrop E of Malmok contains conformable dikes of diorite.

In general, the strikes in the large amphibolite region of NW-Aruba lie between N80E and N100E with locally a dip towards the South. Only a few strikes N50E, N65E and N165E have been found. The strikes in the region NE of Santa Lucia and in the surroundings of Andicouri are about N25E, with local dips towards the East. It must be mentioned that also the hornblende-schists in these regions have aberrant strikes.

GENESIS OF THE CONTACTROCKS, ESPECIALLY OF THE AMPHIBOLITIC ROCKS.

Martin (30) mentioned amphibolitic rocks only from the surroundings of the Santa Lucia and of Rincon. Similar rocks from NW-Aruba have been considered by him as finegrained to aphanitic quartzdiorite, "als lokale Ausbildung ,,des normalen Quarzdiorits" (p. 46). He considers the amphibolites rocks, ,,welche ohne Schwierigkeit mit den Grünschiefern zusammengefasst werden ,,können," ,,und der archaeischen Schichtenreihe angehören" (p. 56). — J. H. Kloos (25) considered the amphibolites a local variety of the diorite, as ,,eine ,,amphibolreiche Ausscheidung im grobkörnigen Quarzdiorit" (p. 68); and remarked moreover: ,,Möglicherweise müssen die schieferigen Amphibolgesteine auf ,,ältere dioritische Ergüsse zurückgeführt werden" (p. 69).

If we take into consideration the transition of diabase into amphibolitic rocks and the occurrence of the amphibolitic rocks between the diabase massives and the diorite batholith, we must come to the conclusion that the amphibolitic rocks represent the very strongly contactmetamorphic diabases. Possibly, the diabase tuffs too have been altered locally into amphibolitic rocks, but no rocks transitional between contactmetamorphic hornblende-schists and the latter rocks have been found. — The amphibolitic rocks between the Santa Lucia and Andicouri border westwards on the gabbro massive of the Matividiri, and more southwards on the diorite. The gabbroic magma of the batholith too must have metamorphosed the diabasic rocks.

The amphibolitic rocks over large distances show a schisty habit with clear strikes which do not differ much from the E-W direction. Therefore, they must have been submitted to the same folding process as that which acted in the diabase-tuff massive. This process must have taken place during and after the metamorphism of these older rocks and, consequently, during the intrusion of the batholith. — There are, however, also amphibolitic rocks which do not show a schisty structure. May be, these rocks came into existence after the process of folding, or they did not react upon this process no more than did the diabases and little altered diabases.

Although the diorite and the diabase are rocks different in age and constitution, the intruding batholith and its contact-action upon the country-rock caused a secondary, gradual transition between both rocks: diabase → uralite-diabase → contactmetamorphic uralite-diabase → transitionrock between diabase and amphibolitic rock → amphibolitic rock → hybrid amphibolitic rock → transitionrock between amphibolitic rock and diorite → altered diorite → diorite. A suchlike transition occurs between the diabase-tuff and the diorite: tuff → little hornblendized tuff → hornblende-schist → transition-rock between hornblende-schist and diorite → diorite; or hornblende-schist → contactmetamorphic hornblende-schist (? → amphibolitic rock).

It is remarkable that this contact series does not occur everywhere in the contactzone. So f.i., the diorite locally borders directly on contactmetamorphic uralite-diabase (see p. 98), whereas in other places different kinds of amphibolitic rocks have developed between these rocks. The dioritic magma can have caused the alteration of the tuffs into contactmetamorphic hornblende-schists or borders on invaded hornblende-schists without strong contactmetamorphism. So, the contactmetamorphism must have been different from place to place.

Since the amphibolitic rocks must be considered as altered diabases and not as a marginal texture of the diorite batholith, it is clear that the contactmetamorphism in Aruba has chiefly been a process of exomorphism. Endomorphism was not quite wanting but must have been of a minor importance. As we have seen, the contactzone has the character of a mutual contactzone, in the sense of LAHEE (26), in several places.

The diorite and the amphibolitic rocks have a different texture and structure but are not so much different in mineralogical composition. This agrees with the ideas of N. L. BOWEN (7), embodied on pp. 197—201 (Effects of magma upon inclusions of igneous origin). The dioritic magma comes into contact with the country-rocks and attacks these rocks, according to BOWEN "reacting with "them in such a manner as to convert them into the crystals with which it is "saturated"; consequently, into hornblende and plagioclase, "at the same time "precipitating a further amount of this hornblende and plagioclase from its own "substance". In this way the diabasic rocks and the diabase tuffs too must have been altered into the different described contactrocks; dependent on the distance from the batholith, this conversion was greater or smaller. Also quartz and biotite which occur in several of the contactrocks must have come into existence in consequence of interaction with the dioritic magma, the latter containing quartz and mica substance. It must be remarked, however, that in some places of the contactzone the conversion of the country-rocks into the crystals with which the dioritic magma is saturated, is not quite carried through; that is to say, in those rocks which occur very near the diorite and still contain primary pyroxene (see f.i. the diabases of the contactzone NW of Shete), and in those amphibolitic rocks with a certain amount of, probably secondary, diopsidic pyroxene. All these pyroxene-bearing contactrocks border on normal quartz-diorite with hornblende and biotite, but without pyroxene. The pyroxene of the amphibolitic rocks, therefore, cannot be the product of a conversion of the diabase into the crystals with which the dioritic magma is saturated.

It can be mentioned here, that the contactmetamorphism of the pyroxene-bearing rocks of the older formation, that of the gabbroid rocks and that of the pyroxene-hooibergites show the same characteristics as to the conversion of their pyroxene into the hornblende with which the intruding dioritic magma is saturated.

Similar contactrocks, as known from Aruba, occur in the Odenwald (Germany) and have been described by VIKTOR LEINZ (27). The amphibolites of the southern Odenwald too must have originated from diabases, ,,Schalsteine" or diabase tuffs, although texture relics are wanting. The original rocks must have been metamorphosed by an intruding diorite. According to LEINZ not only the diabasic rocks have been altered into amphibolite, but also the marginal parts of the intruding dioritic magma have crystallized into pseudo-amphibolitic rocks because of the quick cooling and crystallization (see p. 112). Therefore, these marginal diorites and the true amphibolitic rocks resemble each other very much and show ,,Konvergenzerscheinungen". As far as we can see, nothing points to the probability that the Aruba diorites did crystallize into amphibolitic rocks; they do show, however, a little alteration here and there in the contactzone. The transition rocks on Aruba can all be considered as country-rocks, very strongly altered and flooded by dioritic magma.

INCLUSIONS IN THE DIORITE.

AMPHIBOLITIC ROCKS, OCCURRING AS RATHER BIG INCLUSIONS IN THE DIORITE MASSIVE: In several places in the batholith outcrop, especially in the northern parts, we meet small outcrops of darkcoloured or greeny, schisty rocks with a varying strike. These outcrops are a few meters long and wide, and must be considered as rocks of the contactzone taken up by the dioritic magma. Nevertheless, they are a little different from the described amphibolitic rocks. - A 782—D 13080 (W of Jaburibari), A 783—D 13081 (N of Zumbo), A 784—D 13082 (W of Turibana), A 785—D 13083 (N of Kudawecha), A 786—D 13084 (Jaburibari) and A 787 (W of Turibana) are extremely finegrained, parallel- and partly somewhat banded structured, grano- to nematoblastic rocks. They are chiefly different from the above-described amphibolites in their granularity and in the occurrence of several bigger relic-crystals of hornblende, plagioclase, quartz, and rarely of biotite. These relic-crystals generally do not lie parallel to the schistosity, and the small crystals curve around them. The hornblende relic-crystals are the only ones which occur in all of the rocks, whereas the others only occur in some of them. The relic- hornblendes are non-idiomorphic prisms, partly fibrous or twinned. The relic-plagioclases are zonal labradors (D 13082). The quartzes are roundish or eggshaped grains. D 13084 also contains epidote individuals. A few fibrous biotites and grains of titanite occur in D 13083; the same rock contains parallel strings of biotite and ore between the hornblendes. Oblong quartz nests are present in several rocks. It must be mentioned too that many of the small plagioclase crystals are prismatic, and that several of the small hornblendes of D 13082 have a darker, brown-green core. Some of the rocks contain narrow veins of quartz and epidote. – A 430—D 12515 (NE of Seroe Janchi) is a finegrained, schisty, malchitic-looking rock with a slightly parallel structure, and with several bigger, parallel-stretched, non-idiomorphic hornblendes. Besides, hornblende occurs as small prisms and grains, partly fibrous. Plagioclase is present as partly zonal laths and prisms of labrador, not quite idiomorphic with regard to the hornblende (ophitic relic-texture?). Biotite is the second dark mineral and occurs as very small plates. Quartz mainly occurs in some roundish and eggshaped nests. Apatite, some magnetite and titanite are accessory.

Small Exogenous Inclusions in the Diorite: In several places the diorite contains finegrained, darkcoloured inclusions, roundish, eggshaped or irregularly shaped and of a size from about 1 cm. to 10 cm. These inclusions can be easily loosened out of the enclosing rock or are firmly grown together with the diorite. – A 777—D 13075 (N of Spaansch Lagoen) is an inclusion of contactmetamorphic uralite-diabase with a narrow diorite-aplitic dike. It is curious that this rock has not been totally changed into an amphibolitic rock. A 770—D 13068 (N of Seroe Pretoe, NW of the Hooiberg) is an invaded hornblende-chlorite-schist, roughly-parallel-structured and with a kind of banded structure. The invasion material is albite-oligoclase with some epidote and apatites. A 771—D 13069 (Seroe Janchi) is a quartz-hornblende-diorite with a parallel-structured streak of normal amphibolite. The two rocks do not sharply border on each other. A 772—D 13070 (WNW of the Hooiberg) is an amphibole-plagioclase-quartz-rock with a grano- to diablastic texture and here and there with plagioclase "drops" in the quartz. A 773—D 13071, A 774—D 13072 and A 775—D 13073, found W of the Hooiberg, are dioritized amphibolitic rocks in quartz-diorite. The former are richer in hornblende and ore and do not contain quartz. They are not sharply bordered on the diorite and possess an idiomorphic-allotriomorphic-granulose texture. A slightly parallel structure can only be seen in D 13073. Several bigger, non-phenocrystic plagioclases and hornblendes occur in D 13072. The composition of the plagioclases varies from oligoclase to andesine. The inclusions in D 13071 and D 13072, which lie in quartz-hornblende-biotite-diorite, also contain biotite. That in D 13073, in quartz-hornblende-diorite, does not contain biotite. This mineral occurs in D 13071 as small crystals and as some big, irregularly shaped crystals which wholly or partly enclose non-idiomorphic plagioclases, hornblendes and moreover apatites, titanite and rutile needles (sagenite texture). For the rest, they consist of diorite minerals with normally dioritic properties.

These exogenous inclusions occur in the whole batholithic outcrop and are obviously small stoped blocks from the contactzone of the batholith roof. Just as the rocks of the contactzone the inclusions show here and there a more or less strong dioritization. The enclosing diorites in D 13069 and D 13071 show contact alteration. Their hornblende occurs in aggregates of small crystals. In the former rock quartz occurs abundant in and between the crystals of these aggregates.

Appendix: A 22—D 13085 (Seroe Gerard) is a hornblende-biotite-granodiorite with a darkcoloured segregation, roundish and not sharply bordered. The diorite and the segregation consist of the same minerals and their crystals work in with and between each other. – The segregation consists mainly of very big microperthite individuals (undulose), between which some less big quartz individuals (undulose) occur, the latter allotriomorphic with regard to the potashfeldspar. These crystals contain as oikocrysts a great many small chadacrysts: 1) very small and bigger plagioclase prisms, zonal and of an average composition; 2) hornblende prisms, columns and needles; 3) biotites, several of which have been totally or partly altered into chlorite, titanite and epidote; many of the biotites enclose very small plagioclase prisms; 4) magnetite; 5) apatites. Locally, the chadacrysts lie very close together, so that the oikocrysts cannot be distinguished as such, but still occur between them.

The geological and petrological significance of this segregation is not clear.

LIMESTONE FORMATION[1]).

The limestone is found on Aruba mainly as normal limestone and less as phosphorite-limestone.

The surface of the normal limestone is hard and then shows a "Lapiés" or "Karren" habit, or the rock has a more grainy and softly tuffoid character. The rock has been weathered here and there into a reddishbrown substance, or is covered by limestone fragments and blocks.

At the basis of the limestone beds the rock is strongly conglomeratic and contains fragments (pebbles) and minerals of the underlying older rocks, that is to say, of diorite, diabase, schists, tuffs, and so on. In the upper parts of the limestone covering only the minerals of the older rocks, chiefly the diorite quartzes, can be found. In some places, where the limestone is hardly or no longer present, a covering with pebbles can still be seen; f.i. here and there in the northern regions of the older formation (diabase and porphyrite pebbles) and on the diorite N of Sabana Lodo (aplite pebbles).

Although the limestone occurs in a varying way, the samples can be described together because of the similar composition. The rock is splintery or granular, rarely crystalline, partly porous. The colour varies from white and gray to pinkish, cream- and beige-coloured, yellowish and brownish. Except the limestones found near the uppercourse of Rooi Hundoe, the rocks contain sharply angular, less roundish, quartz fragments in a greater or smaller amount, here and there in a very small amount. Moreover, several rocks also contain some plagioclases, partly chloritized or limonitized hornblendes, pyroxenes, biotites, ore and epidote. Many of the rocks are Lithothamnia limestones. For the rest, their fossil-content is rather varying. The following organisms have been found: *Amphistegina*, *Operculina*, Rotalidae, Miliolidae, Textularidae, Globigerinae, Lamellibranchiata, Gastropoda, Hexacoralla, Echinoidea, Algae. Especially the limestones at the uppercourse of Rooi Hundoe, at Sabana Lodo, and near Seroe Blanco (SE) contain many remnants of, partly "big-bellied", *Amphistegina*.

The following Mollusks, Corals and Echini have been sampled and classified:

M o l l u s c a [2]).

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1) See also the considerations by MARTIN (30) on the "Aeltere quartäre Korallenkalke" (p. 79), "Phosphorite" (p 88), "Jungquartäre Bildungen" (p. 125).

2) The list contains the Mollusks sampled by us (1930) and by I. BOLDINGH (1909—1910). The specimens have been classified with the kind help of Dr. C. G. T. H. BAYER, custodian of the Rijksmuseum voor Natuurlijke Historie te Leiden (Holland). They have been determined through comparison with the recent Mollusks kept in the mentioned museum, and with the material of MARTIN in the Geologisch-Mineralogisch Museum te Leiden (described by J. LORIÉ (29); see also the list of determinations by SCHEPMAN in MARTIN's book, pp. 125—127, M. M. SCHEPMAN (41), L. M. R. RUTTEN (38)). – New species do not occur in the list.

Lamellibranchiata.

Arca deshayesii Hanley - lower terrace SE of Oranjestad; Salinja NW of Oranjestad; left bank of Rooi Taki.

Arca aff. *zebra* (Swainson) - lower terrace SE of Oranjestad. The specimen differs from *A. zebra* in having less strongly developed big ribs, between which about three narrow ribs occur; the central rib of these three ones is the stronger one.

??*Isocardia* - left bank of Rooi Taki. Internal cast.

Chama gryphoides L. - lower terrace SE of Oranjestad.

Lucina aff. *pennsylvanica* Lam. - Salinja Druif.

Lucina tigerina L. - lower terrace SE of Oranjestad. The specimen is aberrant in having a relatively high hinge, and a curved lower part of the posterior border of the ligamental groove.

?*Lucina* - Salinja Druif.

?*Cardium muricatum* L. - left bank of Rooi Taki. The specimen may be too flat to belong to the genus *Cardium*.

?*Cardium* (*Laevicardium*) *serratum* L. - Salinja Druif. Lorié determined similar specimens as *C. laevigatum* (Lam.)

Venus sp. - Seroe Colorado phosphate. Internal casts.

Venus sp. - Ponton; E of Oranjestad. Internal casts.

?*Tapes* - left bank of Rooi Taki.

Tellina ?cf *fausta* Donovan - Seroe Colorado phosphate. Internal casts. The pallial line is a little aberrant, but still lies within the range of variation of *T. fausta*.

Pecten (*Chlamys*) (*Plagioctenium*) *concinnatus* Woodr. 1925 - left bank of Rooi Taki; E of Oranjestad; Boegoeroei. The specimens show concentric lamellae also on the lower part of the ribs. In the description by W. P. Woodring ("Mioc. mollusks from Bowden, Jamaica" - Contr. to the Geol. and Pal. of the W.I., Publ. of the Carn. Inst. of Wash. 366—1925, p. 70) the specimen (a left valve) lacks the mentioned lamellae, although the figure shows them clearly on the lower part of the ribs. - The right valve (not known to Woodr.) is a little more inflated than the left one.

?*Chlamys sp.* or ?*Pecten sp.* - NE of Oranjestad.

Ostrea frons L. - left bank of Rooi Taki.

Gastropoda.

Trochus (*Livona*) *pica* L. - Seroe Colorado phosphate. Internal molds.

Bulla media Phil. - Salinja Druif

Coelenterata[1]).

Anthozoa, Hexacoralla.

Eusmilia fastigiata (Pallas). -

Isophyllastrea rigida (Dana). - Rec. Although the specimen is somewhat rounded-off, the toothed septal margins still can be clearly distinguished. Calice 7—11 (15?) mm. (properly speaking 7—24 mm). Septa 10—14 (15?) per cm. Septa in calice 29—50. More or less hemispherical (diameter 7 mm, height 4 mm). Corallites generally polygonal.

Meandrina cerebrum (Ell. and Sol.).

Orbicella annularis (Ell. and Sol).

Orbicella cavernosa (L.).

Antiguastrea cellulosa (Duncan) Vaughan. - Seroe Colorado. Vaughan 1901 determined the specimen, sampled by Martin, as *Orbicella tenuis* (Duncan). According to Vaughan this species points to Oligocene. Since both Martin and Boldingh sampled this species in the Seroe Colorado phosphate, it is very probable that the fossils occur here in situ and

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[1]) The corals have been classified by P. J. Pijpers and comprise the specimens sampled by Boldingh and those sampled by us. For literature see f.i. Rutten (38), Vaughan 1901 (46) and Vaughan 1919 (Fossil corals from Central America etc. - Bull. U.S. Nat. Museum, 103, 1919, pp. 189--524).

that they are no derived fossils. If the sp. is really Oligocene, part of the Seroe Colorado limestone must be Tertiary. [1])

Colpophyllia natans (Müller).

Agaricia agaricites (L.).

Siderastrea siderea (E. and S.).

Pocillopora cf. *guantanamensis* Vaugh. 1919. – Near Dos Playa. According to VAUGHAN (1919 p. 343 and p. 344) this sp. is of the age of the Antiguan Oligocene (Cuba). The Aruba specimens, however, occur in the lower terrace, which consists of quaternary limestone.

Stylophora sp. – Seroe Blanco (NE of Oranjestad). According to VAUGHAN (1919 p. 334) the stratigraphic range of the genus in America is from the upper Eocene to Miocene. The Seroe Blanco limestone, however, is very probably of a quaternary age. The calices of the Aruba specimen are maximum 1 mm, mostly $^3/_4$ mm. The distances between the calices are maximum about $^3/_4$ mm, mostly very small. 6 Septa. Here and there hardly an indication of a second cycle.

Stephanocoenia intersepta (Esper).

Dichocoenia sp.

Acropora muricata (L.).

Acropora palmata (Lam.).

Porites astreoides Lam.

Porites porites (Pallas).

Hydrozoa, Hydrocorallinae.

Millepora alcicornis L.

Echinodermata.

Agassizia conradi (*Hemiaster* Bouvé 1851). – Left bank of Rooi Taki. In the West-Indies this species is only known from the Eocene.

Clypeaster antillarum Cotteau 1875. – Left bank of Rooi Taki. This species is known from Eocene, Oligocene and Miocene (also recent?).

As to the Mollusks MARTIN, LORIÉ and SCHEPMAN accept a quaternary age for the Aruba specimens: 48 species. *Pecten concinnatus* is the only fossil Mollusk which is miocene (Bowden, Jamaica), as far as is known. It occurs in the left bank of Rooi Taki, in the beds of Boegoeroei and in the terrace E of Oranjestad, probably in quaternary limestones. The two Echini are eocene to oligo-miocene, as far as is known, and occur in the beds of the left bank of Rooi Taki, as well as the ?miocene *Pecten concinnatus*. These beds contain quaternary fossils (Mollusks) as well. — Most of the corals of Aruba are quaternary or even recent: 16 species. (Among these species also *Favia fragum* Esper. and *Maeandra strigosa* (Dana), sampled by MARTIN, are reckoned). *Antiguastrea cellulosa* from the Seroe Colorado may be oligocene. *Goniopora regularis* (Duncan) VAUGHAN 1919 (= *Alveopora regularis* Duncan, in VAUGHAN 1901), from the Seroe Colorado and sampled by MARTIN is oligocene too, according to VAUGHAN. *Pocillopora* cf. *guantanamensis* may be Antiguan oligocene. *Stylophora sp.* may be eocene to miocene. The two latter species, however, occur in the lower terrace limestone, which is quaternary, all but certailnly.

These fossils and the absence of Orbitoid Foraminifera make it obvious that at least by far the greatest part of the limestone is of a Quarternary age. However, Tertiary formations are not entirely wanting on Aruba, in view of the fossils. One

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[1]) Other corals and also mollusks occurring in the Seroe Colorado limestone and phosphate are, however, of quaternary age.

sample (D 13254), from Butucoe (see the map "T"). must be certainly Older or Middle Tertiary. This limestone is a beige-coloured, somewhat splintery limestone without quartz fragments or other minerals. It contains, beside Globigerinae, Textularidae, Miliolidae, Lamellibranchiata and Lithothamnia two species of *Lepidocyclina*. Hence, this rock can be Upper Eocene to Lower Miocene.

Phosphatized limestones occur mainly in the SE-corner of Aruba: Culebra, Seroe Colorado. Near Butucoe, near Pedro Mosa and elsewhere small phosphate spots occur among the normal limestone. The phosphates look breccious; they may contain a certain amount of calcite and grains of quartz. Organisms cannot be recognized except corals. The rocks 3206—D 2262 to 3210—D 2267 (Delft collection) and P 209—D 6563 from the Culebra show the phosphate sharply bordered on and as rounded-off fragments in white or brownish limestone. The phosphates are conglomeratic where they lie just above the older rocks (diorite).

GEOLOGY OF THE LIMESTONES AND THE PHOSPHATES.

The limestone lies unconformably on the two older rockformations which must have been denuded for a great part already before the deposition of this younger formation. Since in almost all of the examined limestone samples – taken from places a few dm. to more than 10m. above the older rocks – quartz occurs as acute-angular, rarely as rounded-off fragments, we can accept all but for certain that only part of the island was under sealevel during the deposition of the Quarternary limestone. Such quartz fragments have been found in the limestone of the higher situated and dipping beds as well as in the rocks of the surrounding low terrace. It must be mentioned that the Tertiary limestone from Butucoe does not contain quartz fragments. May be, the Tertiary sea covered the whole island (compare with Curaçao – G. J. H. MOLENGRAAFF (31, pp. 5—6 and 25)–and with Bonaire (34)).

The limestone covering has been partly denuded and today it is found especially in the Southeastern part, further as a zone, about 2km wide, along the S- and W-coast, and as a narrow, frequently interrupted border along the N-coast. Only in a few places the limestone occurs as isolated and small coverings on the older rocks, f.i. those in NW-Aruba, Seroe Pela, Seroe Plat, near Andicouri, near Dos Playa.

If we accept that already during the deposition of the younger limestone the NE to E tradewinds existed, it is evident that the varying development of these younger limestones along the S- and W-coast and along the N- and NE-coast may be sought in the different conditions on these coasts.

The higher situated limestone beds have a thickness which varies from 1m. to more than 15m.; they show a varying strike and dip:

On the inner side (land side) of the wide zone along the SW- and S-coast, from Ponton o Seroe Colorado: N 90 E to N 140 E with dips towards the S and SW; the latter are on the whole slight, but vary from 0° to about 40°. – Exceptions: San Barbola N 60 E, 25 S; a small outcrop W of Seroe Bientoe, near Plantersrust, N 60 E, 30 N and N 120 E, 30 S (double plunging anticline?); part of the Culebra (SE-Ar) with eastward dipping beds.

The large limestone plateau between Seroe Blanco, Fontein and Baranca Corra is about horizontal; the part N of Seroe Blanco may dip slightly eastward.

The small higher limestone plateaus in NW-Aruba about horizontal or slightly dipping eastward.

Seroe Pela about horizontal.

E of S. Pela slightly dipping towards the SE.

Seroe Plat N 130 E, 30 SW in the S-part, about horizontal in the N-part.

Boedoei beds dip 15° towards the NE.

Small plateaus W of Boca Prins horizontal.

Boegoeroei (W-Aruba) N 10 E, dip slightly to 30° towards the W.

The younger and lower limestone terrace, the thickness of which varies from 1m. to more than 15m., and the altitude of which on the coast varies to max. 10m. (Nanki, near St. Nicolaas, see topographic map), shows a varying width and its surface lies about horizontal or dips very slightly towards the neighbouring sea. There are the following particularities. A slight "anticline" with an E—W axis occurs just W of Noordkaap. — S of Rincon the terrace occurs as two terraces (elevated beaches), separated by an escarpment which lies between the 5m and 10m contour line; more southwards this escarpment is absent and there the lower terrace dips slowly towards the E.—N of the Seroe Grandi (N-Ar.) two levels, separated by an escarpment or a steep slope, can be found lower than the 5m. contour.

The higher situated limestones (altitude 10m. to about 135m.) are bordered by the lower terrace limestone on the seaside (altitude to about 10m., maximum to 20 m.). In many places the higher and the lower limestone merge or seem to merge gradually. In the surroundings of Fontein and Rincon the higher and lower terrace are sharply separated by a vertical escarpment. This escarpment lies on the 20m. contour line or there abouts and is also present in some places along the S-coast (see the topographic map).

Comparing the dips of the higher situated beds we must come to the conclusion that, before the denudation, the limestone must have been present as a slightly arched cap over a great part of the island. The culmination of this brachy-anticline lies nowadays along the NE-coast. Very probably the dips of this anticline are no primary dips and are due to slight orogenic movements. A result of these orogenic movements may be also a limestone troughfault of 10m. wide, 100m. long, in the direction N 100 E, on the plateau of Baranca Kasioenti.

The phosphorites on the Seroe Culebra and the Seroe Colorado are altered, higher situated limestones. The phosphatization has occurred after and during the deposition of excrements of seabirds (guano); see MARTIN (30) p. 93. It is curious that just E of the top of the Culebra, in an old phosphate working, the phosphate beds dip towards the E and are covered by organic limestone with Serpulae (P 209—D 6563) which contains at its basis rounded-off fragments of the phosphorite; the thickness of this bed is 1—2m (This profile was already known to Ir. G. DUYFJES; see also MARTIN (30, p. 94)). Consequently, after the phosphatization different changes in level must have taken place.

Very young limestone deposits occur f.i. in Rooi Prins (with fragments of hornblende-schists, diabase and quartz), in the Boca W of Noordkaap (cemented diabase pebbles), and in Boca Poos di Noord (cemented limestone sand). — In the "rooi" S of Seroe Largo a rock occurs which is very probably a "rooi" deposit with a limestone cement (N 60 E, slightly dipping towards the S.).

Before and about parallel to the S-coast a long, frequently interrupted shore-coralreef rises for the greater part above sealevel. As we can see on the map the lagoon has a varying width and here and there the reef meets the coast. The reef lies on the seaside of a plain of abrasion, and has been partly brought above sealevel by a subrecent descent of the sealevel (see the chapter geological history). — It is clear, that in consequence of the tradewinds and a rapidly increasing depth a coralreef could not grow along the E- and NE-coast. In front of the W-coast only separate coralstocks are met with. The growth of a reef may have been prevented here on account of the strongly sandy character of the covering of the plain of abrasion. — The very low peninsula of Taratata probably must be reckoned too among this very young reef-formation. Between Punta Braboe and Oranjestad, just NE of the lagoon, an abrasion escarpment, 1,5—2m high, separates the lower terrace — which has an altitude of less than 5m here — and the abrasion plain upon which the reef came into being. Along the S-coast similar escarpments occur here and there.

DETRITUS DEPOSITS, DUNES AND PEAT. SOME YOUNG GEOLOGICAL FEATURES.

Especially along the S- and W-coast large deposits of detritus occur, mainly of diorite detritus (sandy detritus). These deposits are typical "rooi" deposits and originated from the hills in the central parts of Aruba. The detritus lies on the younger terrace limestone or on the older rocks. In many places the younger limestone must have been removed and replaced by detritus. In some spots the limestone lies on diorite detritus, which must be older; the upper part of this detritus has been cemented by limestone. Here and there along the S-coast the detritus occurs as a delta-formation. "Rooien" occur in the deposits to a few meters deep. Two areas of diorite detritus SE of the Hooiberg, which lie in the midst of diorite and which are some meters thick, have probably been deposited during a period in which the base-level of erosion of the island was a little higher; these deposits have been dissected by the present "rooien". In some places the detritus is in the depth a hard, loamy rock, rich in sand and small gravel fragments [1]). - (plate I, fig. 2).

The coastdunes, partially composed of limestone-sand, partially of quartz-sand (depending on the place of occurrence) occur on the E-, NE-, N- and W-coast. They lie on the detritus deposits or on the terrace limestone. South of Rincon they partly cover the three terraces. — On the terrace along the N-coast we find here and there heaps of limestone and coral fragments, thrown up by the waves.

Small peat deposits were found in the subsoil of the "rooi"-mouth just SE of Oranjestad, during the foundation working of a bridge. It seems that they also occur in the "rooi" just SE of the Canashito(?).

As in Curaçao (f.i. Schottegat) some handshaped inlandbays with a junction-canal to the sea occur on Aruba on the S-, W- and N-coast. In distinction from the Schottegat they are entirely dry, except the Spaansch Lagoen junctioncanal. As to their genesis, see G. J. H. MOLENGRAAFF (31, pp. 8—12), and MARTIN (30, pp. 119—124).

The E-, NE- and N-coast show many undercuts, wavecut chasms and coves in the rocks, the socalled "boca's", which owe their existence to the tradewinds.

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[1]) MARTIN near Santa Cruz sampled finegrained, lightgrayish to yellowish sandstones with only very little cement. He described them briefly on p. 60 (30) as "Geschiebe" in the chapter "Kreide formation?". This rock proved to be cemented diorite-quartz detritus, psammitic, porous and with a slightly stratified structure. The cement is brownish and siliceous with here and there accumulated muscovites. The allogenic constituents are by far the greatest part acute-angular, less rounded-off, diorite-quartzes. Also a few muscovites, hornblende grains, microclines, tourmalines and ore grains are present.

In distinction herewith the S- and W-coast show large deposits of detritus and a gentle course of the young shoreline. — Where no older rocks form the coast and no terrace coast exists, a sandy beach can be found.

In the large diorite plain of W-Aruba many typical coves occur in the big diorite blocks (plate I, fig. 3). These coves must have been formed during a transgression period. They occur to an altitude of about 70m. and have their openings almost exclusively on the W-, SW- and S- side of the monoliths. A very few coves have their opening on the NW- or N-side; a single one has been found on the SSE-side of a block [1]). The same transgression caused the forming of coves in the higher situated limestones. These can be very well seen f. i. in the escarpment near and SE of Fontein (20m. contour line). The large caves in these higher limestones are for the greater part the result of "Karst" phenomena (sinter deposits). The bottom of many of these caves is covered with excreta of bats. — See also MARTIN(30, p. 106) "Erosion durch das Meer".

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[1]) In connection with the distribution of these diorite coves MARTIN indicated in his map the "alte Meeresbucht" (see also MARTIN p. 48). In view of the small number of observations by MARTIN and of the only partial exactness of his map, this line indicating the "alte Meeresbucht" is only right to a certain extent.

MINING ON ARUBA.

In the nineteenth and in the beginning of the twentieth century Aruba exported some gold. The latter was won partly from the many goldbearing quartz-dikes in the batholith and in the older formation, especially in central, NE- and N-Aruba, and partly from the placers (alluvial detritus deposits). Since about 1914 the exploitation has been stopped. Also the phosphateworking in Seroe Colorado came to an end. Traces of this gold and phosphate mining can be found in several places of the island (see also the topographic map). For further details concerning the occurrence, the mining in the course of years and the economy of these two minerals, see the older literature of Aruba (f.i. MARTIN (30) pp. 60—67 and pp. 88—101).

Instead of the gold- and phosphateworking other exploitations have been started, a short time ago. They are the mining of quartz for highway construction (the quartz was used in the foundation of the new road between Oranjestad and Sint Nicolaas) and the digging away of socalled "fresh sand" (diorite sand) for the fabrication of concrete and cement (C. P. I. M.). These exploitations too have been put an end to after the quartz and the "fresh sand" were no more in demand.

GEOLOGICAL HISTORY OF ARUBA.

The oldest rocks known in Aruba are very probably of a Cretaceous age. They are volcanic products, partly deposited in a shallow sea. Probably in that time Curaçao and Aruba must have formed one country, for diabase pebbles on Aruba very much resemble the diabase rocks of Curaçao. At the end of the Mesozoic time or at the beginning of the Tertiary period this volcanic rockseries was folded in the depth [1]) (E-W strikes) and at the same time intruded and metamorphosed by a diorite batholith magma with its various differentiates. After that, a strong denudation [1]) must have taken place, which removed the greater part of the batholith roof and the highest parts of the batholith itself. — Tertiary limestone has been found only in one place with certainty. Its age could not be exactly determined and lies between Upper Eocene and Lower Miocene. – As far as we can see, by far the greatest part of the Aruba limestone is Quaternary. Except during the deposition of the mentioned Tertiary limestone Aruba must have been above sealevel in Tertiary time and must have been subdued to denudation; at all events, no other Tertiary rocks have been found (only some possibly Tertiary fossils). In older Quarternary time a positive change in level, by which the greater part of the island came under sealevel, caused the deposition of limestone upon the denuded and abraded older rocks and partly upon their detritus. After that, a slight, ?asymmetrical upwarping of the limestone beds must have taken place, for the higher situated limestones occur today as a slightly arched cap with a pitching axis about NW-SE (main axis of Aruba), partly removed. In consequence of this upwarping and a negative change in level (probably in connection with the beginning of the Glacial Period) the older rocks and the limestone in the central parts have been eroded, and their detritus has been partly deposited upon the plain of abrasion which has been formed at the same time at the border of the island. The positive change in level after the Glacial Period may have caused the deposition of younger limestone on the plain of abrasion, the forming of coves in the older limestone and also of the coves in the big diorite blocks. The latter coves occur today to about an altitude of 70m, and have their opening in general on the W- and SW-side of the blocks. So, the higher parts of the island have not been under sealevel during that time. An upheaval of the island followed on this

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[1]) Probably, younger Cretaceous rocks (compare with Curaçao) have been present above the volcanic series, but have been removed without leaving traces. Only one, rounded-off, Cretaceous Ammonite, found in the Quaternary Seroe Colorado phosphate, may have originated from younger Cretaceous beds which occurred on or in the close neighbourhood of Aruba (see MARTIN (30, p. 60); this fossil very much resembles *Ammonites Treffryanus* Karst., known from Cretaceous beds near Bogota).

transgression. A plain of abrasion was formed on the younger limestone (still present today), together with the escarpment in the older limestones (today on the 20m. contour line). A second and very small upheaval caused the genesis of a second plain of abrasion in the younger limestone here and there (f.i. S of Rincon), separated from the former by an escarpment and a little lower. On the seaside of a submarine plain of detritus or of a plain of abrasion (in the latter case another pair of changes in level must be accepted) along the SW-coast, a coralreef grew and persisted (shore-coralreef along the SW-coast). The subrecent descent of the sealevel of some meters (5—6m.; R. A. DALY (13) p. 174) brought the younger limestone and also this coralreef above the sealevel for a great part [1]). The recent denudation of the island began, and big masses of detritus, especially of diorite detritus, were deposited on the terrace limestone and in the lagoon. Dunes came into being along the W-, N- and E-coast, "boca's" along the N- and E-coast. The handshaped inlandbays with a junctioncanal to the sea, which are a "rooi"-system and which are almost (Spaansch Lagoen) or quite dry (f.i. Druif, N-Aruba), may have been formed already during the Glacial Period. The two areas of diorite detritus SE of the Hooiberg, which lie in the midst of diorite, have originated from a time before the subrecent descent of the sealevel, when Aruba had a higher base-level of erosion; today these detritus deposits are dissected by the "rooien". — The valleys in the older formation contain here and there very young limestone, just as the "boca's". The rare peat deposits also must be very young.

It must be remarked that the younger history of Aruba and the occurrence of the limestones agree very much with those of Curaçao (see G. J. H. MOLENGRAAFF (31, pp. 6—12), and (32, pp. 683—687)). MOLENGRAAFF called the older limestone Pleistocene and the younger limestone Holocene.

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[1]) The given history of the younger movements is the most simple one. It goes without saying that the geological data can be interpreted in a more complicated way too, in accepting more changes in level.

As far as we can see, the occurrence of the relevant terraces does not plead against their genesis in consequence of an upheaval or descent of the island. Indeed, the occurrence of the terraces is defined mainly by the mentioned subrecent descent of the sealevel, and by the following erosion. The upheaval and descent of the island must have occurred in a somewhat vertical direction.

CORRELATION OF THE TWO OLDER FORMATIONS ON ARUBA WITH THOSE ON OTHER ANTILLEAN ISLANDS [1]).

Aruba lies tectonically much higher than Curaçao and Bonaire because of the higher upwarping of the Mesozoic rocks, and therefore shows a much deeper denudation [2]). In this way it can be understood that today only the deeper parts of the Cretaceous formation are still present on Aruba, and that a very big part of the quartzdiorite batholith crops out there. Rocks, however, older than Cretaceous and lying under the diabases and tuffs, do not crop out, as far as we know.

Diabase-Diabasetuff formation: This formation can be compared with the diabase formation and the lower beds of the Knip formation on Curaçao (MOLENGRAAFF (31)). The great resemblance between some of the Aruba and the Curaçao diabases, and the occurrence of a conglomerate with Curaçao diabase-pebbles on Aruba point to similarity. — The older formation can also be compared with the lower parts of the Washikemba formation on Bonaire, in which diabases and diabase-tuffs predominate. The diabases on the two islands resemble each other more or less (KLOOS (25), PIJPERS (34)). — As far as we know, diabasic rocks do not occur on the Venezuelan islands between Bonaire and Trinidad. The amphibolite, the different kinds of green schists with hornblende, epidote, chlorite and albite, and the metamorphosed porphyrites on Orchila (see L. RUTTEN (39) pp. 1106—1108) may be compared with the strongly contactmetamorphic and dynamometamorphic rocks in the older formation of Aruba. — Although only the lower parts of the older formation on Aruba have been preserved, this formation as a whole must be the same as the late-Cretaceous volcanic series in the West-Indian islands ?Cuba, Haiti, San Domingo, Jamaica, Porto Rico, the Virgin Islands, St. Croix, St. Barts, St. Martin, ?Anguilla, ?St. Kitts, Antigua. — W. SIEVERS (42) mentions the occurrence of diabase on the peninsula of Paraguana, the part of Venezuela which lies nearest Aruba.

Quartzdiorite batholith with differentiates: Rocks similar to the batholithic and dike-rocks on Aruba occur in NW-, central and E-Curaçao, but do not take up much room there (MOLENGRAAFF (31, pp. 49, 57—58), VERMUNT-M. RUTTEN (50), PIJPERS (35)). In Bonaire the batholith must lie still deeper than in Curaçao. Only one outcrop of a porphyritic quartz-hornblende-diorite dike has been found in the diabase near Seroe Grita Kabai (PIJPERS (34)). — In many of the

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1) See for the correlation of the limestone formation G. J. H. MOLENGRAAFF (31, pp. 60—61) and L. RUTTEN (39, p. 1105). Concerning a comparison between the three Dutch Leeward Antilles and the adjacent regions, see L. RUTTEN (40, pp. 439—440).

2) In this connection it is worth to mention that Aruba lies nearest the South American continent.

islands between Bonaire and Trinidad rocks occur which are comparable with the plutonic and dike-rocks of Aruba, being of about the same constitution and ?age. These islands are El Roque, ?Orchila, Blanquilla, Los Hermanos, Los Testigos (L. RUTTEN (39)). — Intrusions of youngest mesozoic or eocene quartz-diorite in mesozoic rocks, folded in the same time, occur in Mexico, ?Jamaica Cuba, ?Haiti, ?Santo Domingo, Porto Rico, the Virgin Islands, St. Croix, St. Martin, ?St. Barts. — About the occurrence of igneous rocks in NW-Venezuela consanguineous with the intrusive rocks on Aruba or not, and of about the same age or not, see L. RUTTEN (39, pp. 1108—1110). As to a general view concerning the igneous rocks of the Western Cordillera of South America, see f.i. IDDINGS (22, pp. 489—491).

A FEW CONSIDERATIONS ON THE GEOHYDROLOGY.

Since the underground of Aruba consists by far the greatest part of igneous rocks, rather deeply weathered, that is to say of diabasic and dioritic rocks, it is clear that this underground must act as a rather good water reservoir.

The hilly older formation, poor in vegetation, is not suitable for the purpose of winning water, except in the lower course and the mouth of the big "rooien", f.i. of Rooi Prins. The "rooien" with a bed of metamorphic tuffrocks — the latter may be looked upon as not permeable for water — might receive consideration in view to a contingent damming up, f.i. the mentioned Rooi Prins. — The spring of Fontein occurs on the boundary (plain of abrasion) between the limestone covering and the underlying older formation. The plain of abrasion of the older formation must dip slightly to the N here.

The detritus of the batholithic outcrop, and - to a certain extent - also the limestone prevent much rainwater from flowing off, and retain it. Since the higher diorite hills lie along the N- and NE-coast, and the large and flat detritus plains and limestone areas lie on the S- and W-side of the island, water may be won best in W- and S-Aruba. The wells can be made in the lower limestone terrace along the W- and S-coast as well, the limestone covering here being only a few meters thick and overlying diorite and detritus. Still, as some wells prove, water can also be won in the higher diorite hills [1]. — Since the landscape is very flat in the mentioned S- and W-parts of the island, it will be difficult to dam up the "rooien" here. Such damming up will effect inundation over large areas in times of strong rainfall.

It must be remarked that already many wells have been constructed in the mentioned regions suitable for the purpose of water-winning. For the greater part they contain fresh or almost fresh water.

About the geohydrology see further: MARTIN (30, pp. 113—118); MOLENGRAAFF (31, deel 2, p. 97); Ir. G. DUYFJES (17).

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[1]) MARTIN remarks on p. 118, "dass das östliche Kalkplateau für die Wasserfrage "bedeutungslos ist, da die Schichten sich hier in schwebender Lage als Hangendes der Felsen- "meere von Diorit und nur in geringer Höhe über dem Meeresspiegel befinden."

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CONTENTS

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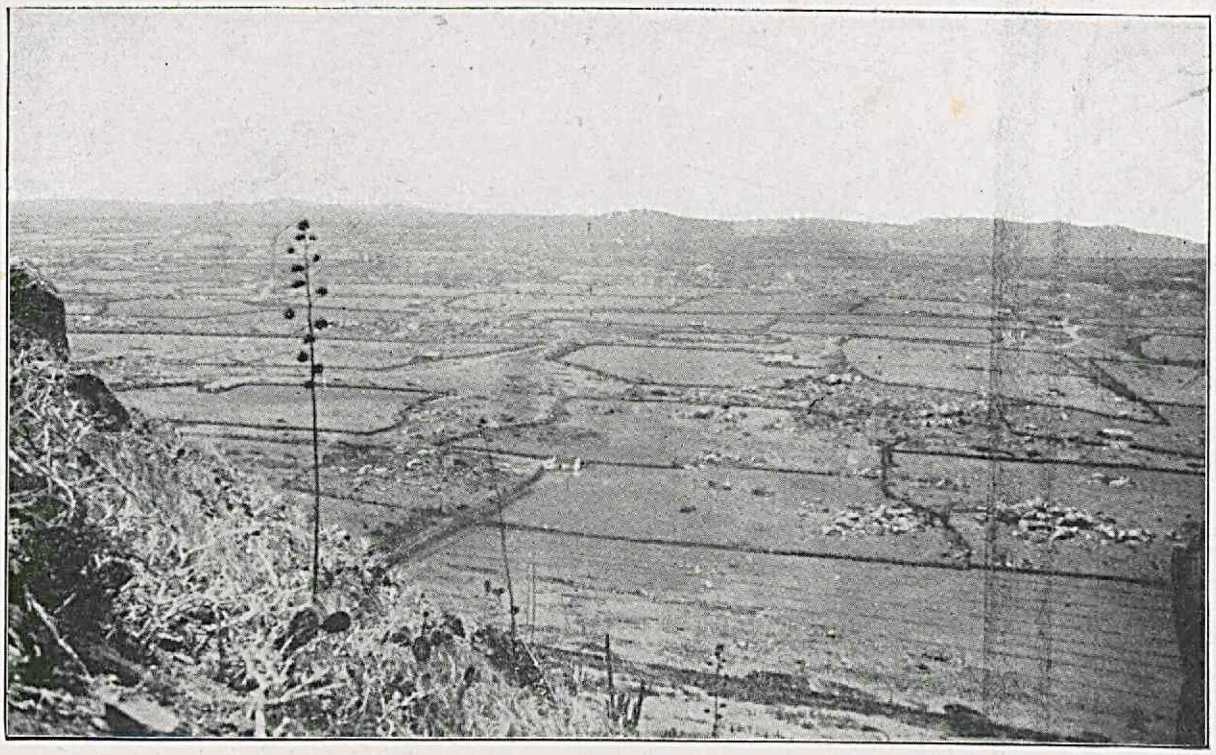

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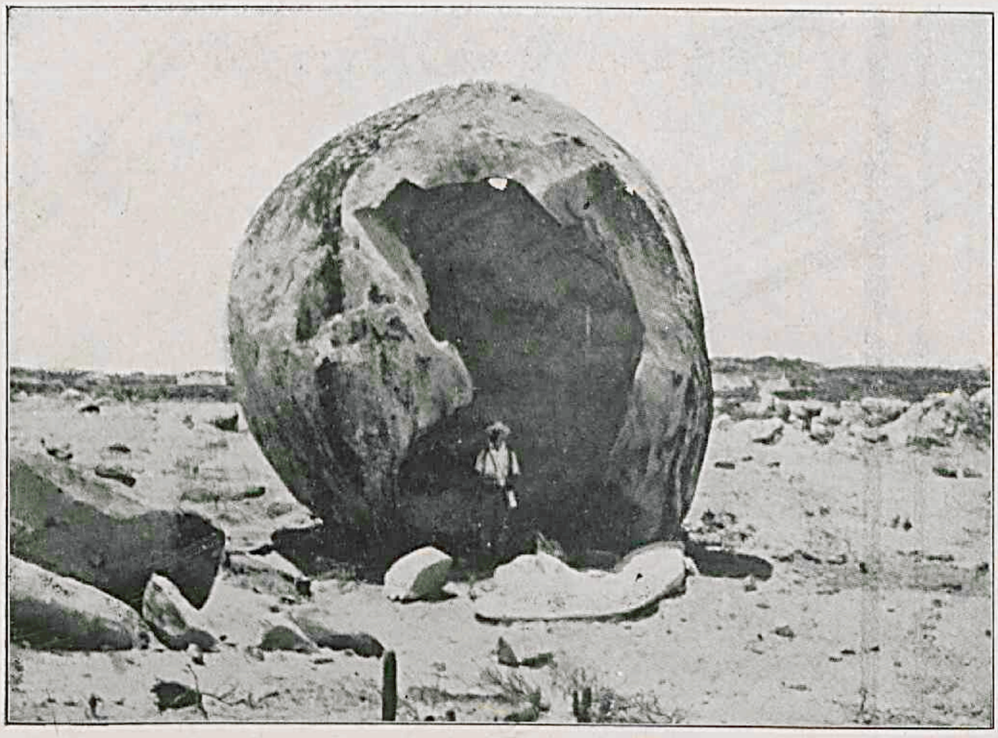

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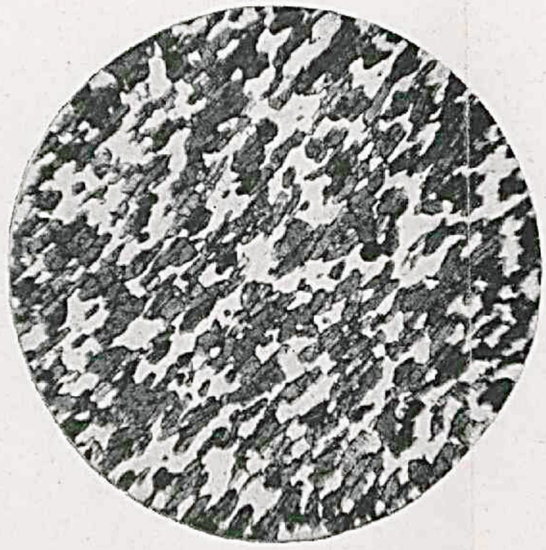

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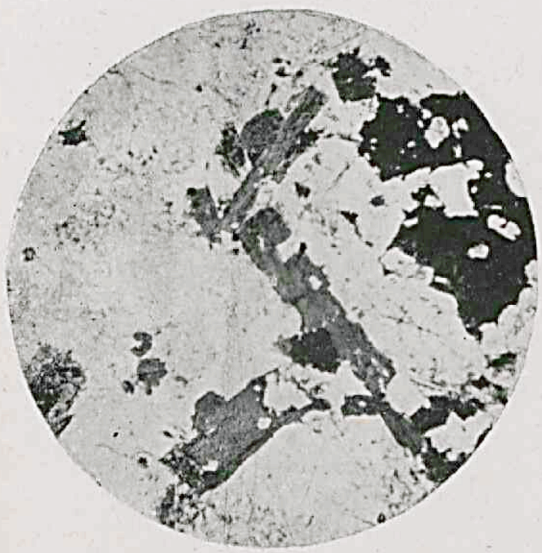

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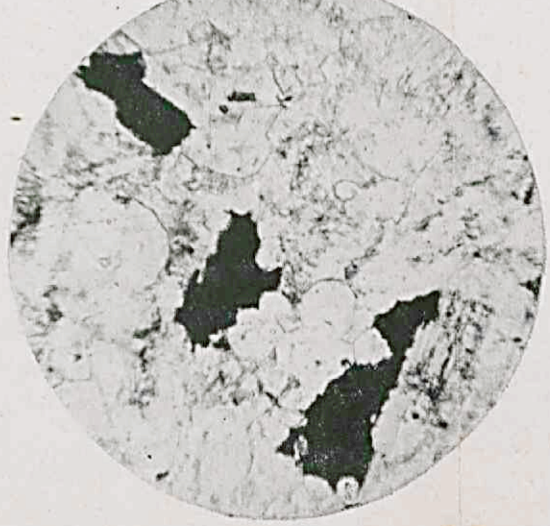

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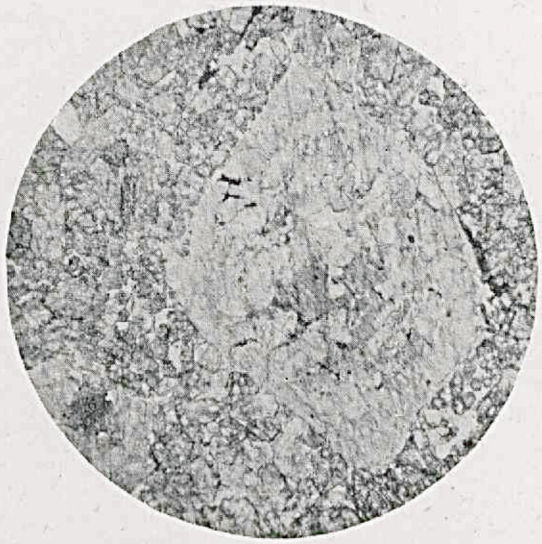

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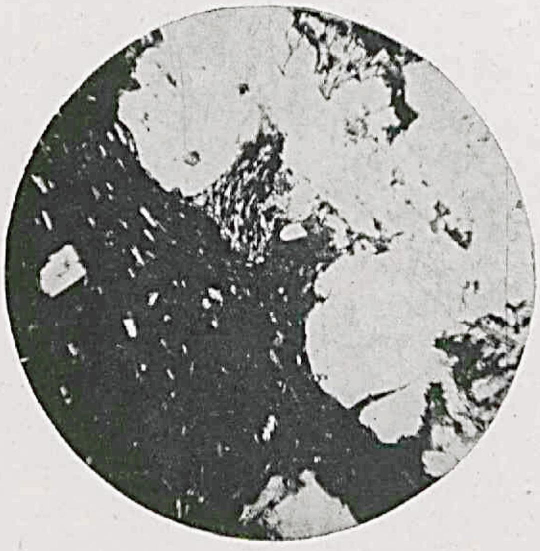

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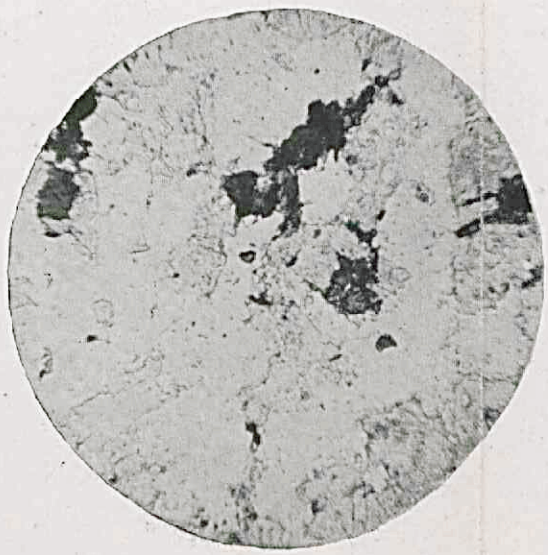

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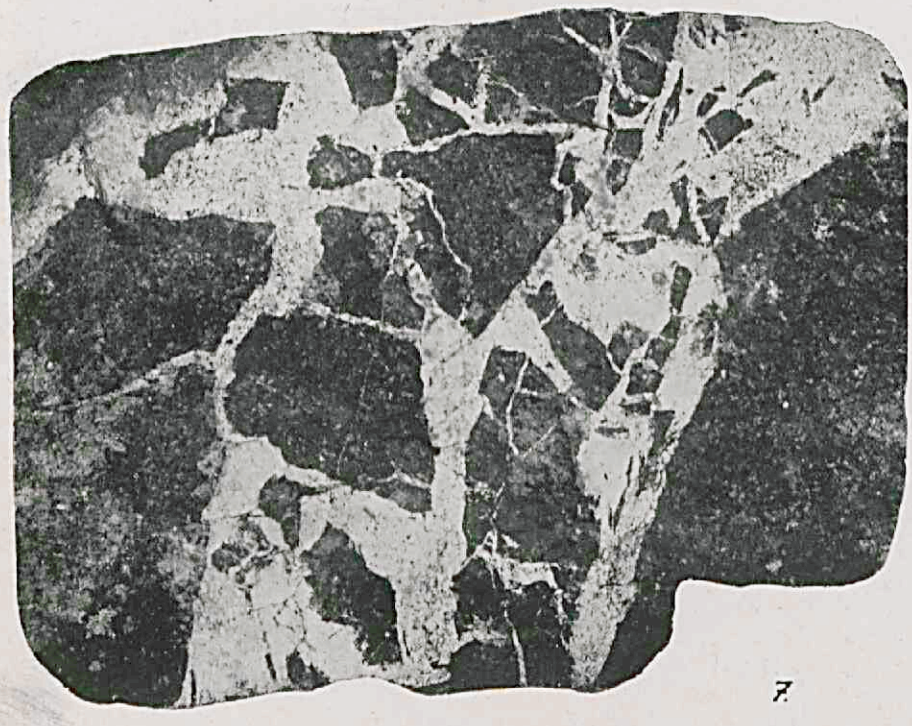

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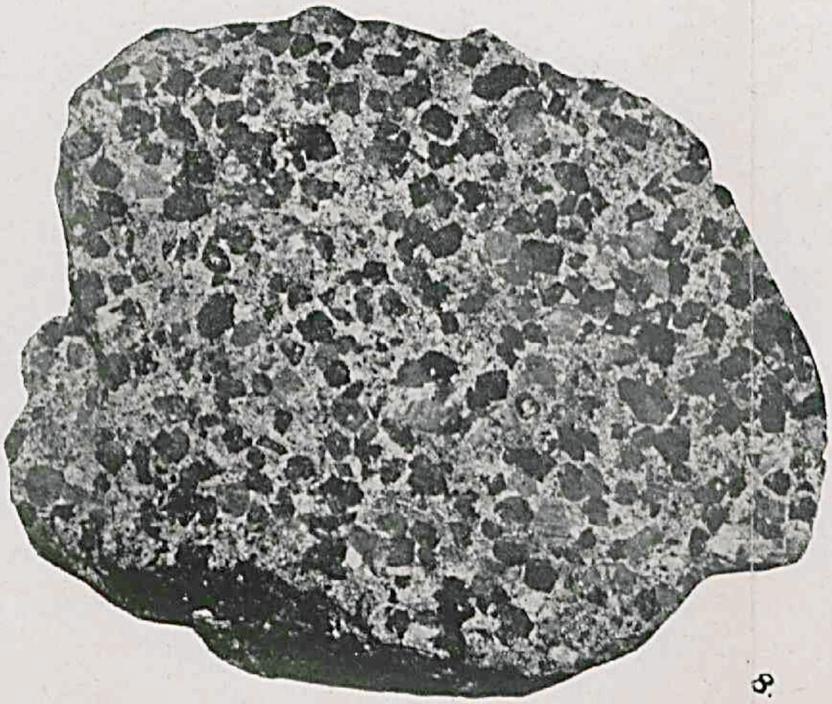

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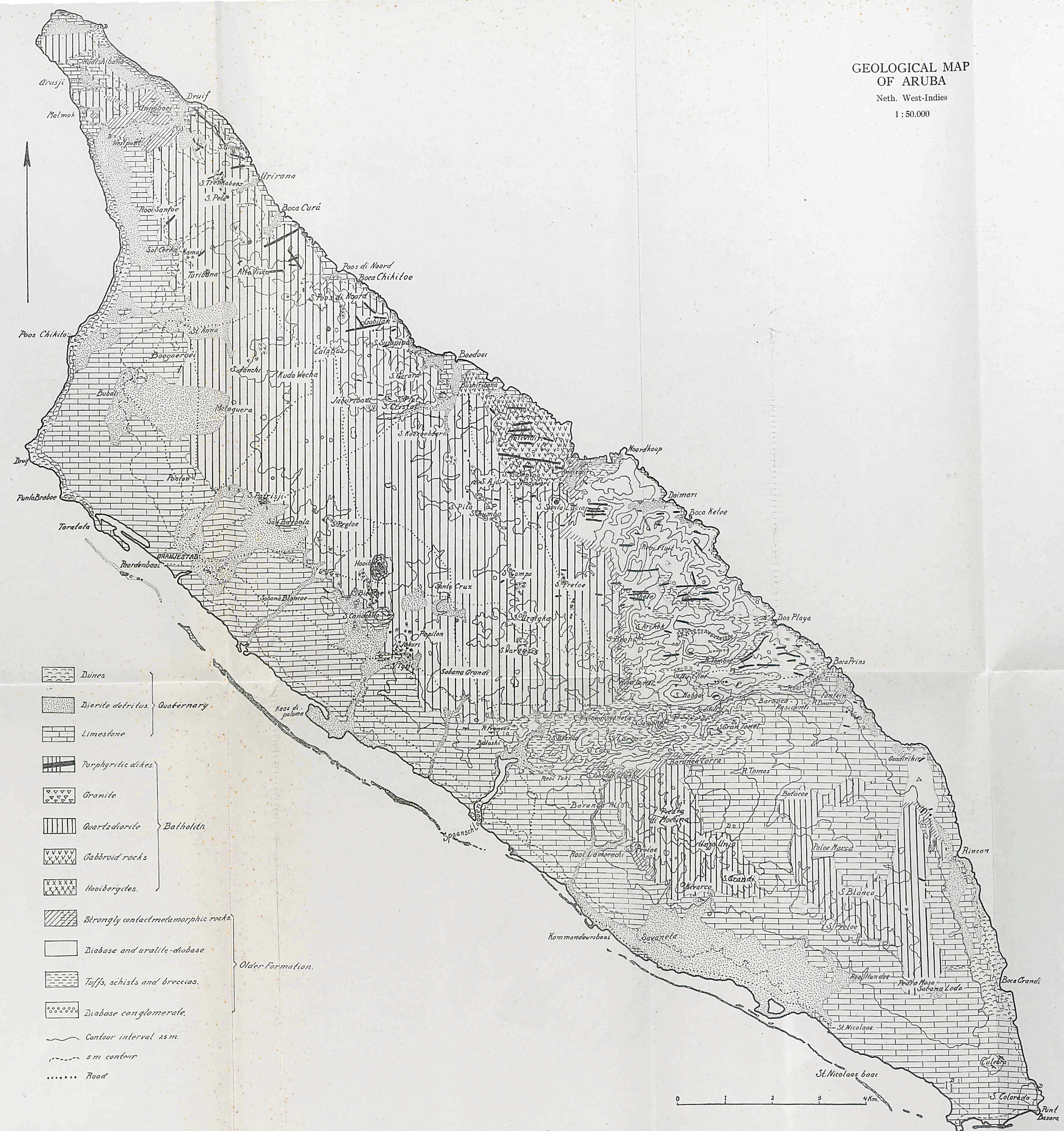
GEOLOGICAL MAP OF ARUBA

Neth. West-Indies

1 : 50.000



STELLINGEN

I

Het Heraklea kolenbekken (Noord Klein-Azië) en het Donetz kolenbekken (Rusland) vertoonen zeer groote verwantschap, en vormden resp. de Z. en N. randslenk van het Boven-Carbonische „Pontische schiereiland" (J. L. Wilser — Geol. Rundsch. 18—1927).

II

A. Born heeft voor het Rijnsche Leisteengebergte waarschijnlijk kunnen maken, dat de metamorphose, behalve door plooiingsdruk, voor een zeer belangrijk deel veroorzaakt is door belastingsdruk (Senckenbergiana 9 —5, 1927).

III

Het is onwaarschijnlijk dat de N-Z breuklijn nabij Klein Schmalkalden (NW Thüringer Woud), waarlangs von Seidlitz tertiaire of post-tertiaire bladverschuiving in de Thüringer Horst aanneemt, reeds prae-varistisch is aangelegd (Centralbl. f. Min. etc. B., 7 — 1928).

IV

Een oude kristallijne kern is op Aruba niet gevonden. De opvattingen over het bestaan ervan zijn onjuist en berusten op een foutieve interpretatie van de contactmetamorfe diabaastuffen.

V

De theorie van R. T. Chamberlin en T. A. Link betreffende de "laterally spreading batholiths" en de laccolieth-achtige vorm van de batholiethen is aannemelijk (Journ. of Geol. 35 — 1927).

VI

De groepeering van strand-rolsteenen langs de Westkust van Lake Michigan (Wisconsin, Illinois) naar grootte en vorm, als beschreven door R. E. Landon (Journ. of Geol. 38 — 1930), is het gevolg van de afslijting en van het selectief transport, in onderlingen samenhang.

VII

Het bestaan van fraaie ,,Karrenfelder" in de kalken van de Benedenwindsche eilanden geeft steun aan de gewijzigde opvatting van W. SALOMON betreffende het voorkomen van ,,Karrenfelder" in landen met warm klimaat (Centralbl. f. Min. etc. B., 15 — 1926).

VIII

De opvattingen van O. JAEKEL over de morphologische beoordeeling van de eerste halswervels, steunende op palaeontologische gronden, zijn van waarde (Anat. Anz. 40 — 1912).

IX

Het probleem van beplanting van buitenwegen in Nederland met boomrijen verdient nadere bestudeering in verband met natuurbescherming, verkeer en techniek.