

**Geology.** — *New data on the smaller islands North of Venezuela.* By  
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In 1931 I reviewed (4) the geological literature of the Venezuelan islands between Bonaire and Trinidad and gave some data on the base of the study of rock-samples, collected by R. LUDWIG and by P. R. LOWE. In 1936 Mr. P. WAGENAAR HUMMELINCK visited these islands on a biological voyage; he made at the same time collections of rocks which he kindly gave to my institute. The following additional data on the geology of the islands are the result of the study of these collections.

**Los Frailes.** Nothing seems to have been published on these small cliffs which lie quite near to the northeast-coast of Margarita<sup>1</sup>). There are samples from Puerto Real and from La Peche.

No. 156, Puerto Real, SW-slope of Morro Grande, alt. 40 m, is a diabasic diorite. The main components are albitized, idiomorphic plagioclase and pyroxene, with ophitic texture; large spots of chlorite with some epidote probably originated from biotite. Some green hornblende, octahedral ore and many very slender needles of apatite; moreover traces of micropegmatite, occurring as interstitial material between the main components.

No. 157 and 158, same locality, sampled from isolated pieces of rock; are diabases. The first is very coarse, the second is fine-grained and fluidal; in both, the plagioclases are more or less albitized.

No. 159, found at the top of Morro Grande in large blocks, is a coarse quartz-epidote-chlorite rock. It contains octahedral limonitized ore and slender needles of apatite. Both epidote and chlorite may occur in spherulites. It is very probably a postmagmatic rock.

No. 160 from the SW part of La Peche is probably a quartzdioriteporphyrite which, however, has some characteristics of a diabase. It contains rare phenocrysts of decalcified plagioclase partly filled with epidote, and a groundmass with an ophitic texture, consisting of laths of albite and small crystals of a green biotite which partly have changed into spherulitical chlorite. There is some interstitial material of quartz and micro-albite-pegmatite.

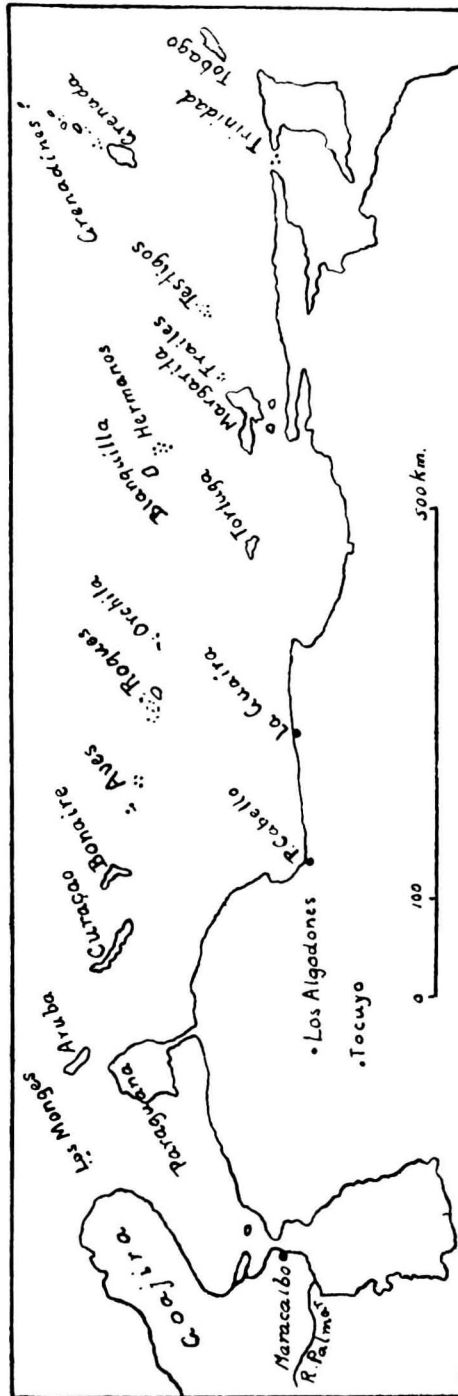
No. 161, same locality, is a green rock, consisting almost entirely of uraltite and albite, with, locally, some prehnite. It is probably a metamorphic porphyrite-tuff. According to Mr. HUMMELINCK's field-notes sample 160 occurs as a "lightcoloured ledge" in 161.

No. 162 is, according to HUMMELINCK, the contact-zone between 160 and 161. It is a dirty-green rock, partly coarse-grained, partly fine-grained. The coarse-grained part is

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<sup>1</sup>) In the academical thesis of Mr. HUMMELINCK (1a) published after the communication of this paper, some notes (p. 16) and a sketchmap (p. 44) are to be found. The latter shows that the islands are arranged "en échelon" with a WNW-strike.

a metamorphosed porphyrite-breccia, each grain being a piece of porphyrite, whilst the intermediate substance consists mainly of uralite. The fine-grained part is a metamorphic porphyrite-tuff, containing equally much uralite and a veinlet of prehnite.



No. 163, from the N-hill of La Peche is a coarse uralite-diabase with large crystals of labradorite and uralitic hornblende, which often includes rests of pyroxene. There are many skeleton-crystals of ore, slender apatite needles and a vein of prehnite.

No. 164, from the basal part of the S-hill of La Peche, is a strongly uralitized porphyrite-tuff: it is a quartz-uralite-albite rock with remains of porphyritic texture.

No. 165, from the depression between the N- and the S-hill of La Peche, is equally a metamorphic, uralitized, porphyritic tuff; it consists of a fibrous fabric of uralite and albite with, locally, remains of plagioclase-phenocrysts, and with an undeniable piece of porphyrite which, although being metamorphosed, shows still clearly the texture of a groundmass. It contains a vein of prehnite.

There is an enormous difference between the magmatic rocks of Los Frailes which have not suffered from crushing forces and the schistose rocks of the near Margarita (5) which have suffered strongly from crushing. On the other hand the rocks of Los Frailes fit in very well with those of the island-row Aruba-Los Testigos, the numbers 157, 158, 161, 162, 163, 164 and 165 resembling the rocks of the cretaceous, volcanic basement of some of these islands, and more especially the contactmetamorphic tuffs and diabases from Aruba (7). It is not certain whether the samples 156, 159 and 160 belong to the volcanic-basement-series or to the younger group of intruding rocks, so well known from Aruba, but also from other islands. They have on the one side "dioritic relations", on the other side "diabasic relations". We suppose that, in any case, an intrusive rock must occur in the underground, near to Los Frailes, given the strong uralitization of some porphyritic tuffs and breccias.

**Los Testigos.** I could state in 1931 (l.c.) the presence of hornblende-granodiorite and of spessartite on these islands. Mr. HUMMELINCK took samples on Morro de Iguana, Chiwu, Angoletta, Tamarindo (Testigo Grande) and Isla de Conejo (see 1a, p. 15, 44). They enlarge greatly our knowledge of this group of cliffs.

No. 138, top of Morro de Iguana, is related to the granodiorite, described in 1931. It differs from it by its femic minerals which are chlorite-epidote (ex: biotite) and pyroxene with a marginal zone of amphibole; the leucocratic components in both rocks are the same.

No. 139, from an elevated place at the E. coast of Morro de Iguana, differs from the foregoing by the presence of more femic components (augite, bronzite, biotite, with skeleton crystals of ore). The leucocratic minerals are idiomorphic, finely twinned, zonally built andesines with more acid margins, and a filling-mass of rather coarse orthoclase and quartz. The rock may be called a biotite-pyroxene-quartzmonzonite.

No. 140, sampled from isolated fragments of rock on Morro de Iguana is a quartz-chlorite-epidote-rock with crystals of limonitized magnetite; it is very probably a postmagmatic rock.

No. 141, from Chiwu, a cliff, measuring about  $300 \times 80$  m, is again a granodiorite. It contains large, porphyritic plagioclases, passing gradually into smaller ones, all idiomorphic, finely twinned and zonal. The femic minerals, probably biotite, have entirely

been changed into masses of chlorite and carbonate. There is an abundant filling mass of coarsely crystalline orthoclase and quartz.

No. **142** from Chiwu is a, probably postmagmatical, quartz-epidote-zoisite rock.

No. **143** and **145**, from the small island of Angoletta (it measures, according to Mr. HUMMELINCK, only  $80 \times 30$  m) are uralitic quartzdioriteporphyrites. They contain phenocrysts of plagioclase and phenocryst-like spots of uralite. In both rocks the texture of the groundmass is granitic-isodiametric, and it consists of plagioclase, quartz and uralite.

No. **144** is a quartzitic rock, probably a sample from a quartz-vein. It occurs as a dike in no. **143**.

No. **146** from top of Morro Grande, Tamarindo, is a granodiorite, resembling **138**.

No. **147** which occurs as a white dike of 20 cm within the former rock, is a plagioplite, consisting of an aplitic intergrowth of quartz and dusty, acid plagioclase ( $n: 1.540$ ); it contains an extremely thin veinlet of epidote.

No. **148**, from Playa Guzman, on the E. side of Morro Grande, Tamarindo, is again a granodiorite, resembling **138** and **146**, but with only a few femic components (hornblende).

No. **149**, from Tamarindo, found in isolated blocks, is a quartz-sand, cemented by phosphorite.

No. **150**, from NW-edge of Isla de Conejo, is a porphyrite with fine phenocrysts and splinters of plagioclase and with some chlorite-spots (?ex femic phenocrysts); the groundmass is very fine-grained and fluidal. The slide contains some inclusions of coarse-grained porphyrite.

No. **151**, from the same locality, is a totally epidotized and silicified porphyrite: the well-recognizable phenocrysts of plagioclase have been replaced entirely by epidote-aggregates; the groundmass, of which the fluidal texture is still visible, consists of epidote and quartz.

No. **152**, from the same locality, is a phosphorite with splinters of quartz.

No. **153**, from top of Isla de Conejo, is a porphyrite, strongly resembling **150**; so is also **154**, from the S-coast of Isla de Conejo, in which some chlorite-spots may be recognized by their form as having originated from amphibole crystals.

No. **155**, from the same locality, is again an epidotized and silicified porphyrite, entirely comparable with **151**.

The rocks of Morro de Iguana, Chiwu, Tamarindo are so alike the rocks of the batholithic sequence of Aruba (7) that they might have been collected on that island; the uralitic quartzdioriteporphyrite from Angoletta with its quartz veins belongs very probably to the same sequence. The rocks from Isla de Conejo, on the other hand, are comparable with the rocks of the volcanic basement of different islands, and there is no reason, why they should not belong to it. The Testigos islands are, as the Frailes, arranged "en échelon" with NW-strike (1a); Isla del Conejo is clearly separated from the rest of the group.

**Los Hermanos** (1a, p. 17, 18, 44). I could describe in 1931 (l.c.) a hornblendegabbro, sampled by P. R. LOWE, from these islands. The character of the rocks, collected by Mr. HUMMELINCK, is not so clear as that of the rocks from Los Frailes and Los Testigos.

There are four rocks which, although not typical, fit in rather well with the batholithic rocks in Aruba etc.

No. 254, from N. slope of Morro Fondeadero, is a hornblendegabbro with hooibergite-habit. The very basic plagioclases (labrador-bytownite) are somewhat zonal; the amphibole is normal, green hornblende.

No. 256, from the NW-side of Morro Fondeadero at sealevel, is quartzhornblendediorite with much apatite in coarse prisms. The partly idiomorphic plagioclases are somewhat zonal; they have the composition of andesine; there is a few quartz, occurring as filling-mass.

No. 258, from N-top of Morro Pando, is an atypical quartzdiorite. The chief components are andesine and quartz without distinct crystallization-sequence, the quartz being, however, more clearly xenomorphic than the feldspar. The feric elements are hornblende, somewhat fibrous and very light-coloured, and small biotite-crystals. The quartz shows feeble undulatory extinction.

No. 261, equally from N-top of Morro Pando, is a quartz-biotite-diorite with acid plagioclase ( $n: 1.540$ ), sometimes strongly epidotized, quartz and streaks of biotite.

Four other rocks may belong to the batholithic sequence; they might, however, also belong to an older basement.

No. 252, from top of Morro Fondeadero, is a coarse amphibolite; the plagioclases are labrador-andesine. At one side in the slide the amphibolite has been covered by phosphorite.

No. 257, from NW-side of Morro Fondeadero, at sealevel (same locality as 256) is an amphibolite with pyroxene.

Nos. 259 and 260 from N-top of Morro Pando, are heavy, black-and-white-spotted rocks with basic plagioclases (labrador-bytownite), green hornblende, some quartz and magnetite. They may be related with the hooibergites of Aruba, but the ill-developed crystallization-sequence and the strongly basic plagioclases make it questionable whether they belong to them.

**Blanquilla.** The only rock, known until now from Blanquilla, is a biotitegranodiorite (4). Mr. HUMMELINCK took samples at Valuchu, in the SE-part and at Puerto Llaque, in the SW-part of the island. The samples from Valuchu are partly young limestones, partly corals, of which Prof. GERTH kindly identified *Favia fragum* Esp., *Porites astreoides* Lam., *Acropora muricata* L., *Orbicella acropora* (L.), and *Platygyra* (*Maeandra*) *viridis* (Le Sueur), partly quaternary molluscs, which are now studied by Miss T. VAN BENTHEM JUTTING, partly quartzdioritic rocks.

Nos. 262, 269, 275 are quartzdiorites which differ from the earlier described granodiorite chiefly by the absence (or extreme scarceness) of orthoclase. The biotite has been partly chloritized; the idiomorphic, zonal and finely twinned plagioclases are oligoclase-

andesine to andesine; the quartz which shows undulatory extinction, occurs as filling mass, together with some albite.

No. 270 is an aplitic quartzdiorite with very scarce chloritized biotite.

Nos. 263—268 are young limestones, all containing clastic material of quartzdiorites and not containing any other clastic material; remains of organisms are rare; 270 has been partly phosphatized.

Nos. 271, 274 are young limestones, full of organic structures.

No. 276 is a young conglomerate with calcitic cement; the grains of the conglomerate are exclusively of quartzdioritic nature; the cement contains very fine Amphiroa's.

The samples of Puerto Llaque are for the most part granitic and quartzdioritic rocks; one sample is a conglomerate.

No. 277, comparable with 276, is a conglomerate of quartzdioritic material with calcitic cement, wherein Amphiroa and remains of Lamellibranchiata and Echinodermata.

Nos. 278 and 281 are biotitegranodiorites; the biotite has been partly chloritized; the plagioclases occur in two generations; the slides present a filling-mass of quartz, orthoclase and myrmekite; accessories are titanite, apatite and zircon. The rocks have suffered from crushing; the quartzes show rather strong undulatory extinction.

No. 279 is a typical quartz-hornblende-biotite-diorite.

No. 280 is a granite-aplite with some large sub-idiomorphic crystals of oligoclase, with large perthitic orthoclases and with abundant, undulatory extinguishing quartzes. Part of the slide shows a micropegmatitic intergrowth of quartz and orthoclase.

No. 282 is a crushed aplite, containing some acid plagioclases and a xenomorphic intergrowth of microcline, microclineperthite, micropegmatite and quartz.

It will be clear from the foregoing that the basement of Blanquilla exists of rocks which are quite comparable with those of the batholith of Aruba: all the rocks of the basement are typical representants of this batholith, and even the clastic material in different young conglomerates and limestones belongs to the same sequence.

**Orchila.** Two years ago M. ROST (3) has published a geological map of Orchila, showing that the island has a basement of crystalline schists with some granitic-dioritic rocks in the W-part of the island. Different masses of "basalt" have been indicated in the centre of the island; the greatest part of the island is covered by young coral-limestones. Mr. HUMMELINCK has taken samples in the W-part of the island, but I do not think that their detailed description is of any worth, as certainly the collections of Mr. ROST which have not yet been studied will prove to be of more importance. I should only like to indicate that the schists of Orchila which have suffered very strongly from crushing, present a great relationship to those of Margarita, that mylonitized granitic aplites

from Orchila seem to be equally related to those of Margarita, and that young limestones contain very fine *Amphiroa*'s.

**Los Roques.** I concluded in 1931 that the rocks of Gran Roque are closely related to the batholithic rocks of Aruba. Since then two descriptions of the island have appeared. S. E. AGUERREVERE and V. M. LÓPEZ (1) have given a detailed description with a fine geological map; M. ROST has equally given a description with a geological sketchmap (3). In his description, ROST presents a "semi-magmatical" theory on the genesis of the phosphorites of the island, which seems to me to be absolutely erroneous; it is, however, here not the place to criticize it. Mr. HUMMELINCK has sampled on Gran Roque, at the side of phosphatic rocks, many magmatic rocks which confirm absolutely the views held by me in 1931. It would be unreasonable to describe the whole collection in detail; the following is an enumeration of the types of rocks in the collection of Mr. HUMMELINCK: hornblendegabbro, uralitic gabbro, uralitic gabbro-diabase, quartzbiotitediorite, quartzamphiboledioriteporphyrite, biotitegranodiorite, biotitegranite, strongly crushed plagiaplite, quartzaplitepegmatite, granitemicropegmatite and amphibolite. With the exception of the amphibolites the samples fit in very well with the batholithic rocks of Aruba; the fine-grained amphibolites are comparable with the amphibolites that have been met-with in Aruba in the contact-zone around the batholithe (7).

On low islands of the Los Roques-group Mr. HUMMELINCK has collected some young calcareous rocks: a sandstone, consisting entirely of rounded fragments of calcite on Isla Larga (Cayo Grande) and fine-grained, partly organic limestone-breccias on Cayo de Agua.

**Los Aves.** On Ave de Barlovento Mr. HUMMELINCK sampled two porous limestones with organic remains, among which *Amphiroa*.

**Tortuga.** SIEVERS (6) has described Tortuga as a low, calcareous island.

Mr. HUMMELINCK took samples (nos. 363—369) of the limestones; moreover he collected molluscs, which are studied by Miss. T. VAN BENTHEM JUTTING and corals, of which Prof. H. GERTH kindly identified the following species: *Pocillopora crassoramosa* Dunc., *Siderastrea siderea* Ell. a. Soll., *Acropora muricata* (L.), *Orbicella acropora* (L.), *Madracis decactis* (Lym.), *Colpophyllia gyrosa* Edw. a. H. and *Eusmilia* sp. The limestones are all very porous rocks with mostly abundant grains of quartz. They contain *Amphiroa* and *Amphistegina* at the side of ill-preserved other organic remains.

**Centinela** (75 km W. of Tortuga). A sample of a very fine-grained siliceous rock (nos. 361, 362) with veinlets of quartz and with larger ones of phosphate has been sampled on this cliff. The rock is probably a (?cretaceous) chert.

*Summary.*

1. The study of the new collection of rocks from the islands between Los Aves and Los Testigos confirms the conclusions, at which I arrived in 1931.

2. These conclusions are extended in so far as: a. the small group of Los Frailes has been proved to belong equally to this row, b. at the side of batholithic rocks there have been found also rocks of the volcanic basement, viz. on Los Frailes and Los Testigos.

3. The metamorphic basement of Orchila presents great resemblance with the basement of Margarita.

4. The young, quaternary, capping limestones in this group are everywhere characterized by the presence of *Amphiroa* which occurs equally in great abundance in quaternary limestones of Curaçao (2).

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