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Geological and Petrographical notes on Gorgona Island in relation to North-Western S. America

by *A. Gansser* (Lugano)

A. Introduction

Gorgona island is situated approximatly at Lat. 3° and Long. 78°, about 40 km off the Colombian Pacific Coast. The main island of Gorgona measures approx. 14 km² while the much smaller Gorgonilla, separated from the former by a very shallow channel, is only $^1/_{12}$ the size of Gorgona. The islands are covered by dense jungle, and the topography is very rough (ref. Photo Nr. 1).

During the years 1944 and 1945, the writer, then a geologist of the Shell Oil Co. of Colombia had the opportunity of studying the greater part of the Pacific coast of Colombia during a reconnaissance. Included in those general investigations was Gorgona Island, where about 10 days were spent, jointly with Dr. HUBACH, then Geologist of Shell Co. During the brief visit, the writer paid attention to the highly interesting basic rocks, the study of which lead to the present publication.

When glancing through the literature dealing with the Pacific coast of S. America, one is struck by the fact, that the Colombian area between Ecuador and Panamà is the least known. Until recently, wide areas had never been visited by a geologist. Only through a temporary activity of various oil companies in the years 1943—46, a regional knowledge of this remote area was achieved. However, the very unhealthy climate, the extraordinary rainfall and the luxurious tropical vegetation greatly hinder the geological exploration.

A geology of the Gulf of Uraba with some notes on the Chocò' was published by HUBACH (in Bol. de Minas y Petroleo, Tomo IV., Bogotà 1930), while on commission for the Colombian Government. A. A. OLSSON, in his regional paper on Tertiary deposits of NW S. America and Panamà (Proceedings Eighth American Scientific Congress 1942), bases his information on the Colombian territory mainly on HUBACH's paper. L. G.

WEEKS compiled what was known in published and partly unpublished reports in his regional paper: Palaeogeography of S. America. (Bull. AAPG Vol. 31, July 1947.)

B. General outline of the Geology of NW South America

In order to understand the peculiar position of Gorgona Island, it will be necessary to outline the geological framework of NW S. America. Special reference is made to the enclosed geological map 1 : 5000000. This map is based on the published geological map of Colombia by the Colombian Government, and the preliminary Geological map of S. America published by the American Geological Society. Considerable additions were made by the author, and are based on his observations as Shell geologist in Colombia.

From W to E and N to S the following tectonic elements are met with:

1. The Coastal Cordillera, recognizable from the Gulf of Panamà to Cabo Corrientes, from where it trends into the sea to reappear as a relic at Gorgona island. Further S the westwards rising Tertiary sediments indicate its continuation in the area of Tumaco, from where the trend continues in a SW direction, touching the western tip of Ecuador in the Esmeralda Province, and probably re-entering the mainland in a SE direction in the Sta. Elena Peninsula of SW Ecuador. The tectonic conditions in Western Ecuador are not easily understood, and it would appear at a first glance more logical to continue the Coastal Cordillera into the basic igneous outcrops of the Sierra de Colonche. The author is, however, more inclined to connect the latter with the West Cordillera explaining the wide Daule Basin as a shallow depression within the West Cordillera. The remarkable Upper Tertiary overlap on basic igneous rocks of the West Cordillera Type, within the Daule Basin seems to support this suggestion.

Strictly speaking, the Coastal Uplift is not a single chain-like trend, but a complex alignment of various en echelon uplifts.

The Coastal Cordillera is characterized by basic and ultrabasic rocks of Upper Eocene to Lower Oligocene age, with relictic Upper Cretaceous and Lower Tertiary in a mainly siliceous facies, followed by purely marine Middle and Upper Tertiary formations.

2. E of the Coastal Cordillera follow the Coastal Basins, a well outlined synclinorium, filled mainly with Upper Tertiary marine sedi-

ments. They can be followed from N to S through the Tuira Basin, the Atrato-San Juan Basins, separated by a SW-NE trending complex saddle (Atrato-San Juan), the Buonaventura-Patia trend, the NW Esmeralda depression in Ecuador, from where the synclinorium seems to strike out into the sea, to re-enter, over a saddle into the deep Congreso Basin of SW Ecuador.

3. The main tectonic feature of NW South America is undoubtedly the West Cordillera. This complex anticlinorium forms the main mountain range in Northern Panamà, trending into the Darian mountains, crossing the Urabà depression in NW Colombia as small isolated relictic hills to rise into the main West Cordillera of Colombia, after joining with the eastern branch the Rio Sinu mountains. The latter can be traced northwards towards Baranquilla as small but very complex uplifts. Following to the South, the West Cordillera forms the high watershed between the Cauca-Patia valleys to the E and the Atrato-San Juan and coastal lowlands to the West. The tectonically very complex range broadens towards Ecuador and changes from a SW direction into a NS strike. The possibility of a superimposed Daule basin was mentioned above.

The backbone of the Western Cordillera consists of slightly metamorphosed Mesozoic sediments (phyllitic stage) which probably include a great part of the Cretaceous rocks. Characteristic are intrusions and extrusions of various ages, beginning with porphyrites and associated tuffs of probably Middle to Upper Cretaceous age, basic, and ultrabasic intrusions of Upper Cretaceous to Eocene and acid intrusions, mainly in form of tonalite batholites of Post Cretaceous age, probably Eocene to Oligocene. Andesitic and dacitic plugs and dykes of Miocene and Post Miocene age are more frequent along the eastern border of the Western Cordillera, and lead to the present active and semi active volcanism of the southern part of the West Cordillera.

It is within the outline given above, that the Geology and the Petrology of Gorgona island proper will be discussed.

C. The Geology of Gorgona and Gorgonilla Islands

Reference is made to the enclosed geological sketch-map (Fig. 1) covering both islands. Less than one fifth of the islands is covered by sediments, the rest of the formations consisting of basic intrusives and extrusives.

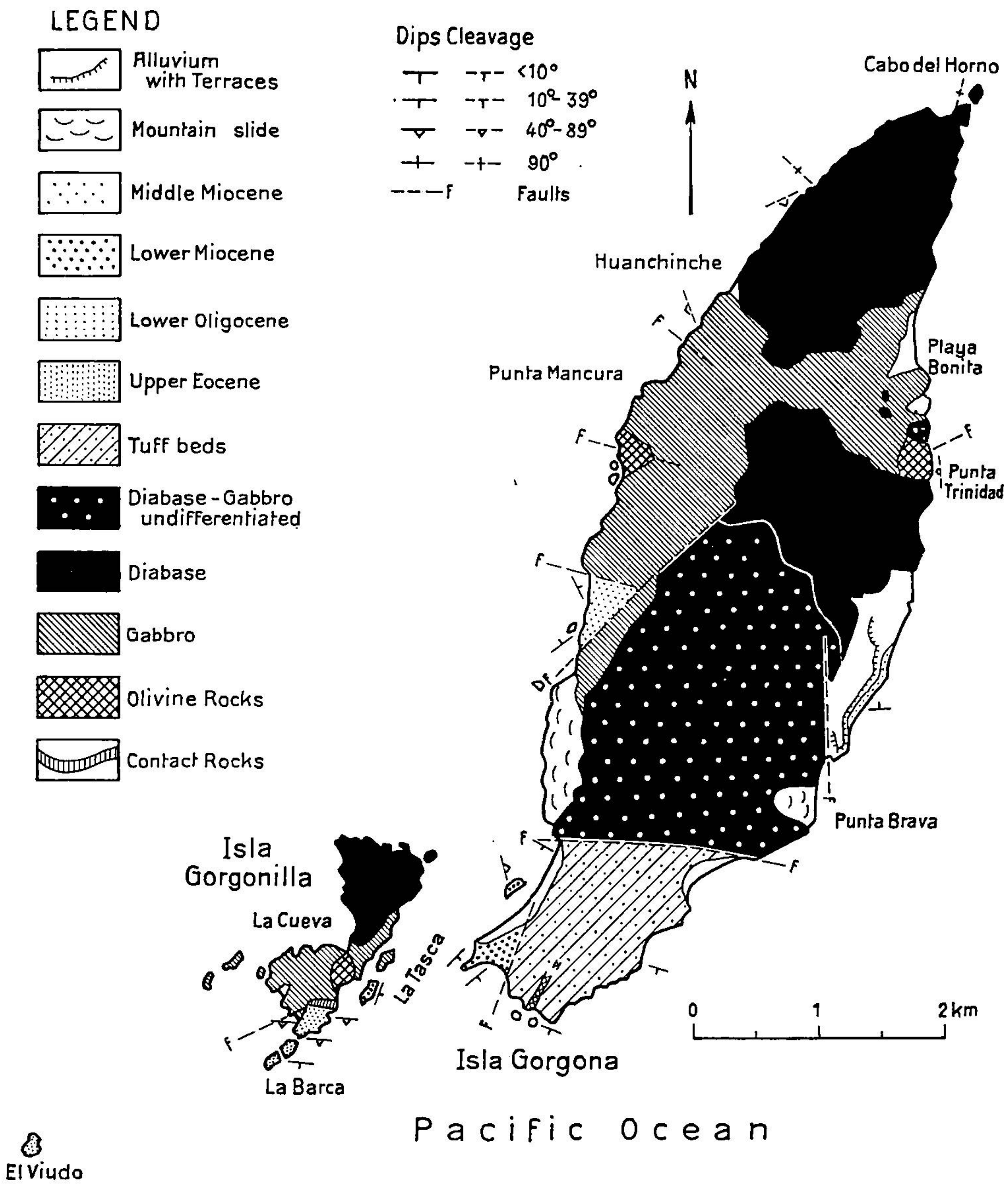


Fig. 1. Geological Map of the Gorgona-Islands.

1. Sediments

a) The Quaternary deposits form small river deltas, block landslides as well as one conspicuous terrace on the E coast of the island. This terrace seems the only vestige of an older Quaternary cycle. The terrace recalls a raised (2 m) flat river delta rather than a strand terrace, for which no clear indications were found.

b) The Middle to Upper Miocene forms a small band of outcrops on the east side of the island, and is covered by the above mentioned terrace. The formation consists of fossiliferous sandy creamy limestones containing small pebbles of gabbros and diabases. A northerly dip of approx. 10° is visible. The age has been given by analogy with similar marine formations along the Colombian Pacific West Coast. The outcrop of Gorgona Island probably forms a marine shore facies corresponding to the thick marine beds on the mainland.

c) The Lower Miocene is well exposed at the S-Westerly tip of Gorgona island (ref. Photo Nr. 2), and forms the greater part of the very shallow channel of La Tasca between Gorgona and Gorgonilla. Well bedded silty shaley clays alternate with thin sandstone beds. The broken cliffs of the SW tip of the island consist of well bedded fine to medium conglomerates, intercalated in the sandy layers. The conglomerates are supposed to be the lower part of the Lower Miocene formation, and indicate the presence of a marked unconformity, well exposed along the Pacific Coast of West Colombia. HUBACH (op. cit. above), in 1930 already, mentions the similarity of the Lower Miocene sediments of the Tasca of Gorgona with similar beds of Lowermost Miocene age in the Gulf of Urabà area (Piso de Tacanales). Basic igneous pebbles and cherts are the most frequent components met with. They are usually well rounded.

d) Lower Oligocene. On the west coast of Gorgona island occurs a small patch of gently folded, somewhat silicified silty shales. They contain some radiolaria and indeterminate, badly preserved foraminifera. Through comparison with similar outcrops along the mainland (towards Cabo Corrientes) a Lower Oligocene age is indicated. The sediments seem free of pyroclastics, in contrast with similar beds in the northern part of the Cordillera de la Costa. (The contacts with the surrounding gabbros seem faulted.)

e) Upper Eocene. The only Upper Eocene exposures were found on the S tip of Gorgonilla island, including the isolated rock called El Viudo approximately 2 km to the SW of the island. The average dip of the beds is to the South with approximately 40°. The upper part of the exposed section consists of light creamy colored siliceous tuffaceous shales, rich in radiolarias. The Viudo rock seems to consist of similar beds. Towards the lower part dark gray-green highly tuffaceous sandstones occur as frequent intercalations within the siliceous shales, giving a characteristic banded aspect (ref. Photo Nr. 3). The deepest outcrops consist of foraminiferal calcareous sandstones and sandy well banded limestones. These lower beds yielded a good Upper Eocene fauna (mainly *Lepidocyclina Peruviana* and *Cibicides Tuxpamensis*).

The contact with the Lower Oligocene is nowhere exposed on Gorgona island, but supposed to be transitional, in analogy with well exposed sections on the mainland. The Lower Miocene beds, forming the Tasca between Gorgona and Gorgonilla most probably transgress on the Eocene. The basal contact with the surrounding basic igneous rocks is not well exposed, partly strongly disturbed, but as far as can be observed, the Eocene beds are cut off by the basic intrusions. Contact phenomena on the Eocene rocks are practically nil. This seems in line with similar observations made on the North side of Cabo Corrientes, where Eocene limestones are completely enclosed by fine-grained augite gabbros and augite basalts.

Of special interest are however nodulous, honey-colored chalcedony lenses and bands, usually 5—20 cm thick, forming irregular layers at the limestone-gabbro contact. The unfortunately strongly disturbed contact does not allow a clear conclusion as to the relationship between the basic igneous rocks and the chalcedony. This phenomenon is not restricted to Gorgonilla island, but was observed over the greater part of the Coastal Cordillera, along the contact of the basic igneous rocks with Cretaceous and Eocene sediments. The most resistant chalcedony nodules form one of the main constituents of the river gravels in the Coastal Cordillera, where basic rocks are in contact with sediments. (Headwaters of Rio Baudò.)

2. Igneous rocks

Basic igneous rocks form the main part of Gorgona and Gorgonilla islands, and will be discussed in detail as far as it is possible from preliminary macroscopic and microscopic analyses. In a following chapter a comparison will be made with similar occurrences from the mainland of West Colombia.

On the enclosed geological sketch-map 1 : 62500 the following generalized subdivisions are made.

a) Diabasic tuffs
b) Diabases
c) Gabbros
d) Undifferentiated gabbros and diabases
e) Peridotitic rocks.

These subdivisions are artificial, but practical when tested directly in the field. Frequent transitions were observed, from tuff to tuffaceous diabases and diabases, from diabases to fine-grained gabbros, from olivine diabases towards peridotitic rocks. The lack of chemical analyses is felt, but such investigations could not be included in the present, cursory studies.

a) *The Diabasic Tuffs*

Tuffs occur at the south end of Gorgona island, where they form good exposures along the south coast. The tuffacous complex is most varied, and consists of agglomeratic and coarse irregular layers, tuff beds with embedded lapilli, occasionally cut by vertical dykes of a fine-grained olivine diabase. In general, the tuff beds are well bedded and dip with about 20° to the South, very similar to the dip of the Eocene formations on nearby Gorgonilla, mentioned above, where tuffaceous shales were observed. Under the microscope, the finer tuffs consist of a very irregular and patchy network of fine augite needles, the other constituents being strongly altered. The approximate visible thickness of the tuff formation amounts to 400—500 m. The contact with the Lower Miocene formations is a clear cut, steep fault. Northwards, the contact towards the undifferentiated gabbro/diabase masses is not clearly exposed, but from the linear expression in the morphology, and the disturbance on the west coast, a faulted contact is most likely. The general composition of the tuffs, as well as the enclosed coarser material in form of pillow-like diabase boulders, smaller, lapilli-like inclusions and diabase lenses is, as far as can be judged without chemical analysis, very similar to the main mass of gabbros and diabases of Gorgona island. Since the tuffs persist into the Upper Eocene, they might be related to the latest extrusions of the basic magma.

b) *The Diabases*

The diabases are concentrated on the northern part of Gorgona island, as well as in the central and more eastern part. Similarly the northern part of Gorgonilla island consists of diabases. Together with the undifferentiated gabbro/diabases of the southern half of Gorgona, diabases are the most frequent rocks met with. Regionally, they are rather uniform, in detail, however, many minor differentiations can be recognized. During the short time of investigation it was not possible to enter into subtile subdivisions of the diabase complex. Equally, the subdivision from gabbros was carried out very arbitrarily, and it was, in the field, often very difficult, to decide whether a rock should be called a coarse, doleritic diabase, or a fine-grained gabbro. All intermediate stages were observed, and where the subdivision was not possible, an undifferentiated formation was indicated on the map (see below).

The diabases are dark green, mostly massive, fine-grained rocks in the field, generally strongly cleaved and fractured. A primary bedding, indicating some basaltic flows, can be observed locally. Equally rare are pillow-like structures. The latter were observed at the Cabo del Horno, on the north tip of the island.

The mineral composition of the frequent and normal diabases is, as far as investigated, rather uniform. Ordinary augite is predominant, practically colorless, but with a tendency towards pigeonite, characterized mainly by the relatively small, varying optical angle. The crystals seem somewhat unstable, and occasionally show resorbtions. A slight tendency to skeletal growth is visible. The plagioclase, by its extinction an acid labradorite to labrador-andesine, forms elongated laths, arranged in ophitic structure. Lamellar albite-twinning is frequent, but the crystals are not as idiomorphic as generally observed in ophitic basic rocks. Magnetite is very common, and regularly distributed in the rock, as partly idiomorphic, smaller grains.

Chlorite is present as alteration product, as well as small epidote grains and leucoxene.

As already mentioned, the texture is ophitic, and the structure massive (ref. Photo Nr. 4).

c) *The Gabbros*

Normal gabbros occur in the middle part of Gorgona island, as well as in the S and southwest part of Gorgonilla. Like the diabases, the gabbros occur as massive, dark green rocks in the field, except that the grain is coarser, and the ophitic structure is clearly visible. A coarse blotchy aspect is not rare, caused by an irregular, patchy enrichment of plagioclases. Less frequent than in the finer grained diabases, but still well marked is the cleavage and fracturing, partly exposing local fracture zones. The main cleavage planes are vertical and approximately 45^0, orientated very roughly in a East-Westerly and North-South direction.

The average mineral composition of the normal gabbros is as follows: Augite is predominant, usually occurring as large crystals, frequently xenomorphic, and rich in idiomorphic plagioclase "inclusions". Under the microscope the augite is pale greenish to light brownish, with a relativly small, but varying optical angle, and an average extinction of 45°. Coarser, ophitic gabbros contain a more greenish, diopsidic augite, with a larger optical angle, but a similar extinction. The diopsidic augites are less rich in inclusions. The augites are in general rather fresh, with only minor alterations visible on the border-zones. Most frequent is a slight uralitisation, with subsequent chloritisation. The plagioclases vary considerably in size, and to some extent in composition, also expressed by the frequent zoning. They are always strongly elongated, mostly idiomorphic, though the terminal faces are not generally developed. The plagioclases are responsible for the marked ophitic texture of the gabbros. Frequently they are altered to some extent, by sericitisation. (acid types.) The zoning is very marked, with a rim of oligoclase-andesine and a core of labradorite. The more acid border is rather thinly developed, and the bulk of the crystal more basic. As more secondary minerals occur a green hornblende, chlorite and some talc minerals, the latter concentrated with smaller xenomorphic plagioclases in occasional patches (Flasergabbro). Magnetite is frequent, partly togther with leucoxene.

As already mentioned, all the gabbros are strongly ophitic, with the exception of some more patchy structures of the "flasergabbro" type.

d) *Diabases and Gabbros, Undifferentiated*

This subdivision was necessary for mapping purposes, since the lower center part of Gorgona island consists of a great mass of finer gabbros and coarser diabases, in which distinctions could not be made during the short field visit. For evident reasons, even areas mapped as gabbros, will, under closer examination, reveal some diabases and vice versa. Furthermore, since Gorgona island is only a relic of a greater mass of basic rocks, it will be most difficult with the available results, as well as with additional studies, to establish a certain sequence of the basic rocks, such as a border zone of diabases and a core of gabbroid and peridotitic rocks.

e) *The Olivine Rocks*

Rocks with olivine are the most interesting discovery on the Gorgona islands, less for the simple presence of olivine, than on account of extraordinary textural habits of some of the olivine rocks. Here again, we do not follow a strictly petrological subdivision, since olivine-bearing gabbros as well as diabases are included in the present chapter, while normal gabbros and diabases have already been described. What characterizes the present basic rock group is the more or less well marked tendency to develop arborescent textures. The term is one, already used at the end of the last century by Michel Levy. It seems to the writer by far the best descriptive name for the phenomena described below. It would include such a term as "skeleton crystals".

The writer is well aware, that the present publication can but outline roughly the presence of these rock types. A special study is needed in order to give an exhaustive description of the phenomena observed.

The observed olivine-bearing rocks are distributed as follows: a small mass at the east side of central Gorgonilla, not far from the contact with the Eocene rocks. A local outcrop at the central part of the west coast of Gorgona and, opposite, on the east coast a similar occurrence, the latter however of special interest due to its arborescent phenomena. Further an olivine-bearing diabase dyke was observed at the south tip of Gorgona island within the tuffaceous deposits. Further investigations in the field might prove the existence of additional occurrences of olivine-bearing rocks, particularly in the interior of the island, were the exploration is greatly handicapped by most luxurious tropical rain forest. All the observed olivine-bearing rocks occur within the gabbros, but border the diabases on the east coast of Gorgona. In spite of the small, reduced occurrences of olivine-bearing rocks, they show a wide variability in their composition. This is particularly true of the Gorgonilla outcrops, but less pronounced in the rocks of Gorgona island.

Gorgonilla island and the west coast of Gorgona exhibit the most basic rocks. They are clearly visible in the field, and recognizable by the dense dark green colour, the marked fracturing without any predominant direction and the more or less advanced serpentinisation. Fracture planes sometimes show strong lustre. The average mineral composition of this ultra basic sequence on Gorgonilla is as follows: olivine is predominant. The axial angle is practically 90^0, indicating forsterite. The typical net-like serpentinisation is well developed, and more or less replaces the olivine grains (ref. Photo Nr. 5). However the serpentinisation is less advanced than would be expected macroscopically. Less frequently occurs a brownish augite, partly altered into hornblende. The latter shows a dirty green to brownish pleochroism. A greenish mass of serpentine (or serpentine-like mineral, not specifically determined) is frequent beside a reduced brownish isotropic groundmass somewhat reminiscent of altered glass. It seems striking that opaque minerals such as magnetite or chromite are practically absent.

The ultra basic rocks on the west coast of Gorgona are less serpentinized, otherwise the macroscopic aspect resembles the Gorgonilla rocks. The olivine is surprisingly fresh, with an axial angle of 90°. The grains are rather idiomorphic, and the serpentine network is little developed. The augite is a diopsidic diallage, and xenomorphic against the olivine. A very fine green-brown hornblende is a secondary alteration product, and occurs together with some chlorite and a serpentine-like mineral. Some small, very subordinate plagioclases were observed, apparently bytownite. Opaque minerals are rather rare, as in the occurrence of Gorgonilla.

Based on this mineral composition, the rocks described above seem to belong to the augite peridotites.

Contrasted with the above-mentioned ultrabasic rocks, the other olivine-bearing rocks types are richer in augites and plagioclases, but seem to grade into the ultrabasic types.

Rocks from Gorgonilla and a small dyke in the tuffs of South Gorgona show the following mineral composition as average:

Olivine as big rather idiomorphic grains, practically fresh with a small border of opaque minerals, and omphacite. Augite, slightly brown to olive brown, smaller and more xenomorphic. Plagioclase, partly zonar with a core of labradorite to bytownite and a border as acid as andesine. Small brownish hornblende, chlorite, biotite and serpentine are secondary minerals. Opaque minerals, mainly magnetite are more frequent in the dyke occurrence.

The Gorgonilla rock is holocrystalline and represents a fine olivine gabbro. The dyke occurrence in the Gorgona tuffs seems to represent a basic olivine dolerite.

Of exceptional interest are the olivine-bearing diabase rocks of the east side of Gorgona island. As already indicated, they merit a special and detailed petrological study. The present description is merely preliminary.

The rocks form a small promontory at the northern third of the east coast of Gorgona island, called Punta Trinidad. This coast is much more easily accessible than the wild and rough west coast, where landings from the sea are a most hazardous undertaking.

At a first glance, the peculiar structural habits of this basic rocks are visible. The dark green, dense formation shows a striking textural pattern, characterized by two principal types: a "radial" texture, caused

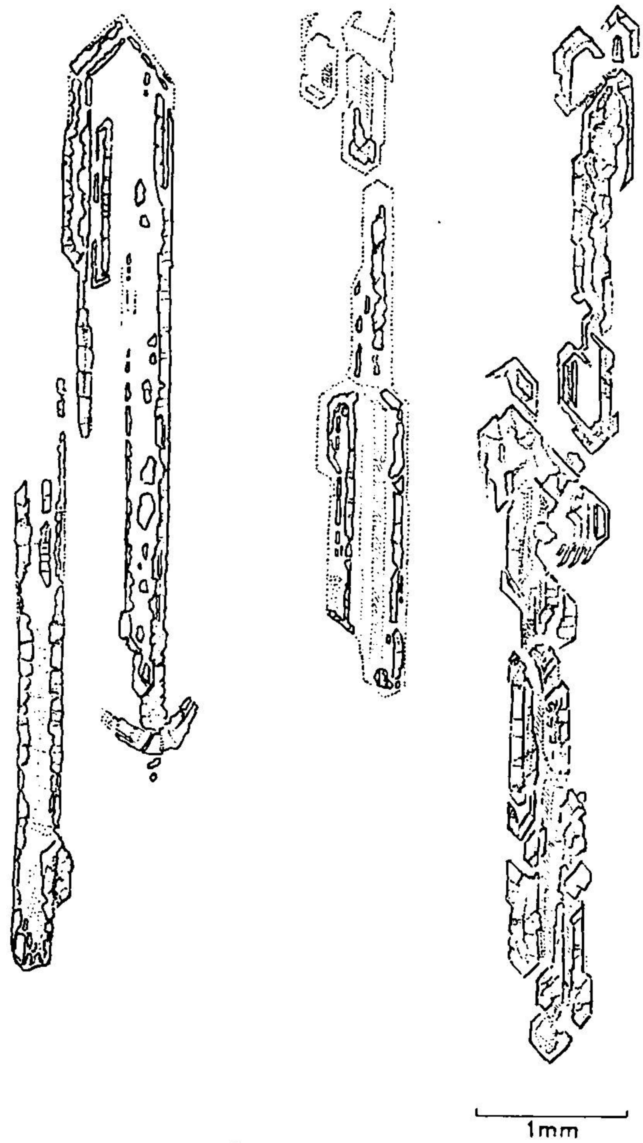


Fig. 2. Skeletal olivines from the radial olivine diabase. Punta Trinidad, Gorgona Island.

by shiny, elongated crystal aggregates, similar to the lustre mottling of recrystallized lime in limy sandstones, and an "octahedral" texture, where the whole rock is characterized by a very pronounced octahedral cleavage. The lustrous faces forming the radial texture vary from 5 to 8 cm in length, while the octahedral cleavage does not surpass 1 cm. This macroscopic aspect suggests a diabasic rock, which must have suffered a peculiar cooling effect. The microscopical investigation seems to warrant the same conclusion.

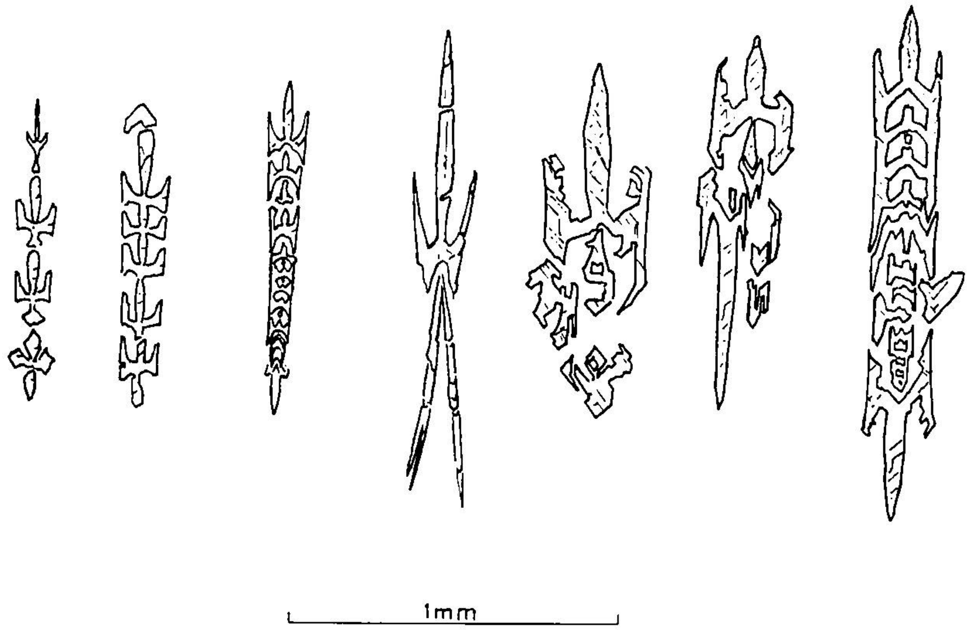


Fig. 3. Various developments of the "harpoon" type skeletal augite. From olivine diabase.

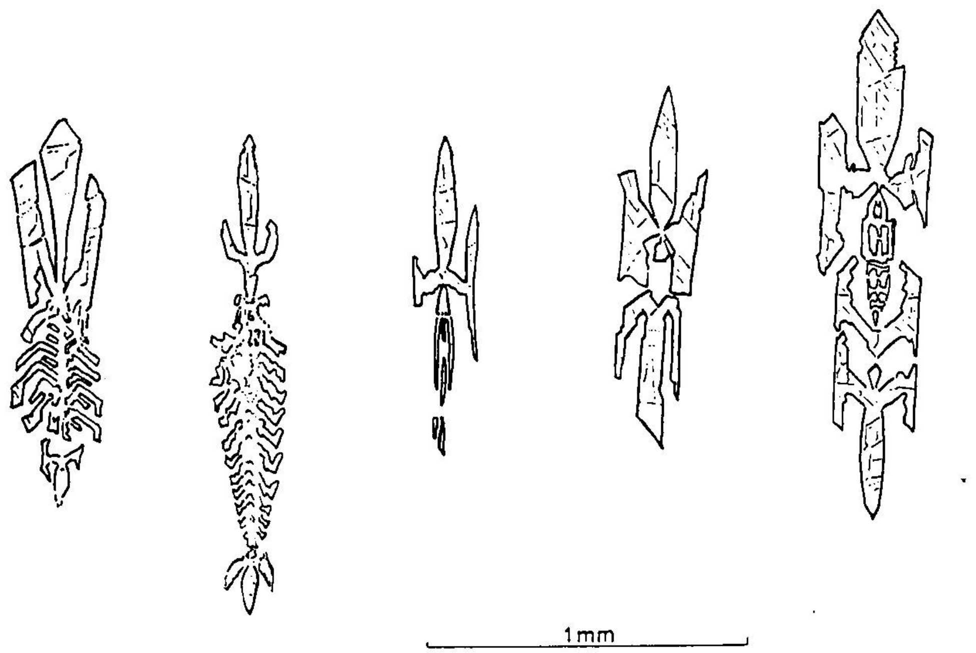


Fig. 4. Simple and complex "harpoon" type skeletal augites. From olivine diabase (radial type).

From the radial rock specimen, several orientated slides were prepared, oblique, parallel and vertical to the radial texture. The microscopical results are as follows:

The olivine occurs in very long (2—3 cm), semi skeletal needles, partly with well developed terminal faces (extension parallel to c axis). (See Fig. 2.) The core of the needles is frequently altered to serpentine-like minerals and magnetite, while along its border the olivine is quite fresh. The maximal width of the olivine needles is about 1 mm. In spite of the skeletal, partly irregular shape of the olivine needles, they each belong to one and the same crystal as clearly shown by the uniform extinction, and the same birefringence colour. The angle of the optical axes is practically 90°, while some crystals possess a slightly smaller angle with a negative sign. The olivines seem to belong to the forsterite-chrysolite group.

Between the olivine needles, one observes a most extraordinary development of arborescent augites of various dimensions together with some fine plagioclase needles. In a slide parallel to the radial texture, the plagioclases are better recognizable, and clearly form an ophitic border along the olivine needles. The thin plagioclase needles are rarely twinned. Based on their extinction angle they belong to the labradorite type.

The augite crystals are never fully developed, and occur always in more or less pronounced arborescent skeletons. This fact makes an accurate optical determination of the augite types quite impossible. As far as could be determined, an ordinary augite seems to be the most common type. However, to judge by the parallel extinction of some skeletal forms, orthorhombic augite is also present, together with the monoclinic form.

Monoclinic and orthorhombic augites occur in two types of skeletal forms, a fine fern-like, typically arborescent type, not unlike the zoisite "Besen" and a most peculiar skeletal augite type with harpoon-like endings. The "harpoon" type can occur as a single specimen (see Fig. 3, 4, 5), or combined as sheafs, with a common ending (see Fig. 6). The arborescent augites are always rich in regularly disseminated magnetite. Single crystals of the harpoon type augites often show a border of fine vertical needles, again consisting of augite. The latter also frequently border the olivine crystals, generally, as already mentioned, in combination with thin plagioclase laths.

Small plagioclase microlites occur in a devitrified groundmass, and within the arborescent augites, without taking part in the arborescent

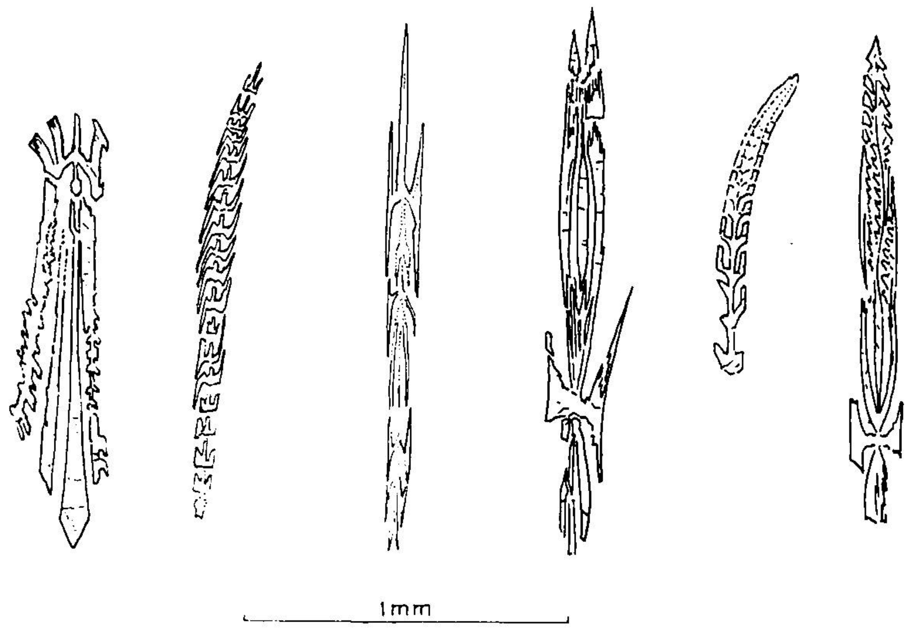


Fig. 5. Elongated forms of the "harpoon" type skeletal augites. From olivine diabase (radial type).

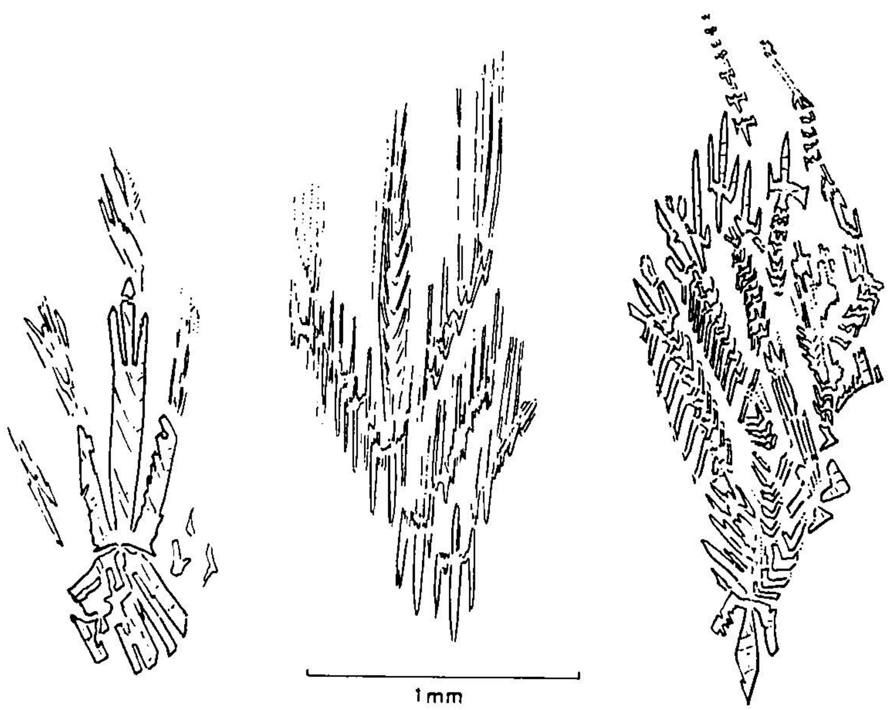


Fig. 6. Sheaf-like, complex "harpoon" type skeletal augites. From olivine diabase (radial type). Punta Trinidad, Gorgona.

texture, apparently not a frequent case in diabasic rocks. (Ref. M. VUAGNAT: Sur quelques Diabases Suisses — Contribution à l'étude du problème des spilites et des pillow lavas. — Min. Pet. Mitt. Vol. XXVI, Nr. 2, 1946.) Figs. 3—6 show some of the most characteristic forms of the "Harpoon" type augite skeletons.

The rock type with the fine octahedral cleavage differs from the above mentioned specimen by the absence of fresh olivine. From the thin section one gets the impression, that we are dealing with a less crystallized part of the rock. The apparent octahedral cleavage is caused by thin lamellae of a serpentine-like mineral. The lamellae appear in the thin sections as a needle-like, very well outlined network, with a maximum extension of the lamellae of 5 mm and a width of only a fraction of one mm. The comparison with the rock type described above, suggests that the lamellae were originally olivine, altered at present to serpentine minerals. This type of crystallisation would however be even more unlike the olivine habit than the needles and lamellae proved to be olivine mentioned above.

Within each of the segments bordered by the above mentioned lamellae, the originally glassy mass has crystallised to a fantastic growth of arborescent fern-like augites (ref. Photo Nr. 6 and 7). It can be easily observed, that within each segment, the crystal growth occurred separately and independently, as a rule beginning from the central part of the segment (ref. Photo Nr. 8 and 9). Between the augite crystal-skeletons a dark brown olive colored altered glass is still visible (ref. Photo Nr. 10 and 9).

Two types of skeleton-crystals can be observed in the various segments. A coarser crystal, fern-like, but still resembling the harpoon type described above, and a much finer skeleton-crystal very much of the "ice flower"-type, but unlike the fine arborescent development (ref. Photo Nr. 7 and 8, 9). Within a single segment one finds the coarse, or the finer "ice flower" type, but the two skeletal developments rarely occur together. From the preliminary examination it seems possible, that the coarser type of crystal belongs to the ordinary augite, while the finer type represents an orthorhombic augite. This interesting conclusion however needs further investigation and one must be well aware of the difficulties connected with determinations of skeleton-crystals.

From the above notes it is evident, that both augite types present a most peculiar skeletal crystallisation caused possibly by an irregular but rapid process of cooling of the molten mass. Within a first network of olivine crystals, however, in a most uncommon type of crystallisation consisting of lamellae and long thin needles, the augite crystallised into an extraordinary growth of skeleton-crystals, while plagioclase segregated only in the more holocrystalline rock-type, forming borders along the olivine.

A reason for this uncommon type of crystallisation is difficult to find. A particular stress condition must have been responsible for the crystallisation of the olivine network. This network probably separated and practically isolated molten volcanic glass within its segments, and an individual crystallisation of the augites set in, which remained uninfluenced by any exchange of matter with the chief molten mass during the local differentiation.

D. Age relation and comparison with the igneous rocks of West Colombia

We refer again to the geological sketch map 1 : 5000000 where the distribution of the various rocks is indicated.

Gorgona island was mentioned as a relic of the Coastal Cordillera. The latter reappears to the South in West Ecuador in the St. Elena peninsula, and to the North, in the Cabo Corrientes area. Dolerites and ordinary diabases are known from the St. Elena area, intruding Palaeocene and Uppermost Cretaceous siliceous sediments.

In the Cabo Corrientes area, the writer was able to study excellent outcrops of titan augite dolerites and basalts, augite diabases and augite gabbros, intruding white algal limestones of Middle Eocene age, and complex Palaeocene and Eocene siliceous shales, as well as green and reddish hornstones of the same age. Limestones and siliceous shales often form isolated blocks within the igneous masses. Similar occurrences were observed further to the North, between Cabo Corrientes and Panamà. It is noted that olivine rocks were not found at the localities visited by the writer, a fact contrasting somewhat with the more basic occurrences of Gorgona island. On the other hand, the Cabo Corrientes rock-types are somewhat "younger looking", if compared with the basic rocks of Gorgona island. Normal basalts are frequent, and much less altered to diabases. Amygdaloid basalts (Mandelsteinstruktur), were observed. Flow textures were frequently noted in the basalts, particularly around the included limestone blocks. Middle to Upper Oligocene sediments North of the Cabo Corrientes, are rich in pyroclastic components, though not intruded by the basic igneous rocks. The Cabo Corrientes basalts are definitely younger than Middle Eocene, and they might be as young as Middle Oligocene, while the age of the Gorgona basic rocks is most likely late Upper Eocene.

The igneous rocks of the West Cordillera compare in many respects with the Costal Cordillera, except for a much greater variability in composition as well as in age. At present only a few interesting facts are mentioned, since any more detailed description would involve a most complex regional study.

The oldest igneous rocks in the West Cordillera seem to be porphyrites, intruding regionally metamorphosed Mesozoic sediments. The latter are in the phyllitic stage (Bündnerschiefer type) and this metamorphism is, in the writer's opinion, not directly related to the igneous activity. Not included here are some gneisses on the more eastern side of the West Cordillera, the genesis and age of which are not known. The porphyritic rocks consist mainly of augite porphyrites and hornblende porphyrites, partly with associated tuffs. The latter however, occur only locally. The plagioclases are generally of the andesine-labradorite type. Porphyrites were not observed in the Coastal Cordillera. Their age ranges mainly from Middle to Upper Cretaceous, but it is possible that some Jurassic porphyrites may be present. The latter, however have their main development in the Central Cordillera, Sierra de Perijà and Sierra Nevada de Santa Marta.

The porphyritic rocks are followed by a basaltic cycle, characterized by augite dolerites, augite hornblende dolerites and augite diabases, occurring mainly as dykes and occasionally as large sills. Greater igneous masses are formed by augite gabbros, partly with pigeonite and/or enstatite as augites. The gabbros are rather fine- to medium-grained. Serpentines, with more or less relictic olivines are frequent in the Patia section of the West Cordillera. The age of the basic and ultrabasic rocks has been rather well established with the help of the contacts with the older Tertiary formations. They range from Lower Eocene to post Upper Eocene and are generally pre Middle Oligocene. They are contemporaneous with the basic rocks of the Coastal Cordillera.

A striking feature of the West Cordillera are the acidic intrusions. They occur as batholites mainly North of the Patia area and form the backbone of the Cordillera along the San Juan-Atrato valleys. As far as is known to the writer, they are characterized by tonalites. Fine- to medium-grained tonalites are frequent, grading, with an increase of the orthoclase into hornblende biotite granites. In various places the tonalites cut through the basic rocks (East of the upper Atrato valley) and are

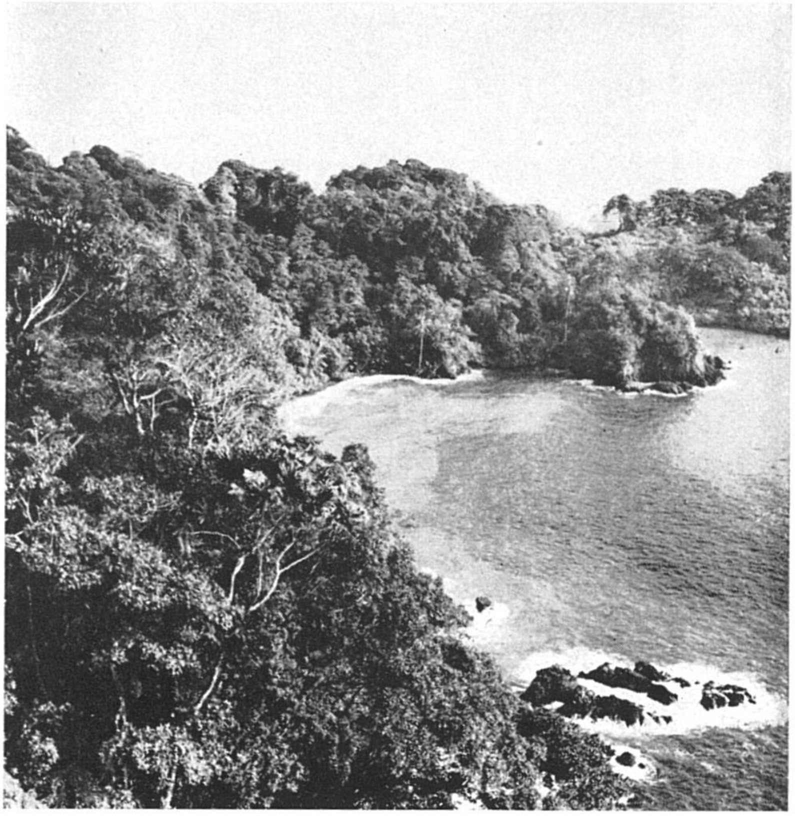


Photo Nr. 1.
The SW part of Gorgonilla island. Dense jungle covering a rough topography of gabbro rocks.

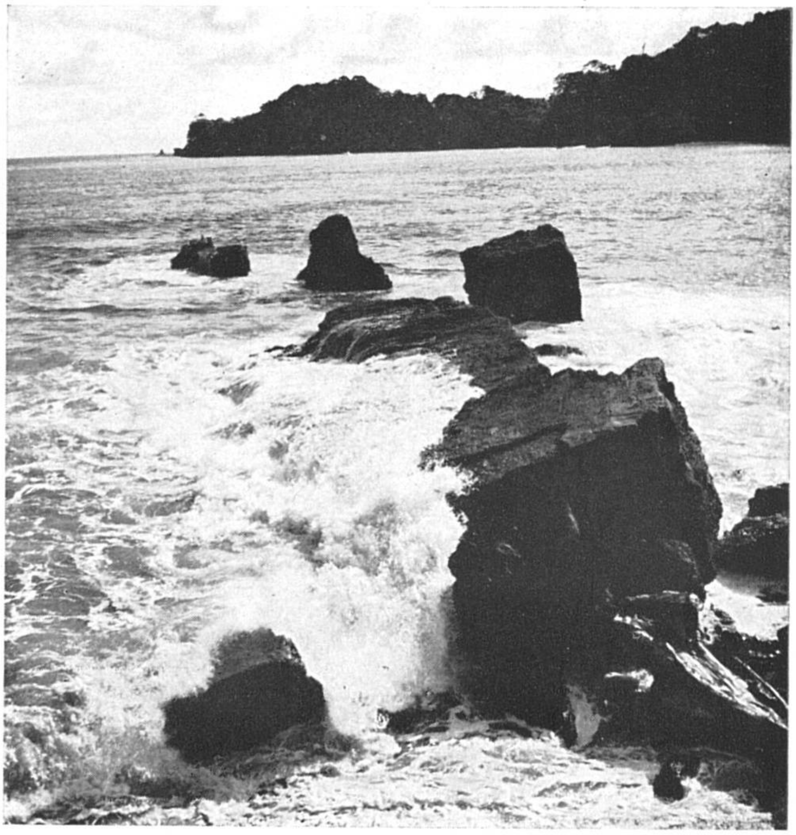


Photo Nr. 2.
Lower Miocene conglomerate rocks of the SW tip of Gorgona island with the Tasca channel and the S end of Gorgonilla.

Photo Nr. 3. Banded Upper Eocene of Gorgonilla, consisting of an alternation of tuffaceous sandstones and siliceous shales.

Photo Nr. 4. Coarse ophitic diabase. Main rock type of Gorgona island. Idiomorphic plagioclase laths and augites. Enlarg. approx. 90 ×

Photo Nr. 5. Peridotite from Gorgonilla Island. The olivines are partly altered into serpentine. Enlarg. approx. 90 ×.

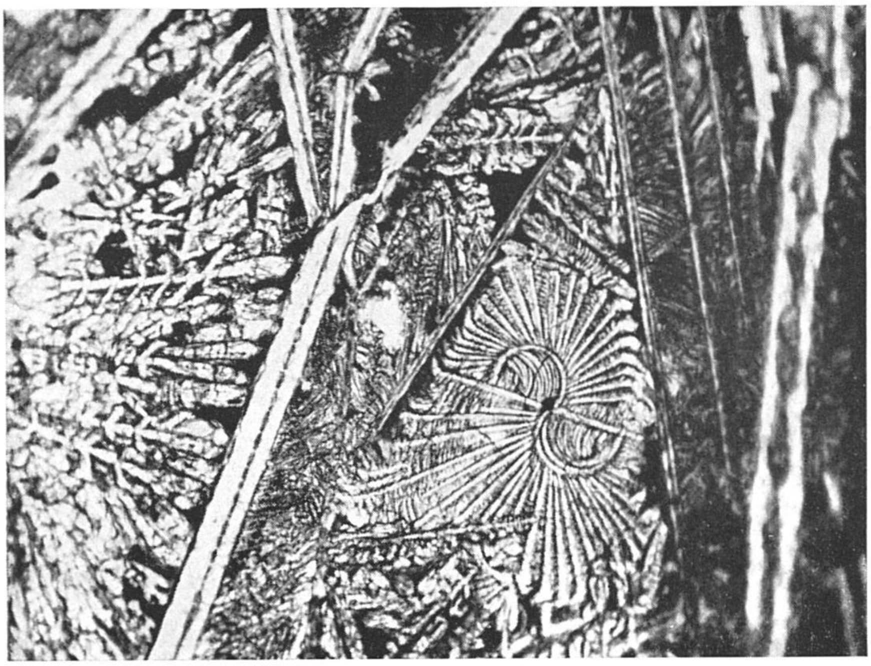


Photo Nr. 6. Arborescent skeletal augite growth, within lamellae of serpentine minerals. Diabase ("Octahedral" type) of Punta Trinidad. Gorgona. Approx. Enlarg. 120 ×.

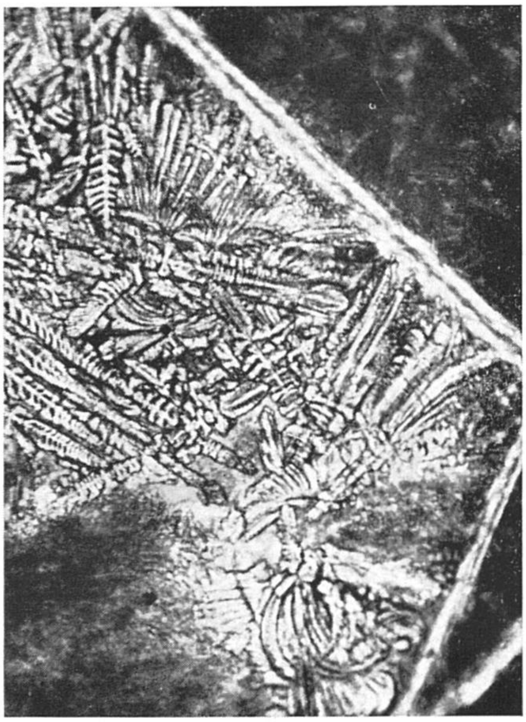


Photo Nr. 7. Arborescent skeletal augite crystals, partly with altered glass. From diabase. Punta Trinidad. Gorgona. Enlarg. approx. 90 × ("Octahedral" type).

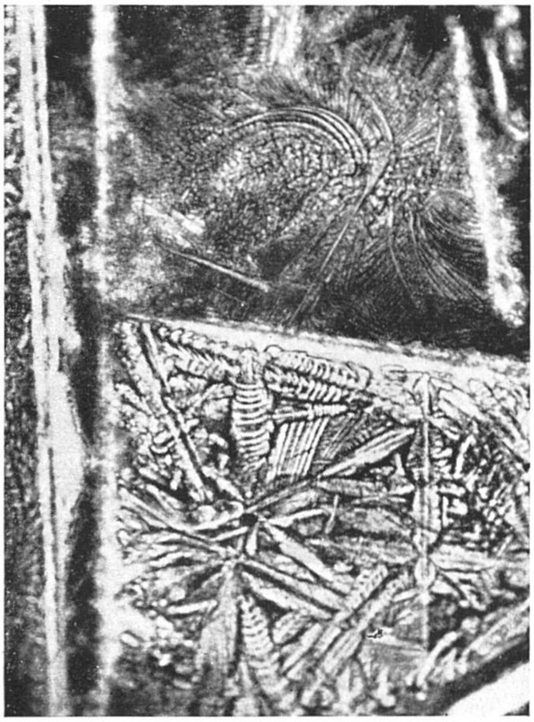


Photo Nr. 8. Independent development of arborescent augites within lamellae of serpentine minerals. Diabase of Punta Trinidad. Gorgona. Enlargement approx. 90 ×.

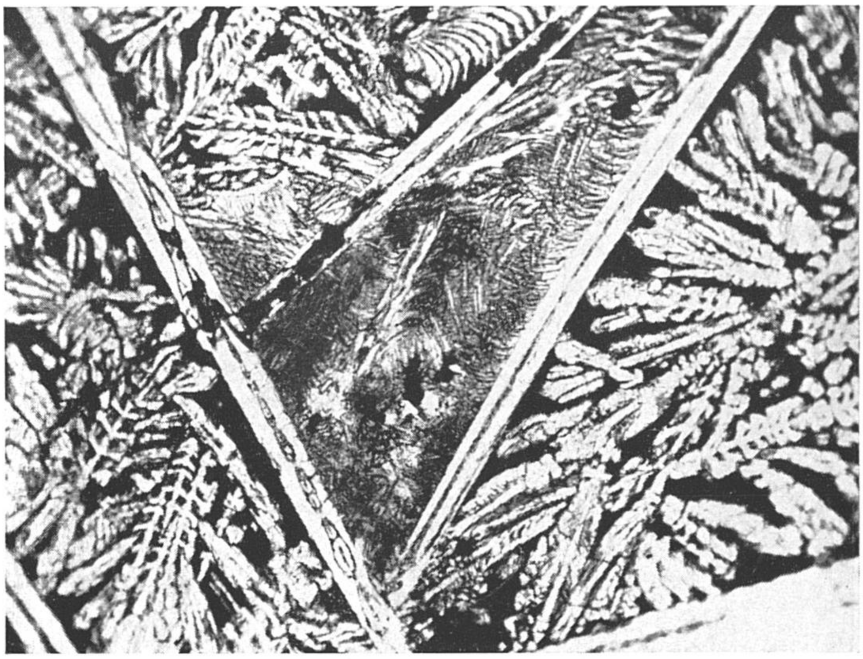


Photo Nr. 9. Independent growth of skeletal arborescent augites within different segments in altered glass. Diabase, Punta Trinidad, Gorgona. Enlargement approx. 120 ×.

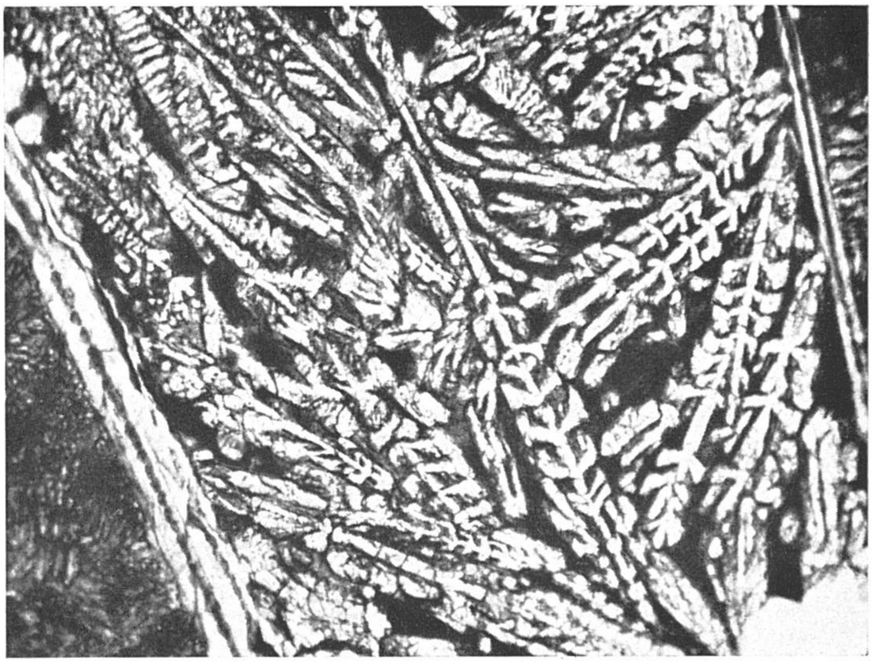
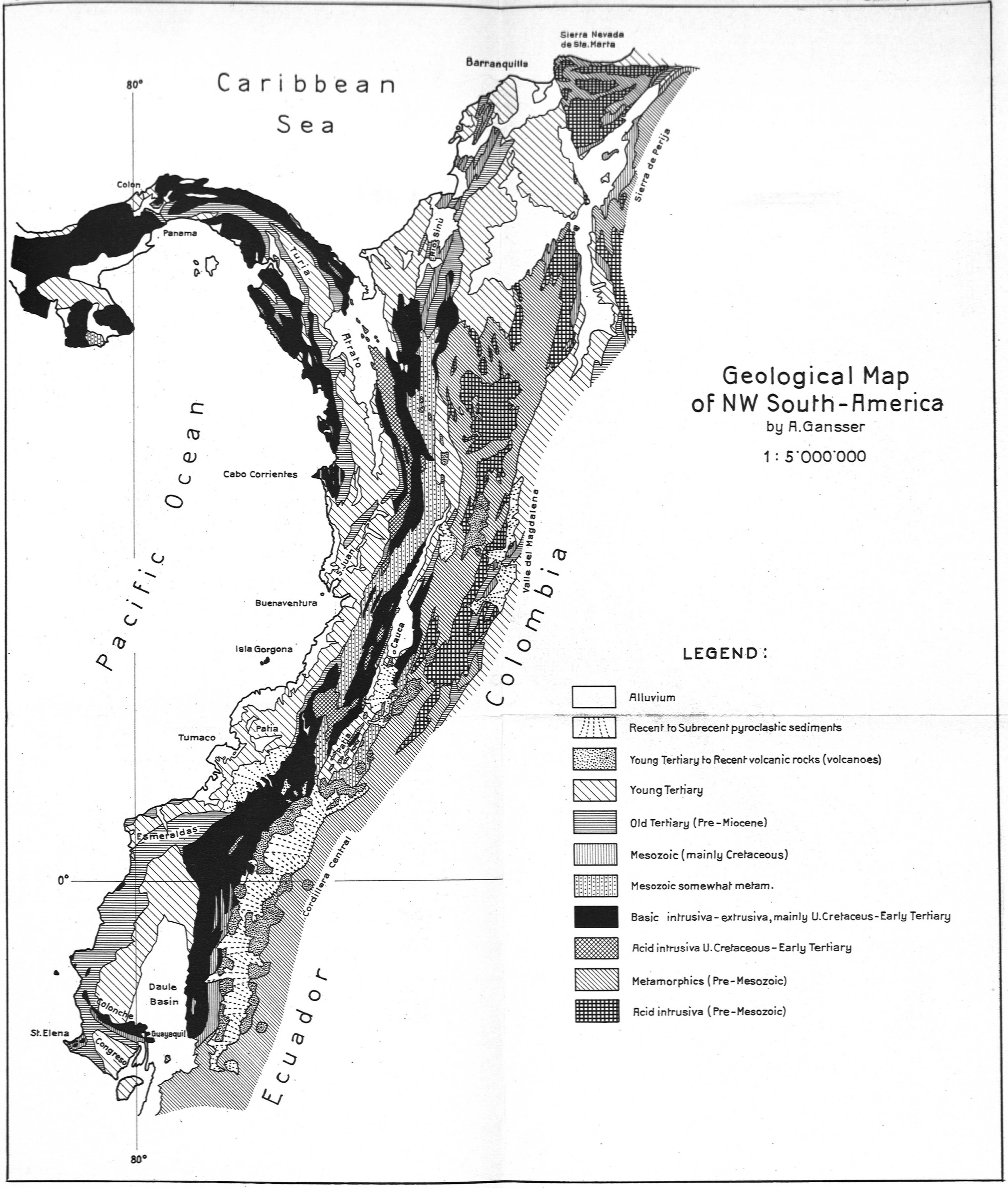


Photo Nr. 10. Coarse, arborescent "harpoon" type augite crystals in the "octahedral" diabase rocks of Punta Trinidad, Gorgona. Enlargement approx. 180 ×.


Geological Map
of NW South-America
by A. Gansser
1 : 5'000'000
LEGEND:
Alluvium
Recent to Subrecent pyroclastic sediments
Young Tertiary to Recent volcanic rocks (volcanoes)
Young Tertiary
Old Tertiary (Pre-Miocene)
Mesozoic (mainly Cretaceous)
Mesozoic somewhat metam.
Basic intrusiva-extrusiva, mainly U. Cretaceus-Early Tertiary
Acid intrusiva U. Cretaceous-Early Tertiary
Metamorphics (Pre-Mesozoic)
Acid intrusiva (Pre-Mesozoic)
Caribbean Sea
Pacific Ocean
Colombia
Ecuador
Sierra Nevada de Sta. Marta
Barranquilla
Sierra de Perija
Colon
Panama
Turia
Atrato
Rio Sinú
Cabo Corrientes
Valle del Magdalena
Buenaventura
Isla Gorgona
Cauca
Tumaco
Patia
Esmeraldas
Cordillera Central
Daule Basin
Colonche
Congreso
St. Elena
Guayaquil
80°
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80°

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thus most probably early Oligocene in age. Direct contacts with the Tertiary sediments were not observed by the writer.

The tonalites and their contacts with the basic rocks play an important role in the distribution of the platinum and gold occurrences of West Colombia. It is however most difficult to detect the platinum in its primary emplacement, since so far it is practically only known from secondary deposits.

Along the East slopes of the West Cordillera occur the andesitic and dacitic rocks, cutting through Miocene sediments. They are already related to the subrecent and recent volcanism. As far as is known to the writer, post Miocene rocks are practically absent West of the West Cordillera, and were not observed in the Coastal Cordillera. On the other hand they have a wide distribution over the Central Cordillera, particularly in the volcanic belt of S Colombia and Ecuador.

We may finally recapitulate the types and age relations of the igneous rocks of North-West South-America as follows:

Pre Paleozoic igneous rocks are not known. They were studied in the Central and East Cordilleras, as well as in the Llanos of Colombia (towards the Guayana shield). (See also GANSSER in D. TRÜMPY: Pre Cretaceous of Colombia, Bull. of the Geol. Soc. of America. Vol. 54, 1943.) They are represented by granosyenitic to syenitic rocks. Acid syenitic rocks form also one of the main constituents of the Guayana shield basement.

Palaeozoic intrusions are frequent in the Central Cordillera and the Sierra Nevada de Santa Marta, characterized by granodiorites and diorites. They were not observed in West Colombia.

Mesozoic igneous rocks form a great part of the West Cordillera in form of complex porphyrites.

At the end of the Cretaceous and in the early Tertiary occurred the wide-spread intrusions and extrusions of basic and ultrabasic rocks accompanied and mainly followed by acid intrusions of tonalites.

The younger Tertiary is characterized by frequent andesitic and dacitic volcanic rocks, which finally lead to the present active volcanism of S. Colombia and Ecuador.

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1 map of NW South America. Geol. 1 : 5000000
1 map of the Gorgona islands. Geol. 1 : 62500

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