Geology. — *On rocks from the Caribbean Coast Range (Northern Venezuela) between Puerto Cabello-La Cumbre and between La Guaira-Caracas.* By L. RUTTEN.

(Communicated at the meeting of September 26, 1931.)

In the summer of 1930 I had the opportunity to visit with some students the new road between Puerto Cabello and Valencia and between La Guaira and Caracas and to make a small collection of rocks on the first road between El Palito and La Cumbre and on the second between La Guaira and the vicinity of Caracas. The available time being very short, our investigation could only be cursory. The roads have been superficially mapped in such a way that the findspots could be indicated on the map with sufficient accuracy (see accompanying sketches). The purpose of our survey was twofold. We had detected on the island of Bonaire a gravel-formation. the pebbles of which — partly of gneissic composition — could not have originated in the island itself [1]). It seemed probable that they had been conveyed to Bonaire from Northern Venezuela in a time, when the island was still connected with the mainland, and it was possible that some of the pebbles of Bonaire would resemble to some samples of a rock collection from the nearest parts of the coast range. In the second place the available data on the composition of the schistose rocks which are known to compose the Venezolan coast range are rather poor so that a description of our samples would be of some value for the knowledge of this part of the coast range. It is, therefore, desirable to give first a short survey of what is known about the petrographic composition of the coast range in the two regions visited by us.

G. P. WALL [2]) has given in 1860 some details on the schists of the "Caribbean formation" of the Venezolan coast range. They are no more of interest. H. KARSTEN [3]) published two years later a special essay on the geology of the province of Caracas, the petrographical details of which are equally no more of any use. W. SIEVERS has visited on his first journey to Venezuela the region of Puerto Cabello and Valencia [4]); in the description of his second voyage [5]), however, he is much more detailed and explicit.

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[1]) P. PIJPERS, The occurrence of foreign pebbles on the isle of Bonaire. These Proceedings. XXXIV. 1931. p. 169—174.

[2]) G. P. WALL, On the geology of a part of Venezuela and of Trinidad. Q. J. Geol. Soc. London. XVI. 1860. p. 460—470.

[3]) H. KARSTEN, Die geogn. Beschaffenheit der Gebirge der Provinz Caracas. Z. Deutsch. Geol. Ges. **14**. 1862. p. 282—287.

[4]) W. SIEVERS, Reisebericht aus Venezuela. Mitth. Geogr. Ges. Hamburg. 1884. p. 272—286.

[5]) W. SIEVERS, Zweite Reise in Venezuela in den Jahren 1892—1893. Mitth. Geogr. Ges. Hamburg. XII. 1896. 327 pp.. map and sections.

He says:

"Den nördlichen Abhang bilden an der Küste bei El Palito bis zur Quebrada Vallecito und Limoncito grossentheils krystallinische Schiefer, an denen besonders der... Glimmerschiefer auffällt. Er steht hauptsächlich zwischen Cambur und José Luis an, während nordwärts gegen das Meer namentlich dunkelbläuliche quarzreiche Schiefer erscheinen, die über dem Glimmerschiefer liegen... Gegenüber der Quebrada Limoncito steht... flaseriger Gneiss an, der von quarzreichen Schiefern überlagert wird, und ein typischer Gneiss bildet auch das Gestein der Quellen von Las Trincheras. Ausserdem tritt bereits im Unterlaufe des Rio Agua caliente bei José Luis rother Granit vereinzelt auf, schwarzweisser, grobkörniger beginnt bei Vallecito... häufiger zu werden, und setzt nun von Limoncito an aufwärts das Gebirge, im Verein mit Gneiss, grossenteils zusammen. Namentlich die Strecke von Las Trincheras bis La Entrada besteht fast ausschliesslich aus Granit mit grossen weissen Feldspathen" (l.c. p. 136—137).

SIEVERS mentions still other rocks from the neighbourhood of San Esteban, in the mountains S. of Puerto Cabello: micaschist with clorite and garnet, calschist and marble (l.c. p. 137). It is rather disagreable that the localities José Luis, Vallecito and Limoncito have not been indicated on SIEVERS' maps. SIEVERS gives equally information about the region of La Guaira:

„Im Westen besteht das Gebirge zwischen Caracas und La Guaira aus Gneiss und Glimmerschiefer; vom Meere aus erreicht man sogleich die rothen Lateritfelsen, deren Material aus verwittertem Glimmerschiefer entstanden ist, und steigt über diesen und gelegentlich auftretenden Gneiss zur Passhöhe empor... Granit habe ich nicht gefunden auch scheint derselbe in diesem Theil der Nordkette kaum vorzukommen (l.c. p. 158)".

SIEVERS does not doubt, which rock forms the main component of the coast range:

„Man muss... die Nordkette... vom Yaracui bis zum Cap Codera als ein Glimmerschiefergebirge auffassen, in dem nur an einzelnen Stellen grössere Einlagen von Gneiss sich zeigen, wie bei Colonia Tovar und an der Silla de Caracas, und einzelne Granitstöcke die hohen Gipfel bilden... auch zuweilen in niederigeren Niveaus, wie bei Las Trincheras... auftreten" (l.c. p. 159).

It is clear that SIEVERS regards the coast cordillera as a mountain range composed almost exclusively of micaschists.

I am sorry that I could not consult a short essay by E. CORTESE [1]) on the geology of Venezuela. A publication of DALTON [2]) states that the "Carribbean series" of the coast range:

„includes silvery mica schists... graphitic schists and gneisses" (p. 205).

Whilst SIEVERS does never doubt the archean age of the schists of the Caribbean range, DALTON, although not pronouncing a definite opinion, takes into consideration the possibility that the Caribbean series is paleozoic or, possibly, even mesozoic.

A. JAHN [3]) indicates in his sections through the coast range concordant

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[1]) E. CORTESE, Escursioni geol. al Venezuela. Boll. Soc. Geol. Ital. XX. 1901. 447—469.

[2]) L. V. DALTON, The geology of Venezuela. Geol. Mag. (5). IX. 1912. p. 203—210.

[3]) A. JAHN, Esbozo de las formaciones geologicas de Venezuela. Caracas, 1912.

superposition of archean schists and gneisses on granite; in his descriptions he follows almost litterally the descriptions of SIEVERS; in his geological map of Venezuela there is a queer mistake, in so far as he indicates between El Palito and Las Trincheras a large region of cretaceous sediments.

A short notice of M. REINHARD [1]) is the first and only one to give some more details on the rocks between La Guaira and Caracas:

„Les schistes crystallophylliens dans la région de La Guayra-Macuto sont identiques aux schistes de Casanna de nos Alpes. Nous ne voulons nullement leur attribuer de ce fait le même âge; mais il est très probable qu'ils représentent du Paléozoique ou même du Mésozoique métamorphique... Intercalés dans les schistes crystallophylliens on trouve dans la région de La Guayra des gabbros, des amphibolites et des eclogites" (p. 15).

Although the newest and most extensive publication on the Geology of Venezuela by R. A. LIDDLE [2]) is a very useful book for all geologists interested in the country, it has two bad qualities: it lacks criticism and it repeats itself too often. Both qualities come to the fore in LIDDLE's description of the coast range. LIDDLE thinks that it is possible to distinguish in the schist-formation of the coast range an "older" and a "younger" series, and assures so frequently that the older series is paleozoic that no reader will be convinced [3]). LIDDLE's statement has been based without criticism on a publication of DREVERMANN [4]), who, long ago, has described some silurian fossils which he believed to have come from Venezuela without, however, knowing the exact findspot. DREVERMANN's statement has afterwards been contested by SALOMON [5]), and there exists nowadays no more any doubt, that DREVERMANN's fossils did not proceed from Venezuela but from North America. LIDDLE could know these facts, because the title of SALOMON's publication is found in LIDDLE's bibliography. As to the petrographic composition of the coast range, LIDDLE seems to share SIEVERS' opinion that micaschists are by far the most frequent rock:

"gneissoid schists, mica and garnet schists, schistose slates and phyllites" (p. 55).
"...composed chiefly of silvery gray mica schists" (p. 68).
"silvery-gray mica schists, talc schists and garnet schists... are predominant".

We shall describe now our rock samples, beginning with those that have been collected between La Cumbre (the highest point on the road Puerto Cabello-Valencia) and El Palito (see sketch 1). The samples proceed from 11 localities.

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1) M. REINHARD, Géol. de la région orientale du Vénézuela. C. R. Soc. Phys. et Sc. Natur. Genève. **39**. 1. 1922. p. 13—16.

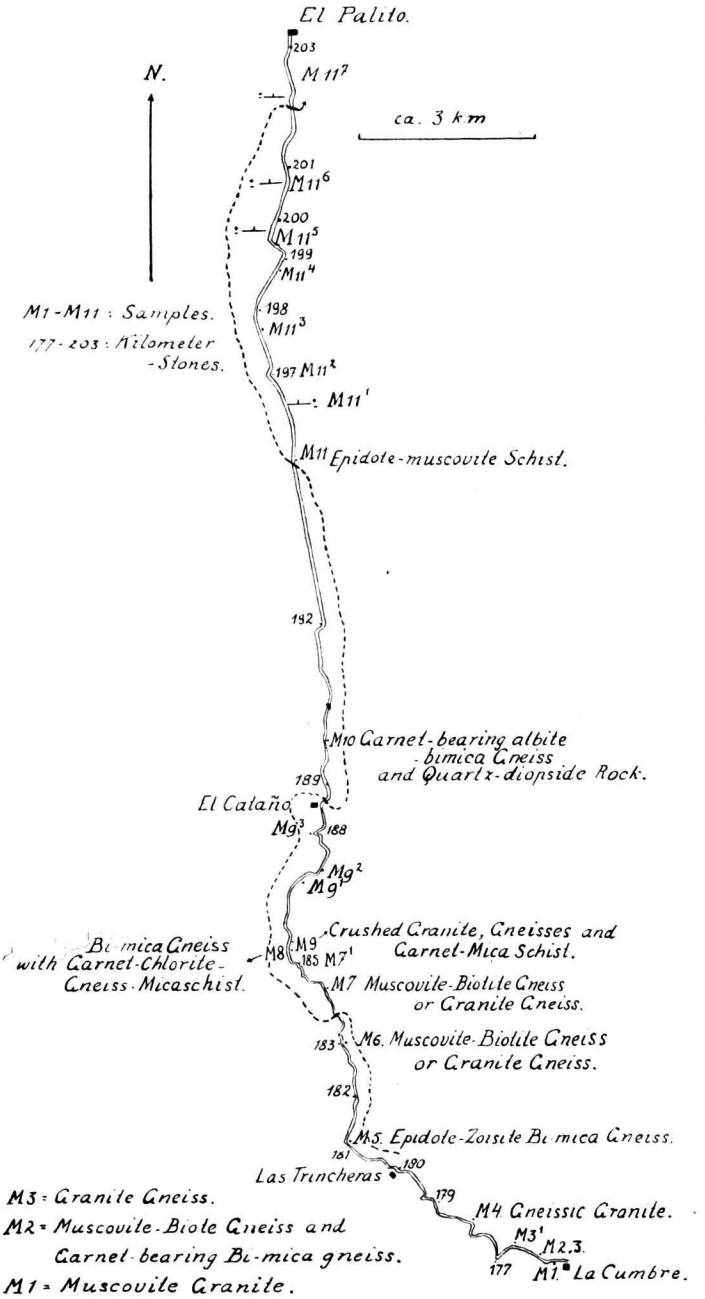
2) R. A. LIDDLE, Geology of Venezuela and Trinidad. 1928. 552 pp.

3) "without doubt paleozoic" p. 68; "probably early or middle paleozoic", p. 69; „undoubtedly paleozoic" p. 70; "without much doubt paleozoic" p. 71.

4) F. DREVERMANN, Ueber Untersilur in Venezuela. Neues Jahrb. etc. 1904. I. p. 91—93.

5) W. SALOMON, Ueber angebliches Untersilur in Venezuela. Z. Deutsche Geol. Ges. 1909. Monatsber. p. 193.

Sample 1. Field observation: "Small dike of ?aplite in granite". The granular rock consists of muscovite (in rather large, strongly bent crystals, in smaller crystals, and as filling in crush-zones), albite (with traces of idiomorphism, with inclusions of secundary



muscovite), potash feldspar (orthoclase and microcline without any idiomorphism), and quartz (very cataclastic). The rock has been very strongly crushed: cataclastic quartz and many micro-crushzones. As there is a trace of sequence of crystallization, it may be called a crushed muscovite granite.

Sample 2. Field observation: "gneiss". There are two fragments or rock from this locality.

The first consists of muscovite (in large and small crystals and as sericitic filling in plagioclase), quartz (in large mosaics), albite (without any trace of idiomorphism), and xenomorphic, perthitic orthoclase, sometimes with quartz-drops.

The quartz and the albite are more or less clearly arranged in parallel bands. muscovitegneiss.

The second rock differs from the foregoing by smaller grain, and by the occurrence of microcline, biotite (in large crystals and in streaky masses), and numberless small garnets. It is a garnet-bearing bi-micagneiss.

Sample 3. Field observation: "dikes in gneiss". Strongly crushed rock, consisting of xenomorphic, cataclastic quartz and xenomorphic potashfeldspar (with cataclastic margins and microcrushzones, both orthoclase and microcline occurring). Moreover some acid plagioclases with partial idiomorphism are enclosed in the potash feldspar. Biotite and muscovite only in traces. ?granite-gneiss.

According to my notes the rocks of sample 2 and 3 occur as far as point M. 3^1 (see sketch).

Sample 4. Field observation: "gneiss". Coarse-grained, somewhat schistous rock, containing quartz (in large mosaics), muscovite (in large and small crystalls and as sericitic filling), potash-feldspar (always xenomorphic, microcline and perthitic orthoclase), and albite (in partially idiomorphic, strongly sericitized crystals). gneissic granite.

Sample 5. Field observation: "micaschist with veins and lenses of quartz". Is a rather coarsely grained, clearly schistous rock, containing in a substratum of quartz, albite, orthoclase and muscovite many prisms of epidote and zoisite and irregular crystals of biotite; moreover traces of rutile and haematite. epidote-zoisite bi-micagneiss.

Sample 6. Field observation: "coarse gneiss". Very coarse-grained, schistous rock with lenses and layers of: quartz (in mosaics, sometimes strongly cataclastic), orthoclase (in large, xenomorphic, perthitic crystals), albite-oligoclase (xenomorphic, always with sericite, sometimes with filling of sericite-epidote-garnet), and dark minerals (some garnet, apatite, with more epidote and chiefly biotite and muscovite; all concentrated in dark spots of the rock). bi-micagneiss or granite gneiss.

Sample 7. Field observation: "?Granite". Coarsely granular rock. Biotite and muscovite with some apatite and zirkon are clearly concentrated in dark spots. Very large, perthitic orthoclases may include quartz. Quartz occurs moreover in very large mosaics, albite-oligoclase in crystals, that for the greatest part are filled with sericite, only the marginal rims remaining free of sericite. bi-mica gneiss or granite gneiss.

According to my notes the same rocks are continuing as far as point M. 7^1.

Sample 8. Field observation: "coarse gneisses with micaschist". The gneissic sample shows layers, rich in mica, and between them lenses and layers of lighter material. The first contain biotite (brown-black), muscovite, many small grains and crystals of titanite and some apatite. The lighter lenses contain large mosaics of quartz, large, xenomorphic, perthitic orthoclases, in some places many, non-twinned, xenomorphic albites, in other places large, twinned albites, with traces of idiomorphism. The rock is a bi-mica gneiss. The other sample is clearly schistous; it contains in a substratum of much quartz and some, non-twinned albite much biotite and muscovite, many small crystals of garnet, many small crystals of epidote-zoisite, frequent grains of black ore and large spots of chlorite with quartz-drops; besides traces of zirkon. It is a garnet-chlorite gneissic micaschist.

Sample 9. Field observation: "Granite with inclusions of micaschist and in contact with micaschist". No less than six samples have been taken at this locality. Some of the "granite"-samples contain somewhat idiomorphic albite oligoclase, partly enclosed in perthitic orthoclase, fields of strongly cataclastic quartz, whilst muscovite, biotite and epidote are concentrated in dark spots. In one section lies a large, idiomorphic garnet-crystal. These samples might be called crushed bi-mica granite. The "granite"-sections from the neighbourhood of the contact have a more gneissic habit: they are poor in biotite (frequently chloritized), richer in muscovite; they contain almost no sub-idiomorphic plagioclase; they bear many small, non-twinned albite crystals with quartz-drops. It is questionable, whether these rocks still merit the name of granite gneiss. In some sections there is a clear concentration of muscovite at the contact with the schist.

The schistous samples show still more variation than the "granite". An inclusion in the "granite" consists of a substratum of quartz with albite and orthoclase with much biotite and epidote-zoisite: an epidote-zoisite-biotite gneiss. Near the contact with the "granite" occur garnet-bearing micaschist and garnet chlorite-bimica gneiss.

According to my notes the same rocks continue rather far to the North and are especially visible at the spots M 9^{1}—^{3}.

Sample 10. Field observation: "Micaschists with veins of ?quartz". The schistous sample contains in a xenomorphic substratum of quartz, albite (non-twinned, frequently with quartz-drops) and less orthoclase many fine, small garnet crystals (110) and, especially concentrated in the darker layers, much biotite and lesser muscovite, the biotite sometimes having changed into chlorite. The rock is a garnetbearing albite bi-mica gneiss. The sample of the "vein" is a very strange rock, consisting exclusively of quartz and diopside, each forming one half of the slide. quartz-diopside rock.

Sample 11. Field observation: "Micaschist". The finely schistous rock is composed of an intime, rather coarse tissue of muscovite and quartz with many prisms of epidote-zoisite, with rather rare, large crystals of non-twinned albite, containing quartz-drops and with some chlorite. epidote muscoviteschist.

According to my notes the rocks of S. 11 are continuing far to the North, and are especially visible at the spots S. 11^{1}—^{7}. I feel, however, not at all sure that all these rocks are true micaschists, as some rocks, which in the field seemed to be micaschists (Samples 5, 8, 9, 10) proved afterwards to be gneisses.

The samples from the road El Palito-La Cumbre give rise to the following remarks.

All the non-finely schistous rocks show evidence of very strong crushing. In consequence it is not easy to distinguish between gneissic and granitic rocks. True granites, with a clear crystallization sequence, are absent. Some rocks, however, bear some evidence of granitic origin. The "granitic" features are: 1. slight idiomorphism of the plagioclases, 2. slight zonary development of the plagioclases with the most acid parts at the outer margin (sample 7), 3. the concentration of the dark minerals in well-defined dark spots of the rock, 4. the occurrence of clear eruptive contacts (Sample 9). These rocks have been called: crushed granite, granite gneiss or gneissic granite.

The study of the slides shows that true gneisses have a much larger distribution in the coast range than the field observations would make

suppose. Indeed: of the 11 samples only one (Sample 11) is a normal micaschist.

Most of the samples show no trace of resemblance with the gneissic pebbles from Bonaire. This, however, is very comprehensible. The clearly schistous rocks, and especially those who contain layers, very rich in mica, will not suffer a long transport: after having been rolled only over a short distance in a river they will fall to pieces. Only the most resistant rocks will suffer a transport in the form of pebbles over about 200 km.. this being the distance between the coast range and Bonaire. It is of importance that there are indeed some samples which show some relation to the pebbles of Bonaire while there is one general character, which is common to both groups of rocks. This is the very strong crushing, occurring in both, and giving rise to many micro-crush-zones in the rocks and to the formation of strongly cataclastic quartzes, and, more rarely, of cataclastic feldspars. The samples of the coast range and of Bonaire which show some resemblance, are the following.

The ?granite gneiss of sample 3 is much like a microcline-gneiss from Bonaire, the difference being chiefly that the rock from Bonaire contains relatively more microcline and no plagioclase.

Also the muscovite-free parts of sample 4 resemble clearly to a gneiss from Bonaire.

Passing to the samples from the road La Guaira-Caracas, it may be stated at once, that there have not been found here rocks which resemble to the gneissic rocks of Bonaire. They bear generally another character than the schists from near Puerto Cabello. On the one hand there is no trace of granitic rocks in the Hinterland of La Guaira, on the other hand we find some rocks, not known from Puerto Cabello. These are:

Sample c. A rock with phyllitic habit, with much calcite in layers and in a vein. The slide contains much calcite in irregular crystals, much muscovite and less chlorite (both in large and small crystals and in aggregates), very much quartz (in small grains, sometimes giving the impression of being clastic), and some feldspar in rather large crystals. calcite-micaschist.

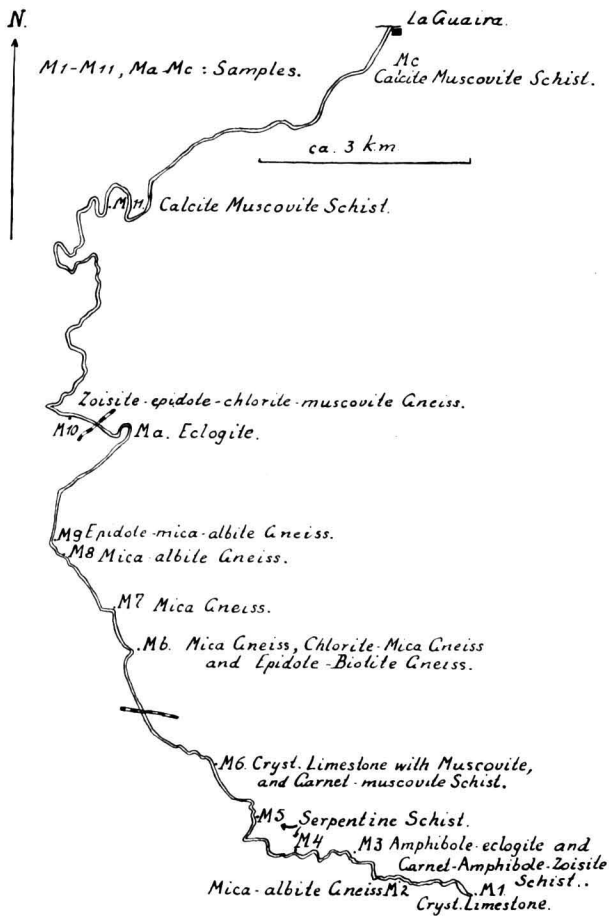
Sample 11. Is a rock, nearly related to sample c, but without feldspar and with some titanite. calcite-micaschist.

Sample a. A granular, very heavy, lightgreen rock with light-red garnets. It contains many idiomorphic garnets, containing inclusions of quartz and other minerals, much muscovite (in fine crystals and locally as filling masses), many crystals of omphacite and fine, idiomorphic crystals of zoisite; lastly numerous small grains and crystals of rutile. It is a typical eclogite.

Sample 3. Two samples have been taken at this locality. The first has much resemblance with sample a, differing from it only by the presence of quartz and of pale bluegreen hornblende. It is an amphibole-eclogite. The second sample resembles macroscopically also to an eclogite. It differs from the former, however, by the absence

of omphacite, so that the rock, presenting the mineral combination garnet-amphibole-zoisite, must be called a garnet-amphibole-zoisiteschist.

Sample 1. is a crystalline limestone with very few scales of a mineral that in most properties resembles to a colourless mica, whilst, however, the index of refraction is considerably lower, being between 1.55 and 1.56. crystalline limestone.



Sample 6. Three samples have been collected here. The first is a crystalline limestone with muscovite and zoisite, containing moreover pyrite in cubi and grains, and quartz in undulously extincting grains. The second sample is a crystalline limestone with muscovite, containing quartz (in cataclastic grains), some chlorite and titanite with pyrite. The third sample is a garnet-muscovite schist (with quartz, rare albite, many garnets, much muscovite and some chlorite and titanite). We got the impression that the three types of rocks pass into each other.

Sample 5 and 4 are very simple rocks, being composed almost exclusively of foliaceous serpentine with a little black ore in grains and as dust. The rocks are somewhat schistous. serpentine schist.

Samples 2, b, 7, 8, and 9 are all very nearly related to each other. In the field they gave the impression of being true injected schists, as they always consist of dark layers, rich in mica, interchanging with colourless layers, lenses and eyes, whilst the colourless parts may even cut the coloured bands. It has been, however, impossible to state under the microscope any sequence of crystallization in the lighter bands, so that it is impossible to prove that the rocks are really injected schists. As they all have the mineral composition mica, feldspar and quartz, they must be called banded mica gneisses. It is desirable to add the following details.

The feldspar is most commonly untwinned albite, which in some samples is the only feldspar. We have then mica-albite gneiss. In most samples, however, there occur also orthoclase and microcline. Only in very few crystals of some of the samples there is a faint indication of some idiomorphism in the albites. Bij the side of albite there may occur a lamelled plagioclase, somewhat more basic (albite-oligoclase). Generally the biotite is much more frequent than the muscovite; the latter being even absent in some samples. The biotite belongs to three varieties: one very little pleochroitic (colourless to pale-green), one light green to dark green, one light brown to blackish brown. The quartz occurs in mosaics or as cataclastic masses. In some samples there is a clear banding in the colourless parts of the rock, in so far as some bands consist almost exclusively of quartz, other bands of untwinned albite, others again of potash feldspar. The most frequent accessory mineral is titanite, occurring in crystals and in grains; in some samples there is much epidote, sometimes probably accompanied by orthite; other accesories are apatite, pyrite, magnetite and, in one sample, calcite, occurring in some layers of the rock.

Sample 10, with pronounced schistosity, contains as colourless minerals non-twinned albite and quartz; both without any idiomorphism. The coloured minerals are: many prisms and grains of epidote and zoisite, much chlorite and muscovite and some magnetite and apatite. zoisite-epidote-muscovite gneiss.

The samples from the road La Guaira-Caracas show once more the predominance of gneisses in the Venezolan coast-range. In contradistinction with SIEVERS' and LIDDLE's opinion we see that micaschists are rare: only sample 11 and c merit this name. It must, however, be remarked that in the field many rocks give the impression of being micaschist; the microscopical investigation shows then, that by the side of quartz there is always much feldspar in the rock.

Whilst there is generally much difference between the rocks on the road El Palito-La Cumbre and La Guaira-Caracas, there are also affinities. In the first place we find that on both roads the less strongly metamorphosed rocks are found near the coast. The calcite-muscovite schists from near La Guaira (samples c and 11) and the epidote-muscovite schist (sample 11) from the road El Palito-La Cumbre are clearly less strongly metamorphosed than all the rocks, farther in the interior. Whilst the rocks from near the shore may be reckoned to the epi-zone, the rocks from the interior seem to belong mostly to the meso-zone, whilst the eclogites even may belong to the kata-zone of metamorphism.

A second point of resemblance between the rocks from the two roads is that the type which is most common near La Guayra (sample 2, b, 7, 8, 9) is also present South of El Palito (sample 8).

SUMMARY.

1. In contradistinction with the opinion, mostly expressed in the existing literature the most frequent rocks in the Venezolan coast range seem to be gneisses, micaschists occurring only in the neighbourhood of the coast.

2. The granites of the coast range are strongly crushed rocks, which in many respects resemble to gneisses. They do not show any resemblance with the abyssal rocks that are known from the islands North of Venezuela.

3. The schists from the coast range belong partly to the epi-zone (rocks from near the coast), mostly to the meso-zone, partly also to the kata-zone.

4. Nothing can be said about the age of the rocks in the coast range.

5. It is quite possible that the gneissic rocks, occurring as pebbles in Bonaire have been derived from the Venezolan coast range, and more especially from the Hinterland of Puerto Cabello.

Utrecht, 17 September 1931.