

Geology. — *Remarks on the geology of Colombia and Venezuela. I. The age of the non-fossiliferous slates and of the metamorphic schists.* By L. RUTTEN.

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The author has been in the necessity of studying, during the past months, the geologic literature on Colombia and Venezuela. He has got, thereby, some ideas which differ materially from the conceptions generally held with regard to the geology of these republics. He regrets that he has paid only short visits to the republics — the longest having been an excursion to NW. Venezuela and Cucuta, where he travelled as a guest of the Caribbean Petroleum Company — but he is of the opinion that this lack of local experience needs not impede him to form and to publish personal conceptions on the geology of the area. There are especially three subjects which the author would like to treat: the age of the non-fossiliferous slates and sandstones and of the metamorphic schists, the areal distribution of the cretaceous, and the historic geology and the tectonics of the tertiary.

The metamorphics of Venezuelan Guyana, which so clearly belong to the Guyanan-Brazilian shield, are generally regarded as prepalaeozoic, although this age has not been proved with absolute certainty (45). In the following we shall not discuss them; we shall occupy ourselves exclusively with the metamorphics of the cordilleran region.

The slates and schists of the Cordilleras have been regarded by many authors as palaeozoic or pre-palaeozoic. W. BERGT (5, 6, 7) called the slates palaeozoic and the schists prepalaeozoic; W. SIEVERS (36, 37, 38) considers slates and schists both to be archaean; E. GROSSE (13), under the influence of G. STEINMANN, regards all the slates and schists of Antioquia as prepalaeozoic and thinks that their age increases with increasing metamorphism; E. HUBACH (17) and E. SCHEIBE (30) consider the Quetame-schists to the East of Bogotá as praecambrian and H. GERTH has, in the most general sense, pronounced that slates and schists in Northern South America are prepalaeozoic. He writes:

„Die Hauptmasse der fossilfreien regionalmetamorphen Gesteine, die durch die ganzen Kordilleren immer wieder an die Oberfläche kommen, halte ich für algonkisch. Wiederholt sehen wir paläozoische oder mesozoische Schichten mit den metamorphen Gesteinen verfaltet, ohne dass die erstere ihre Fossilführung eingebüsst haben Wohl werden auch die jüngeren Sedimente bei intensiver Faltung dynamometamorph verändert, aber dann nehmen sie doch nicht den Habitus der hier behandelten regionalmetamorphen Gesteine an“ (11, p. 80—91).

Two years later, GERTH is somewhat more prudent in his opinion, at least with regard to the schists of the Caribbean Coast Range, where LAMARE has found — amidst the schists — true radiolarites (24). GERTH writes:

„Wenn diese (the radiolarites) auch nicht gerade als absolut beweisend für ein paläozoisches Alter der betreffenden Gesteine angesehen werden können, möchten wir uns nicht mehr so entschieden gegen das paläozoische Alter gewisser metamorpher Gesteine in der nördlichen Kette des karibischen Gebirges aussprechen, wie wir es früher getan haben“ (12, p. 346).

Whereas the authors hitherto mentioned apparently try to give the rocks in question a very high age, there are others who have regarded them as palaeozoic or, partly, even as mesozoic. EUGSTER (10) calls the metamorphics of the Cordillera de Bogotá palaeozoic; R. SCHEIBE (32) equally considers some schists of the Cordillera Central of Colombia as palaeozoic; DE CIZANCOURT and SCHNEEGANS (9) do the same with respect to the Venezuelan metamorphics. REINHARD (28), who is strongly convinced of the postalgonkian age of the schists of the Coast-Range in NE. Venezuela, discusses the possibility of their mesozoic age.

Various authors, who described slates and schists from Colombia and Venezuela, have not given an opinion about their age. Among these we may mention AUBERT DE LA RÜE (3), BENDRAT (4), HETTNER-LINCK (16), RUTTEN (29) and STUTZER (40).

In general, the hitherto mentioned authors did not give thorough arguments for their opinions; we may say that their opinion has been based chiefly on a certain "feeling". Two arguments, however, have been put forward from time to time. Firstly that there are known from Colombia and Venezuela non-metamorphic, fossiliferous, carboniferous, devonian, and, according to some geologists, non-metamorphic ordovician deposits, and that therefore all the metamorphics must be predevonian resp. pre-ordovician. Secondly that the lack of fossils in the slates and schists under discussion proves their great age. It is desirable to argue that these two "proofs" have only very small value. As to the first argument we may cite that, on the island of Aruba (44) there have been found hornblendeschists of cretaceous age which are strongly metamorphic and which, according to their metamorphism would f.i. be regarded by GROSSE (13) as to be of archaean age. Moreover, there occur in many countries at the side of non-metamorphic, older rocks younger ones which are more or less metamorphic. As to the second argument it is sufficient to indicate that f.i. the Cambrian of the Ardennes and the Silurian of Brabant are slightly metamorphic and that they are so poorly fossiliferous, that, if they occurred in a country so slightly investigated as Colombia or Venezuela, they certainly would not have yielded fossils until now.

We shall now pass to the discussion of the different regions, for which there have been given somewhat better arguments for the age of their metamorphics.

1. W. KEHRER (22) found in the southernmost Colombia two metamorphic series: "Glanzschiefer", phyllitic slates and quartzitic sandstones are resting with an angular unconformity on sericite-chlorite-schists, phyllites and quartzitic conglomerates. He proves with these interesting observations that there exist certainly two independent formations of schists in this part of the country, of which the older one presents the strongest metamorphism. He regards the older formation as Algonkian and the younger one as possibly Cretaceous, but for this interpretation he does not give convincing arguments. As a matter of fact the algonkian age remains absolutely unproved, as palaeozoic rocks in this part of the country have not been found until now.

2. R. SCHEIBE (31) has found in Antioquia a formation of porphyritic lava's and tuffs, the cretaceous age of which has been proved by some intercalated fossiliferous layers. In sections, where this porphyritical formation outcrops, he finds also a series of green schists, and he feels sure that these schists are of the same age. E. GROSSE (13) regarded some years later, on the base of their metamorphism, these schists as of middle-algonkian age. I should say that SCHEIBE's opinion is by far more convincing, but that he has not proved the cretaceous age of his green schists. As he has not shown — by careful sampling and by microscopical study of the samples — that there exists a gradual transition between the members of the porphyritic formation and the green schists, it remains possible that there are two formations of quite different age, which, in consequence of intense folding or thrusting, have been brought into seemingly normal contact.

3. HETTNER (15) described from the area E. of Bogotá a series of blue clayshales, quartzites and quartzitic conglomerates which he called "Quetame-series" and which he regarded as probably pre-cretaceous: they occur below fossiliferous, cretaceous rocks. STUTZER found to the W. of this zone of ancient rocks (40) fossiliferous, non-metamorphic carboniferous strata, which contain, however, according to W. KEHRER (21) true quartzites. In the neighbourhood have been found also non-metamorphic, devonian rocks (33). The Quetame schists are, therefore, very probably pre-devonian. W. KEHRER (22) calls them even pre-palaeozoic, and, although this is quite possible, it is far from being proved. We have f.i. to consider that there have been found in Colombia ordovician fossils in a series of rocks, which, according to SCHUCHERT (33), are "strongly folded quartzites, slates, marbles and black limestone", whilst, in Venezuela, ordovician fossils have been found in "a partially metamorphic shale and sandstone series, in some places approaching a micaceous schist" (TERRY, teste SCHUCHERT, 33, p. 693). L. KEHRER, equally, calls the rocks of the Venezuelan Ordovician "semimetamorphic" (20). It is, therefore, very well possible that the semimetamorphic Quetame-schists are silurian.

4. The strongly metamorphic rocks of the Eastern Cordillera N. of Bogotá may very well be pre-palaeozoic. It is, however, necessary to

consider that there have been found in the Cordilleras during the last twenty years more and more outcrops of "hercynian" rocks, and that it is not impossible that the strongly granitized rocks N. of Bogotá are palaeozoic, and metamorphosed by hercynian granites. LERAS CODAZZI (26) even regards the granites of this region — without proving his opinion — as "Andengesteine", i.e. as old-tertiary or as youngest-cretaceous.

5. The silver-white phyllites which have been found as float in rivers on the eastern side of the Sierra de Perijá (25) are very probably pre-devonian, because in these same rivers the devonian is fossiliferous and non-metamorphic. It can, however, not been proved for the present that these phyllites are prepalaeozoic.

6. The gneisses of the Sierra Nevada de Santa Marta may very well be pre-palaeozoic, but they might equally well be palaeozoic, their metamorphism being due to hercynic granitization or to hercynic dynamometamorphism (5, 36).

7. The schists of Goajira peninsula (40) are certainly pre-cretaceous, their pebbles having been found in cretaceous conglomerates; it is, however, impossible to say, even approximately, how much older than the Cretaceous they are.

8. The area in Venezuela where the metamorphics have been best studied, is the Cordillera de Merida. In the past thirteen years there have been published four stratigraphical surveys, which are reproduced here in a diagram. This diagram shows, that great differences in interpretation are

Pre-mesozoic Stratigraphy of the Cordillera de Merida.			
Christ 1927.	Oppenheim 1937.	L. Kehrler 1937 and 1938.	Kündig 1938.
Palmarito series, carboniferous.	Palmarito.	Palmarito.	Palmarito.
Mucupati series, (?Devonian limest., sandst., marl a. quartzite).		Mucuchachi series, (?Devonian: quartz-slates to phyllite etc. Rare traces of fossils)	Mucupati ? (Devonian?)
Caparro-Bellavista series (?lower palaeoz. limest., shales, sandst., micaschists).	Caparro-Bellavista ser. (Middle ordovician schists and semimetamorphic quartzites).	Caparro-Bellavista (Middle Ordovician; metamorphic sandstones and shales).	Caparro series (Ordovician).
	Mucuchies series (green-greyish and black schists and slates: Lower Ordovician).		
	Mucuchachi series (Cambrian).		Eo-palaeozoic granites in sills and apophyses.
	Micaschists and Estanque gneiss (Algonkian). Santo Domingo gneiss, quartzites, phyllites, old granites (Algonkian).		Eo-palaeozoic metamorphics (Mucuchachi Merida, Bellavista, Micaschists, Contact rocks).
Mucuchachi series (Archaean black schists)			Iglesias series. (Archaean gneisses, migmatites, arterites etc.

still in existence. There are only two pre-mesozoic formations, the Palmarito series and the Caparro series, as to which no disaccord exists among the four authors, their age having been proved by carboniferous and ordovician fossils. The Bellavista series, united by three authors with the Caparro, is separated from it by KÜNDIG (23) and regarded as older. The Mucuchachi phyllites are taken by CHRIST (8) for Archaean, by OPPENHEIM (27) for Cambrian, by KÜNDIG (23) for eo-palaeozoic. The fact that L. KEHRER (20) has found traces of fossils in this series — he mentions even the occurrence of ammonites — renders a pre-cambrian age highly improbable. KÜNDIG states that the rocks of the Mucuchachi series pass gradually into those of the Bellavista series, into micaschists and into true contactrocks on approaching a contact with post-Mucuchachi granites. It is clear that, if this is true, it becomes improbable that the Bellavista schists and the micaschists are pre-palaeozoic. As possibly pre-palaeozoic rocks there remain then only the rocks of the Iglesias series (KÜNDIG): gneisses, migmatites and arterites. KÜNDIG regards them as archaean "Unterbau-Gesteine". He does not prove, however, that the Mucuchachi-Bellavista-Micaschists-series and the Iglesias-series really belong to different geologic cycles. His sections nowhere show a normal contact between the rocks of the first and second group, nor does he mention the existence of conglomerates in the Mucuchachi, containing pebbles of the Iglesias series. As long as no unconformity has been found between the Iglesias and the Mucuchachi series nor pebbles of Iglesias rocks in Mucuchachi conglomerates, we must take into consideration the possibility that both series have the same (?palaeozoic) age, the rocks of the first series having been metamorphosed more intensely by stronger granitization and migmatization in deeper zones of the palaeozoic geosyncline.

9. LIDDLE has tried to prove that a great part of the schists of the Coast Range of Venezuela is of silurian age (25). His arguments, however, are by no means convincing, as he departs from the wrong supposition that limestones of the Coast Range have yielded silurian fossils (29).

10. LIDDLE has been the first to publish data on the occurrence of metamorphic, cretaceous rocks in Northern Venezuela (25) between the meridian of Barquisimeto and the eastern part of the Coast Range. He states that in this area cretaceous sandstones, shales and limestones have been converted into quartzites, schists and marbles. His contention that the metamorphosis is due to the influence of an intrusion of augite-porphyrite (25, p. 68—69) is certainly wrong. SCHÜRMAN (34) equally states that in the neighbourhood of Barquisimeto even the eocene rocks show signs of beginning metamorphosis, and that rocks of cretaceous age have been changed into silvery-white micaschists. L. KEHRER (19) says that the cretaceous limestones in NE and E. Lara have been changed into marbles, and the shales, marls and shales with organic substance into sericite-schists and graphite-schists. The statements of these three independent and

competent geologists are so positive that it seems impossible to avoid the conclusion that in this part of Venezuela there occur on a large scale metamorphics of cretaceous age. This conclusion, however, is so important that we can not feel satisfied by the general statements, published until now. Only a map, on which the transition from normal to metamorphic sediments in the direction of the strike of one or more structures is indicated, accompanied by a detailed description and by microphotographs of samples from crucial localities might satisfy completely our curiosity. It may be added that the author is not the only one who is longing for more evidence in this important matter. GERTH (11) has cited with some suspicion LIDDLE's opinion about the cretaceous metamorphics, and, in the second volume of his "Geologie Südamerikas" (12, p. 347), when SCHÜRMAN's publication had already appeared, he still regards the schists of the Serranía del Interior as parts of the basal complex of Venezuela.

I may add, that, during an excursion in 1930, I collected myself some cretaceous rocks in Venezuela. The description of three samples follows here:

Lower Cretaceous Tomon Sandstone from Agua Caliente near San Antonio, SW. Venezuela. The rock is a white, somewhat porous, quartzitic sandstone. The slide presents in some places a very coarse, quartzitic structure. In other parts of the slide the rounded, original quartzgrains are still visible, each quartzgrain having, however, been enlarged by apposition, so that the general structure has become equally quartzitic. There are also places, where the pores between the original, rounded quartz grains have been filled with quartz which has an orientation of its own.

Lower Cretaceous Tomon Sandstone from La Cuchilla between Carora and Valera. A grey, quartzitic rock. The slide shows quartzitic structure throughout. In some places, however, the original "sand-grains" are still recognizable. Between the quartzes there are to be found many small flakes of sericite, sometimes passing into semi-coarse muscovite; moreover there occur some idiomorphic crystals of tourmaline. The rock is a sericite-quartzite with tourmaline.

Lower Cretaceous Tomon Sandstone from La Cuchilla between Carora and Valera. A red-yellow mottled, feebly schistous rock. The slide shows an irregular fabric of quartz grains and sericite flakes; the latter sometimes passing into muscovite. Small grains of limonite are responsible for the red colour. The rock is a slaty quartz-sericite schist.

From the foregoing description it is to be seen that the Cretaceous presents traces of metamorphism, even far to the W. of Barquisimeto. The described samples may be reckoned to belong to the uppermost part of the epizone. These facts seem to support the views of LIDDLE, SCHÜRMAN and L. KEHRER.

11. If I rightly understand the data of the geologic literature, the rocks, treated with sub 10 all belong to the Serranía del Interior. SCHÜRMAN (35) as well as L. KEHRER (19) are of the opinion, that there occur equally cretaceous metamorphics in the northernmost range of the Caribbean mountains, and, according to LIDDLE (25, p. 75), there are to be found on the island of Margarita at the side of "silurian" schists also cretaceous metamorphics. As LIDDLE himself states that it is hardly possible to

differentiate these two complexes of schists, we may neglect for the moment his contentions.

The arguments of SCHÜRMAN and L. KEHRER are the following. The radiolarite described by LAMARE (24) from the northern part of the Coast Range might very well be a cretaceous rock, the Cretaceous of Venezuela abounding in many localities with radiolarites; the marbles, so common in the northern parts of the Caribbean Mountains might be metamorphosed cretaceous limestones; the limestone of Valencia — from which LIDDLE has erroneously mentioned silurian fossils — might be a cretaceous limestone. As to the last argument the authors might find support in a very old publication of KARSTEN (18), who, in a diagrammatic section, indicates the Valencia-limestone as "Exogyrenkalk" and who, in his text, points to the similarity of this limestone with that of the Morros de San Juan — on the southern side of the Serranía del Interior — in which, according to LIDDLE, Exogyras have been found. TRECHMANN's discovery (42, 43) of rocks with cretaceous fossils in the Northern Range of the island of Trinidad, and SPATH's description of tithonic ammonites from the same area (39), which seem to indicate that the metamorphic rocks of this range are cretaceous, might equally support the views of SCHÜRMAN and KEHRER. HEDBERG (14), mentioning TRECHMANN's discovery, has indicated, on the other hand, that it is difficult to understand that in the easternmost part of the Coast-Range of Venezuela there should occur at the side of strongly metamorphic, cretaceous rocks other rocks of the same age which are absolutely non-metamorphic. Dr. TRECHMANN was so kind as to provide me with some samples from the neighbourhood of his fossil-locality in NE. Trinidad. Their description follows here.

Conglomerate, W. of Jetty, Toco, NE. Trinidad. It consists of pebbles of more than 1 cm with a sandy cement. The elements of the conglomerate are chiefly quartz and quartzite. Some small pebbles of a limonitic rock which contains quartz-splinters and muscovite-flakes. The cement contains quartz, muscovite and some calcite.

Dark, calcareous shale, E. of Jetty, Toco, NE. Trinidad. Very dark rock with an unmistakable echinid spine. The slide shows numerous organic remains (echinid fragments, calcified sponge spiculae etc.) in a brown, dense, isotropic "groundmass". There is no trace of metamorphism.

Dark, calcareous shale, W. of Jetty, Toco, NE. Trinidad. The slide shows remains of organisms in a dark "groundmass" with quartz splinters and mica flakes. There is no trace of metamorphism.

Conglomeratic sandstone, S. of Toco, NE. Trinidad. The slide reveals the presence of the following elements: 1. very much quartz, partly cataclastic, 2. finegrained quartzite to quartzschist, sometimes with muscovite, 3. grains of perthite, 4. grains of orthoclase, 4. coarse quartzite. The cementing material consists of much quartz and sericite. The rock contains metamorphic material and has itself not suffered from metamorphosis.

Black limestone E. of Jetty, Toco, NE. Trinidad. There is — in the slide — not a trace of metamorphism in this very finegrained limestone; it contains siliceous sponge spiculae, and grains and some crystals of pyrite.

Conglomeratic, calcareous sandstone, 4 miles S. of Jetty, Toco, NE. Trinidad. The elements of the conglomerate are: 1. microcline, 2. abundant quartz, partly cataclastic, 4. grains of an intergrowth of quartz and plagioclase, 4. quartzite with some muscovite, 5. very dusty plagioclase.

Apparently there occur in this part of Trinidad non-metamorphic limestones and grits, which contain pebbles of metamorphic rocks. It has been known for a long time, that there occur also in the Northern Range of Trinidad true metamorphics. It is, therefore, not impossible that, in N. Trinidad, we have to do with a folded basement with in-folded jurassic and cretaceous rocks.

AGUERREVERE and ZULOAGA (1, 2) have, in two very recent publications, described the Serranía del Interior and the Coast Range s. str. They distinguish to the S. of Carácas two different groups, both metamorphic: the Carácas group and the Villa de Cura group. They are of the opinion that there occur many cretaceous rocks in the Serranía del Interior. Their conclusions are, however, somewhat contradictory. In their first publication they say that the Carácas group is cretaceous, in the second that the Carácas group is cretaceous or older, the Villa de Cura group cretaceous or younger. With regard to the rocks of the Coast Range s. str. they say at some place that they might equally be cretaceous, at other places, that they are possibly archæan. It seems better, for the moment, to leave out of this discussion the work of AGUERREVERE and ZULOAGA.

Whilst many observations seem to indicate that probably a part of the metamorphics of the "Serranía del Interior" is cretaceous and that possibly some of the metamorphics of the Coast Range s. str. may be cretaceous, there is one publication which indicates that there occur probably also much older elements in the Coast Range. IJZERMAN (45) has studied a series of granitodioritic rocks of the Venezuelan cordilleras and comes to the conclusion that:

"the granitodiorites of the Andean folding area reveal less constant features than those of the old core of South America On the one hand they are characterized by greater variabilities, on the other hand many types cannot be differentiated from those belonging to the old core It is a fact of more significance that the typical orthite and the primary epidote we met with in many countries of the old core, seem to be absent in the Andean folding area" (45, p. 492—493).

Now, LAMARE (24, p. 142) has described from the Silla de Carácas in the Coast Range s. str. a granite, which, according to his description can hardly be distinguished from the granites of the Old Core; it contains large microclines, primary epidote and orthite. This discovery indicates that there may exist in the Coast Range, at the side of possibly much younger rocks, very old, precambrian elements.

The facts, discussed in the foregoing, allow for the following conclusions.

1. The age of by far the most non-fossiliferous slates and schists in the Columbian-Venezuelan Cordilleras is unknown; it is not permitted to

speak — as has been done very frequently — of an extensive precambrian basement.

2. There is only one case, where the precambrian age of rocks is rather probable: the granite of the Silla de Carácas.

3. Many schists are certainly precretaceous (Goajira, Sierra de Perijá, Sierra Nevada de Santa Marta, Cordillera de Merida, Cordillera Oriental) and probably predevonian (Sierra de Perijá, Cordillera de Merida, Cordillera Oriental); it is quite possible that many of these schists are precambrian.

4. The fact that W. KEHRER (22) has found in S. Colombia two different formations of schists, separated by an unconformity, indicates the possibility that there exist in both republics complexes of metamorphics of very different age.

5. It is possible that the green schists of Antioquia are cretaceous.

6. It is very probable that in some parts of the Caribbean Mountains (s.l.) there exist metamorphics of cretaceous age. Every generalization, which would lead to the conception, that all the metamorphics of this area are to be regarded as Cretaceous, is to regard with the greatest suspicion. The granite of the Silla de Carácas, the data of HEDBERG for the NE. part of Venezuela and the data procured by the Northern Range of Trinidad may induce us to the greatest prudence.

I cannot deny that the harvest of this critical study on the metamorphics of Colombia and Venezuela is somewhat meagre. We have seen that there exists the greatest uncertainty about the age of these rocks. It is, however, better to know this uncertainty than to feel satisfied with a not-founded knowledge. Happily, the remedy for gaining better knowledge can be indicated. Careful fieldwork, combined with intensive sampling and laboratory-study of the samples will with great probability lead to more definite knowledge of the age of the rocks under discussion. It is chiefly the green schists of Antioquia, the metamorphics of the Serranía del Interior, parts of the Coast Range and the Northern Range of Trinidad, which promise good results.

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