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Autor: Gansser, August
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The Guiana Shield (S. America)

GEOLOGICAL OBSERVATIONS

With 12 figures and 4 plates (VIII–XI)

by **August Gansser**

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Zusammenfassung

Ausgehend von eigenen Felduntersuchungen und der erhältlichen Literatur werden gewisse Formationen des Guiana-Schildes beschrieben, mit besonderer Berücksichtigung der Roraima-Sedimente. Letztere lassen sich in drei Unterabteilungen gliedern, wobei die obere Abteilung die grösste Verbreitung hat. Die mittlere Abteilung ist durch Jaspis-Horizonte und gabbroide Intrusionen charakterisiert.

Gestützt auf stratigraphische Vergleiche mit durch Fossilien belegten Formationen in den Grenzgebieten gegen die kolumbianische Ostkordillere, wird die Roraima-Formation zur Hauptsache als sandige Fazies der Kreide angesehen. Lithologische Betrachtungen deuten auf eine Herkunft der sandigen-konglomeratischen Sedimente aus einer östlichen Richtung, was sich auch strukturell begründen lässt.

Die strukturellen Elemente der angrenzenden andinen Gebiete werden analysiert und eine Übereinstimmung mit den Hauptstrukturlinien des Schildes (Lineamente) festgestellt. Diese Überlegungen lassen eine grössere Ausdehnung des Schildes gegen Osten vermuten und zeigen, dass die heutige atlantische Küste durch eine subrezente Senkung des Schildes bedingt ist.

Introduction

The following notes are based on personal observations by the author made on various occasions between the years 1940 and 1948 and on the available literature. While working for the Shell Oil Co. in Colombia, I had the opportunity to visit the western edge of the Guiana Shield in the Cordillera de la Macarena and in the isolated outcrops of the Rio Guayabero/Guaviare in the San José region (Colombian Llanos). Further reconnaissance work led me to the lower Vichada River and the rapids of the Upper Orinoco river at Maipures (Frontier zone Colombia–Venezuela).

By the end of 1948, I was able to spend a leave period in the region south of Mt. Roraima, visiting thus the remote corner between British Guiana, northernmost Brazil and SE Venezuela. On this trip, I was accompanied by my wife and Mr. D. Roberts, Chemist. Flying from Georgetown (Brit. Guiana) by chartered plane, the Orinduik falls on the Ireng river were reached. From there, with the help of Indians, we walked through northernmost Brazil into SE Venezuela, which was reached S of Wei Tepui, a mountain subsequently climbed by the party. For the return journey the same route was followed, including some side-trips.

I am greatly indebted to Mr. S. Bracewell, Director of the Geological survey of British Guiana, for his valuable assistance before and after the expedition. The Royal Dutch Shell Group kindly permitted the publication of some informations related to the Guiana Shield, gathered by the writer while in the company's service.

GEOLOGY

The regional geological investigation of the Guiana Shield and in particular of its sediments has been greatly neglected, most probably due to the remoteness and the difficult access of most of the areas of interest. Only more recently have parts of the Guiana shield been covered by a systematic geological investigation. The Geological Survey of British Guiana, under the direction of Mr. S. Bracewell has done most valuable geological pioneer work, and has thus covered a considerable part of its territory by more or less detailed geological maps and reports. Unfortunately, these surveys are limited by the political boundaries. Venezuela has added a contribution through the investigations of the Gran Sabana, and the reconnaissance work of the Imataca range. (AGUERREVERE 1939, ZULOAGA 1939, LOPEZ 1942). Regarding Surinam (Dutch Guiana), the voluminous geological outline by IJZERMAN (1931) forms a valuable base for reference.

Though marginal parts of the Guiana shield are covered with aerial photographs, this most important tool for regional geological and structural investigations has been so far left practically unused. A preliminary aerial investigation of the S side of the Orinoco river in the Departamento Antonio Diaz (Venezuela) has yielded a wealth of structural information (LOPEZ 1946). The basement pattern in parts of British Guiana is clearly visible when flying over the area, but still much valuable time is lost, trying to depict tectonical features by tedious field work, just because aerial pictures, though partly present, are not available.

One of the most intricate problems of the Guiana Shield are the origin and the age of its sedimentary cover. Not less important is the tectonical pattern of the shield rocks and its comparison with the surrounding orogenetic belts to the W and N. These problems have by far not been solved, but suggestions are offered herewith which, based on some new observations, may contribute toward their solution.

The detailed description of the areas visited by the writer precedes a more regional discussion on the various problems involved.

A. Observations in the Central and Western Guiana Shield

In a very regional way, four broad geological divisions are recognized, namely:

4. Subrecent to recent deposits.
3. The Roraima Formation.
2. The Volcanic Group.
1. The Basement Group.

The subrecent to recent deposits are related to important mineral occurrences, such as bauxite deposits, gold and diamond placers etc. They are not discussed in the present paper, but merely mentioned as cover of the Roraima formation where the upper age limit in British Guiana is concerned.

Our special attention is given to the Roraima formation.

It has to be emphasized beforehand that so far no determinable fossils have been found in the Guiana Shield proper. In an endeavour to fix a tentative age for the Shield sediments, our criterion must be based on observations from and interpolation with marginal areas, where fossiliferous formations cover Shield rocks, allowing to draw a certain upper age limit for underlying rock units, although no continuous outcrops from such marginal fossiliferous sediments to Shield sediments proper have been observed so far. For this reason the "mise en place" of the latter still must remain speculative in spite of careful comparisons made with possible edge equivalents, also bearing in mind possible facies changes.

I. The Basement

The term of "Basement", such as used in the present note, includes all rocks which antedate the regional volcanic cycle, widespread in the northern and central part of the Guiana Shield, but excludes fossiliferous Paleozoic sediments. The basement thus represents a complexity of igneous rocks and more or less metamorphics of igneous as well as sedimentary origin with all possible gradations from one rock type to the other.

In the area visited by the writer south of the Roraima region, no basement rocks have been observed.

In the Colombian Llanos I was able to study Guiana Shield basement at various localities (Macarena, San José de Guaviare, Maipures rapids of the Orinoco river). Some of these observations already have been mentioned earlier (TRÜMPY 1943). The macroscopic and microscopic studies revealed a striking predominance of acid syenitic rocks, characterized by well developed microclines. This fact is of regional interest, since equivalent rocks were not observed in the younger intrusivas of the Colombian Andes, characterized by a more granodioritic rock type. In the Macarena (ref. Plate IX, fig. B) granosyenitic orthogneisses are clearly transgressed by fossiliferous Cambro-Ordovician, leaving no doubt about the Pre-Cambrian age of the basement. Similar facts occur in the Garzon massive of Colombia, most probably a Guiana Shield element incorporated in the andean orogenesis. Classic nepheline syenites form the basement in the San José de Guaviare region (GANSSER, see TRÜMPY 1943). The various rapids of the upper Orinoco (Maipures–Atures), as well as the outcrops in the lower Vichada river expose excellent basement complexes. The study of the various slides revealed a predominance of microclines with excellent quadrille texture, microcline perthites, orthoclase perthites, quartz, some biotite and/or hornblende, with some subordinate acid plagioclase. The alkali feldspars in form of microcline and more rarely orthoclases, both often perthitic, form the largest phenocrysts giving the characteristically pinkish aspects to the outcropping rock. The quartz is often somewhat idiomorph and occurs in two distinct forms, firstly as small inclusions in the larger feldspars, often showing a uniform orientation, and secondly as larger, single sub-idiomorphic grains. Undulatory extinction is very weak. The most striking aspect of the quartz grains is the remarkable violet blue colour in hand specimens and in outcropping rocks. This fact may have a diagnostic value for sediments derived from shield rocks.

The hornblende has a strong pleochroism and seems to grade somewhat towards the alkali type. The biotite is primary or formed from altered hornblende. Accessory constituents are mainly epidote, orthites (forming pleochroic haloes in biotite), titanite, chlorite, magnetite and rarely some garnet.

The rather uniform mineral composition represents clearly the alkaligranite type, here called grano-syenite.

The above mentioned observations led to the preliminary assumption, that granosyenitic rocks form a major acidic constituent of the Pre-Cambrian basement-rocks. Characteristic are microclines and blue quartz.

It remains to check these facts in other areas of the Guiana Shield basement-complex.

In British Guiana the writer studied basement-rocks from stone-quarries in the lower Demerara river. The rocks are very complex and range from amphibolites to aplitic granites. The former contain acid plagioclases and a normal green hornblende. A biotite granite gneiss is rich in quartz with strongly undulatory extinction and lobe-lined edges. Acid plagioclases and small microclines and orthoclases are present. A dark brown biotite shows strong pleochroitic halos around orthite inclusions. More massive rocks are represented by fine grained, gray granite to granosyenites, grading into coarser muscovite granosyenite and coarse pinkish pegmatitic, acid granosyenites. In all observed rock specimens the microclines are predominant. They seem to increase with the coarseness of the grain. The finer types have an equal amount of orthoclase. However, the alkali-feldspars strongly predominate over the acid plagioclases. In all specimens the quartz has a strong undulatory extinction and very lobe-lined edges. No blue quartz has however been observed macroscopically.

From the available reports on British Guiana the writer was not able to draw conclusive evidence regarding the age-relation of syenitic rocks. The main difficulty remains in the age assignement of the various basement-rocks, since younger acid intrusions – some probably even post Paleozoic – intrude the older formations. Under the various granites described some seem to be of a granosyenitic type. It may be possible that by future investigations, a more subtle subdivision of the acid intrusive rocks may assist in a better differentiation of the complex basement.

In Venezuela more recent investigations also deal to some extent with the petrology of the Guiana basement (AGUERREVERE 1939, ZULOAGA 1939, LOPEZ 1942, 1946). The northernmost outcrops of the Guiana Shield are of particular interest for the presence of extensive quartzites (itabirites) forming the Imataca range.

Mostly, the various acid intrusive rocks are described invariably as granites, but based on the mineral composition grano-syenites and even quartz-syenites are frequent. The acid rocks of the lowest Caroni rapids, the rocks of Piacoa, along Rio Toro, and on the lower Rio Amacuro (frontier with Brit. Guiana) all contain microclines as a predominating mineral. The similarity with rocks described from the Upper Orinoco (see above) is striking and proves the great extension of granosyenitic intrusions.

In Surinam, the basement has been described comprehensively by IJZERMAN (1931). He mentions the preponderance of granitic to grano-dioritic rocks. They seem to form much larger complexes than those known from British Guiana. IJZERMAN stresses the widespread occurrence of microclines, mostly as larger phenocrysts. Many of his acid intrusive rocks are comparable to rock types described by the writer as grano-syenites. It seems, to some extent, a matter of nomenclature, though IJZERMAN's careful descriptions undoubtedly reveal rocktypes which, in my opinion, are granites with a more syenitic tendency. The genetic relationship of the various intrusive bodies in Surinam still remains to be studied.

Of great interest in the *northern Guiana Shield* are the old sedimentary rocks in form of banded, folded quartzites, which, through an increase in haematite and magnetite content, grade into *itabirites*. The predominant quartzes are not recrystallized and show variable undulatory extinction. The itabirites are intruded by various types of igneous rocks. They are steeply folded, forming narrow sling structures, well recognizable on aerial photographs (Sketch map, Lopez 1946). The predominant structural trend is ENE, one of the predominant lineaments of the Guiana Shield.

The itabirites have been compared with the Roraima sediments, but their metamorphism, their tectonics, and ultimately the presence of itabirite pebbles in the basal Roraima sediments (Aguerrevere 1939) strongly suggest a Pre-Cambrian to early Paleozoic age.

Somewhat similar quartzites have been reported from the Rupununi Savanna in British Guiana and from Rio Branco in northern Brazil (Martin Kaye 1952). They are said to be older than the Roraima formation and may correspond to the Imataca itabirites.

II. The Volcanic Group

As far as is known from the available literature and the writer's own observations, the Volcanic group is covering only a restricted part of the Guiana Shield, mainly the central and northern part. In these areas it seems somewhat related to the presence of the overlying Roraima sediments.

A rough two fold division of the Volcanic group is generally adopted, namely a lower part, represented by volcanic rocks and its related tuffs, and an upper part grading from tuffs to shaly sediments (the Haimarakka shales of Brit. Guiana).

In the Roraima area, the writer was able to observe only the upper group, reminiscent to a certain extent of the Haimarakka shales. The lower group is described from the St.Elena region of SE Venezuela (Aguerrevere 1939, Lopez 1942).

The best known development of the Volcanic group occurs along the present east and north border of the Roraima sediments. Since wide areas of the Shield have only received a most cursorily geological investigation, the above mentioned picture may be partly wrong. The frequent occurrence of the volcanics in British Guiana may be due to a better knowledge of the geological conditions of the latter country. On the other hand there is little doubt that large areas are devoid of the volcanic cover, such as the Shield border along the Orinoco river as well as the western-most exposures in the Colombian Llanos.

1. The lower part of the Volcanic Group

The lower group consists of a most complex sequence of quartz feldspar porphyrites and its tuffs, agglomerates and more basic gabbroid lavas, together with pyroclastic schists and phyllites. The latter are the results of low grade metamorphism, caused by orogenetic movements having preceded the Roraima sedimentation. In British Guiana the Volcanic group has been described in detail in various reports of the Geological survey (Bracewell 1927, 1946, 1947, Dixon 1949, Martin Kaye 1951, 1952). Aguerrevere 1939 and Lopez 1942 mention volcanic rocks from the Santa Elena region (predominantly red ryolitic porphyry and granitic porphyry together with talkschists). The sedimentary upper part has not been observed.

2. The upper part of the Volcanic Group (Haimarakka Formation)

In British Guiana the tuffs and agglomerates of the Volcanic group are reported to grade into purple, violet to chocolate brown weathering shales, following the base of the Roraima formation in relatively restricted outcrops. They are usually steeply folded. So far they are reported only from the NE border of the Roraima sandstone plateau in British Guiana. They have not been mentioned from the Venezuelan part of the Guiana Shield and seem so far unknown from the western Shield areas in Colombia.

Similar shales were discovered by the writer SE of Mt. Roraima along the Wailan river, a western tributary of the Ireng, in northernmost Brazil (ref. Plate VIII, fig. B). In its position and lithology these shales form a separate unit, resembling somewhat the Haimarakka formation. I have called them *Wailan formation*.

This Wailan formation consists of a rather uniform sequence of gray to brownish gray, silty to sandy, well bedded shales. Platy, argillaceous sandstones are rare intercalations. White, thin quartz veins occur locally.

The shales are clearly, though rather gently folded, with maximum dips of 30°.

The basal part of the Wailan shales is cut by intrusive gabbros along the Wailan river. Contact metamorphism is very marked where the shales are bordering the large igneous masses of the southern Wailan region. Two meters above the contact, the shales become slaty and change into a dark blue gray colour. 30 cm above the the contact occurs massive dark blue gray hornfels. Under the microscope, both the slates and particularly the hornfels, contain cordierite with small needles, probably representing sillimanite. Xenomorph biotite and large muscovite flakes (phlogopite) together with magnetite and quartz form additional constituents of the rock.

At the contact the intrusive rock is an orthaugite dolerite, probably a marginal rock facies of the main gabbroid and dioritic mass. The relative strong contact metamorphism of the Wailan shales with basic intrusive rocks is striking, and according to the writer's experience rather unexpected. Similar diabase sills within the Wailan shales have, on the other hand, caused no visible contact metamorphism. Well marked contact metamorphism however is known from gabbro intrusions into the Haimarakka shales in the Mazaruni river, British Guiana.

The top of the exposed Wailan formation is transgressed by the basal conglomerates of the Roraima formation (see following chapter). The intrusion into the basal shale complex as well as the transgression of the Roraima formation are responsible for the rapid variation in thickness observed ranging from 0–400 m.

The shales were carefully searched for fossil remains, but no such evidence could be found. Subsequent investigations for microfaunas were equally unsuccessful.

Most probably the Wailan formation is the more western equivalent of the Haimarakka "series" of British Guiana. Once a definite correlation is established, probably along the eastern main scarps of the Roraima formation, the name Wailan formation could then be replaced by Haimarakka formation instead of Haimarakka series, as frequently called in the British Guiana reports.

The more recent investigations of the British Guiana Geological survey as well as my own observations place the Volcanic group, including the Haimarakka

(Wailan) formation, between the Paleozoic and older basement and the Roraima formation. A diastrophism involving also the Haimarakka shales preceded the deposition of the Roraima sediments. This diastrophism seems less marked in the Wailan shales, though it is still evident. Some local folding is undoubtedly caused by disharmonic movement during a gentle folding-phase (uplifting) of the rigid Roraima sediments.

III. The Roraima Formation

The most spectacular and problematic geological phenomenon of the Guiana shield is undoubtedly the deposition of the Roraima sediments. The importance of this formation is well reflected by the fact, that uniform sediments of the Roraima type have covered originally over 1200000 km² of the Shield area with an average thickness of at least 800 m. The sediments thus deposited would amount to approximately 1000000 cubic kilometers. Of this enormous amount of over one million cubic kilometers of original sediments probably not much more than 200000 cubic kilometers remain, admittedly a very rough estimate. If we accept this figure, more than 700000–800000 cubic kilometers of sediments must have been removed and drained into adjacent basins. We may surmise that over 500000 cubic kilometers of sand have been transported into the Orinoco basin. This enormous erosion, producing this great amount of sediments, must have been active mainly during the later part of the Tertiary, subsequent to the regionally accepted Mio-Pliocene diastrophism. The relative youthful age of the present remnants is best reflected in the spectacular cliffs of the actual Roraima mountain, shown by the panorama in Plate IX, fig. A. The effect of this erosion is reflected in the Tertiary history of Eastern Venezuela and Trinidad, influencing the oil prospects in a dominant way.

Roraima type sediments have been variously described in more or less detail from British Guiana (BROWN 1875, BRACEWELL 1927, MARTIN KAYE 1951, 1952), from Venezuela (AGUERREVERE 1939, LOPEZ 1942), Dutch Guiana (IJZERMAN 1931), Colombia (TRÜMPY 1943) and from Brazil (OLIVEIRA 1938).

Yet, the writer felt, that an attempt should be made to consider the Roraima sediments from a more regional viewpoint, in order to outline the many unsolved problems and to put forward some suggestions to their solution. The following report is based on the available literature, on some verbal information by colleagues, and the writer's own observations in the southern Roraima region and in the Colombian part of the Guiana Shield.

After completing the draft of the present paper, I received from the British Guiana Geological Survey the comprehensive publication, entitled "The Roraima formation in British Guiana" (MARTIN KAYE 1952). This, as far as I am aware, is the first attempt toward a more regional investigation of the Roraima formation.

The Roraima sediments have been given various names according to the area investigated. (Kaieteurian in British Guiana named after the Kaieteur Fall, San José sandstones in Colombia after San José de Guaviare, Formaçion Roraima in Venezuela.) Originally the term "Roraima series" has been introduced by L.V. DALTON in 1912 (LIDDLE 1946). Since the Roraima mountain exposes some of the most spectacular cliffs of sandstones, and represents the highest elevation of the whole Guiana Shield, where Brazil, British Guiana and Venezuela join, the writer feels that the term *Roraima formation* should be generally adopted, once the correlation of similar formations in other areas with the sediments exposed in Mt. Roraima is established. This proposal is in line with the term Roraima formation

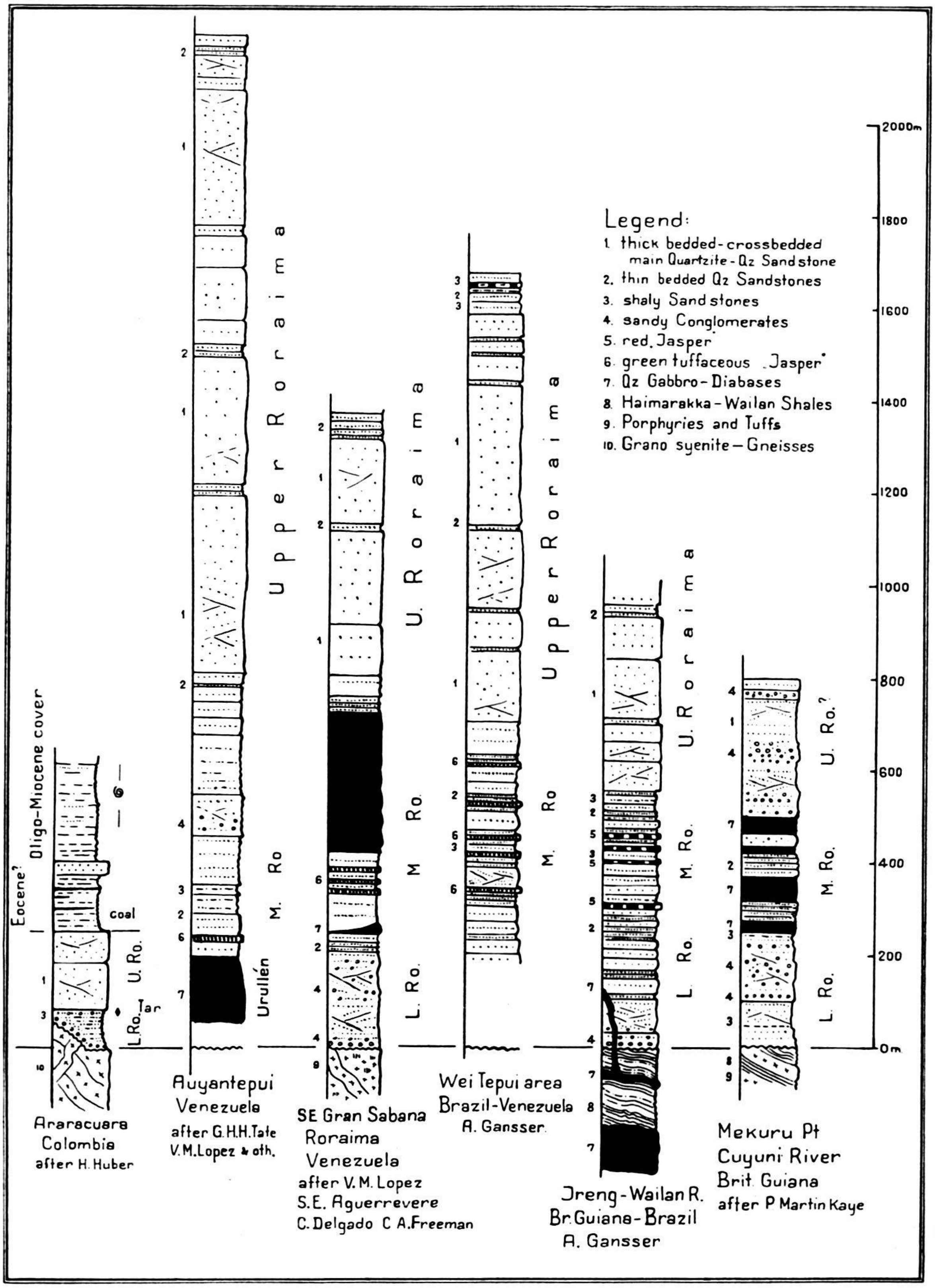

Fig. 1. Stratigraphical Sections, Roraima Formation, Br. Guiana, Brazil, Venezuela, Colombia

recently established by the Geological Survey of British Guiana (MARTIN KAYE 1952).

In the area SE of Mt. Roraima (Wei Tepui and Ireng) the writer could distinguish roughly three subdivisions of the Roraima sediments viz. a) basal member, including the basal conglomerates if present, b) middle member, characterized by frequent intercalations of jasper beds, and c) upper member, comprising the thickbedded sandstone horizons forming the spectacular cliffs of the highest table mountains.

The type of sedimentation implies regional lithological changes, so that the above subdivision may not be easily recognized in other areas. From our own observations elsewhere, and based on the available literature, it seems however conceivable, that the top member is most consistent, that a middle member can generally be recognized, though with considerable changes of facies, and that a basal member with or without basal conglomerate is relatively well developed.

1. The Roraima Formation in the Ireng-Wei-Tepui area (SE Mt.Roraima)

(Ref. to Map, Plate X and Fig. 1)

a) The Lower (Basal) Roraima Member

The best exposures of the basal member were found just N of Wailan, on the Wailan river, a tributary to the Ireng, situated in Brazil.

The Wailan shales, described in our previous chapter, are transgressed by irregular, medium sized, sandy-quartzitic *conglomerates*. They seem to form the base of the Roraima formation and are here approximately 50 to 100 m thick.

The contact of the conglomerates with the shales is well exposed, represented by a sharp unconformity which is accentuated most probably by disharmonic folding between the plastic Wailan shales and the more rigid Roraima sandstones.

The conglomerate is unsorted and the pebbles do not surpass fist size. They are subrounded to rounded (smaller fraction) and consist predominantly of white vein quartz and some pinkish, often banded quartzites. Igneous pebbles are rare. They are cemented by a quartzitic sandstone.

Upwards, the sandy cement increases gradually, the pebbles decreasing in frequency and size. The sandy conglomerate grades into a coarse unsorted sandstone, and finally into well bedded, better sorted, platy and more or less quartzitic sandstone layers, frequently exposing a clear current bedding. Thin bedded quartzites and thick bedded, softer, often very fine grained sandstone horizons alternate frequently and form the main mass of the lower Roraima member.

In the field, the conglomerate horizon is feature forming, and thus readily recognizable as shown on the Panorama (Plate VIII, fig. B).

The upper boundary of the lower Roraima member is arbitrarely chosen. The middle member begins with the first shaley, platy sandstone and siltstone layers, often alternating with the first incoming jasper bands.

In the Wailan area, the lower member is approximately 200 m thick.

b) The Middle Roraima Member

The well bedded, often somewhat shaley aspect of the middle member is characteristic throughout the whole area visited by the writer. It appears in marked contrast with the massive, high cliffs forming the upper member.

Most conspicuous for the middle member are intercalations of *jasper beds*. (Under the term "Jasper" I understand a dense, cryptocrystalline siliceous sediment, with a predominantly red (less frequent green) colour, caused by a fine admixture of iron oxides. It would thus form a variety of the chert group and resembles morphologically some alpine radiolarites. The siliceous groundmass is most likely composed of chalcedony and cryptocrystalline quartz.) The jasper beds alternate with well bedded fine grained quartzitic, pinkish sandstones. They occur

Fig. 2. Current ripple marks in pink quartzite. Middle Roraima Member. Karakanan river. Brazil.

in thick single layers or form horizons of rapid alternations with fine quartzites. Regionally, they are however restricted to two main zones, viz. one zone near the base of the middle member, the other, more conspicuous and better developed one, in the middle to upper part of the middle member. The regionally flat dips of exposures in the broken country, as well as the very limited investigations, may be the reason why some levels may have been missed, or others wrongly correlated owing to their occurrence in numerous disconnected outcrops.

The rocks between the jasper levels consist of a complex sequence of fine grained, well bedded, shaley sandstones, of platy, fine grained, often pink quartzites and softer, white sandstones with a characteristic kaolinic matrix. The kaolinic matrix increases in certain levels, forming finely bedded claystone layers, somewhat reminiscent of the "porcellanite" horizons of the San José quartzites in Colombia (see later).

Most of the pink quartzite horizons are finely crossbedded. On their bedding planes some expose excellent ripple marks which occur mainly as current type ripple marks (Fig. 2) and interference ripple marks (Fig. 3). Asymmetrical ripple marks of the current type are more frequent than the more symmetrical wave type. The pattern showing interferences seems to indicate a compound system of wave and current action.

Within the quartzitic sandstone horizons, approximately between the main jasper layers, occur most interesting syngenetic slumping features, a rather unexpected exposure in this type of sediments. The finely bedded sandstone horizons show sharp disharmonic folds, illustrated in Fig. 4 and 5.

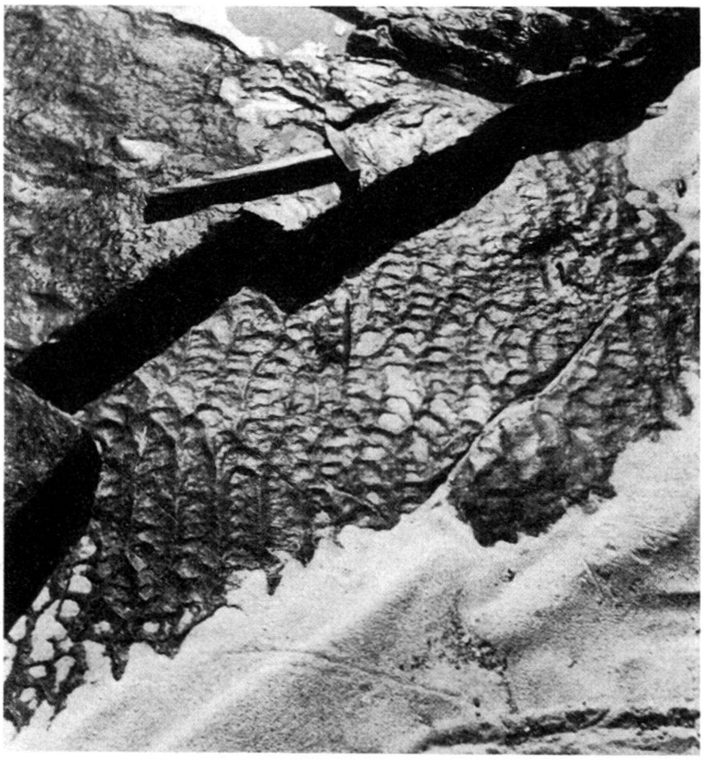

Fig. 3. Interference ripple marks (wave and current action). In pink quartzite. Middle Roraima Member. Karakanan River. Brazil.

The jasper horizons in the Ireng area have been mentioned in reports of the Geological Survey of British Guiana (BRACEWELL 1927, MARTIN KAYE 1952). I found them well exposed between the Ireng River and the southern Roraima area. Between the eastern (Ireng) and western (Wei Tepui) regions I observed a conspicuous colour change within the various types of jasper beds, viz. from brillant red Ireng jaspers bands, to gray green Wei-Tepui jaspers horizons.

The red jasper: The red jasper forms well banded layers, intercalated between reddish, fine grained, crossbedded quartzites. The single jasper band varies between several centimeters to 2–3 m in thickness (Fig. 6). The very resistant horizons are clearly feature forming, and are responsible for many of the spectacular waterfalls, the beauty of which is intensified by the colour contrasts.

The contact between the jasper bands and the adjoining rocks (quartzites) can be sharp as well as gradual. The latter fact is of particular interest in connection with the genesis of the jasper horizons. The sharp contacts are more apparent than real, brought out by a selective erosion of the softer though coarser sediments.

The lithology of the various jasper bands can differ considerably, in particular the grain size. One can observe how the siliceous cement of the quartzites increases, becoming red and forming jasper like horizons, still containing original quartz grains from the sandstone. The sandstone grain can decrease in size, grading into silts with a jasper groundmass. Finally the grains disappear completely and macroscopically dense red jasper bands are the result. The sandy and the silty grains within the jasper layers mark a clear bedding, and often even distinct crossbedding, a fact demonstrating the sedimentary character of these types of jasper beds. The crossbedding of the coarser jasper beds is particularly well developed when embedded in quartzite layers with strong crossbedding. Under the microscope, the various red jasper types show the following characteristics:

Fig. 4. Small sharp folds in fine quartzite. Probably caused by syngenetic slumping. Middle Roraima Member. Rio Pipi. Brazil.

Jasper with sand grains: The quartz grains predominate and are very well rounded without signs of recrystallisation (ref. to quartzites in upper Roraima member). Some show a marked, some no undulatory extinction. A few quartz grains have fine enclosures of rutile needles, other contain haematite dust. Fine rounded iron-quartzites form inclusions derived most likely from itabirites. Acid plagioclases are subordinate, and occur as angular fragments. In the groundmass one can recognize smaller quartz grains, some feldspars, limonite and, relatively frequent, a strongly pleochroitic (yellow-red violet) orthitic epidote. The rest is cryptocrystalline with limonitic haematitic powder (Fig. 7).

Jasper with silt grains: The quartz grains are small, rounded or angular (broken). Subordinate small feldspar grains are altered. Recognizable are some acid plagioclases and a few microcline grains. Further occur some epidote and magnetite grains as well as small muscovite flakes. In the cryptocrystalline groundmass the iron oxide is enriched in irregular zones of haematitic (limonitic) dust, reflected by a most peculiar flowing pattern.

Dense jasper: The cryptocrystalline groundmass predominates with irregularly distributed iron oxide (haematite) dust, responsible for the red colour. Within this groundmass occur some few small angular quartz grains. Some aggregates of small epidote needles form peculiar halos, bleaching the dense red iron oxide dust. No other inclusions are recognizable.

The green jaspers: The red jasper beds mentioned above have not been found in the Venezuelan part of the area visited. In fact, the last observed occurrence of red jasper was found just E of the Kotinga river. The next jasper horizons W of At-

Fig. 5. Syngenetic slumping features in fine quartzite. Middle Roraima Member. Rio Pipi. Brazil

nareng, near the Venezuelan border, are gray green to green in colour, and expose a peculiar, whitish kaolinic weathering. The name "jasper" is evidently less adequate for this type of rocks, but has been used for correlative purpose with the prefix "green". Lack of continuous outcrops of the jasper horizons did not permit to follow the change from the red into the green variety. The change seems however relatively sharp. No red jasper beds have been seen west of the Kotinga river, nor have red and green horizons been found superimposed in the same area.

Similarly to the red variety, coarser and finer types of green jasper have been observed. Some of the jasper beds W of Atnareng appear very well bedded, not unlike the typical siliceous marl horizons ("Plaener") of the Colombian Upper Cretaceous, a similarity brought out by the strong whitish kaolinic weathering. Some of the coarser green jasper beds display fine, dark green dots in the lighter green groundmass. Coarse and fine green jasper were examined under the microscope:

The spotted coarser green jasper contains small quartz grains, mostly angular fragments from larger well rounded grains of which some relics are preserved. Less frequent are plagioclases of andesine composition, often presenting elongated crystals. Quite characteristic are small epidote aggregates. They are concentrated in certain areas and form the green spots visible on the hand specimen. The groundmass is very fine, mostly cryptocrystalline and altered. In places it resembles a devitrified glass mass. This type of jasper beds shows no kaolinic alteration.

Fine banded green jasper with white kaolinic alteration border: Under the microscope this jasper is not unlike the coarser variety except that the quartz grains enclosed in the groundmass are smaller and exclusively angular. The groundmass is

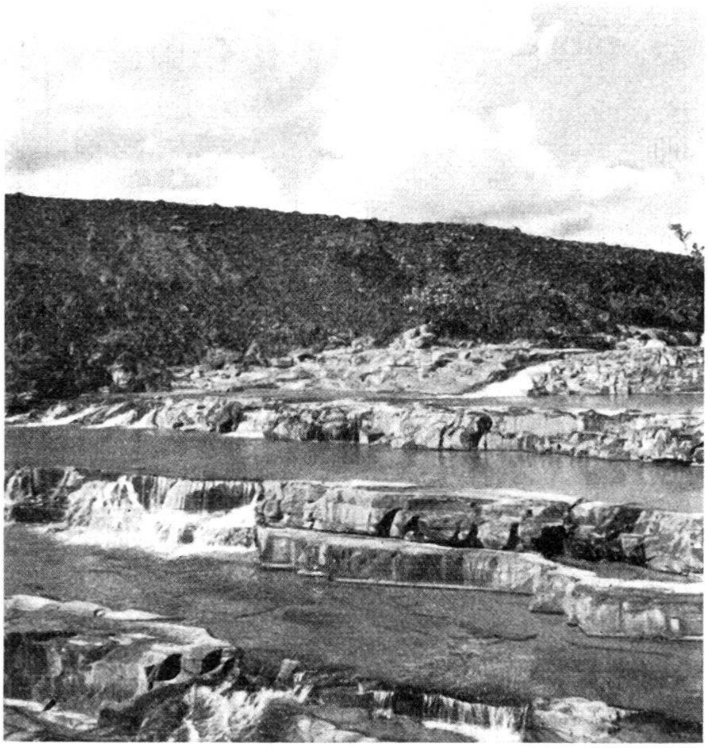

Fig. 6. Thick bedded coarse red jasper layers, alternating with pink quartzites. Upper Karakanan River. Brazil.

very fine, cryptocrystalline with patches of very fine epidote needles. The alteration border begins gradually, with an increase in the grain size of the groundmass, giving a dust like appearence. The epidote nests increase in size.

No gradual change from green jasper bed into quartzite horizons has been observed. This contrasts with the red jasper intercalations. Crossbedding, noted in the coarser red jasper, was not recognized in the green variety.

Conceivably, the green jasper intercalations may represent altered pyroclastics, while the red variety most likely has a predominantly sedimentary origin.

c) The Upper Roraima Member

The third subdivision of the Roraima formation is the best exposed one and therefore the best known. It forms most of the phantastic, vertical rock cliffs of the high table mountains in the wider Roraima area. The inaccessibility of these cliffs precludes in many places a continuous observation of the sedimentary section. The writer was able to study the upper member in the Wei Tepui. In this area, the upper member follows directly above the middle member whereas to the NW, in the actual Roraima mountain, a large gabbroid laccolite separates the middle from the upper member.

Characteristic for the upper member are very thick bedded to massive, very uniform quartzitic sandstone horizons of a light pink colour. They form the main part of the upper member, and measure in the Wei Tepui approximately 600 m. The quartzitic sandstones are medium to fine grained, and well sorted. They often have a somewhat sugary aspect and the minute quartz crystal faces sparkle in the light. Under the microscope, the rocks consist predominantly of quartz, with grains of a rather uniform size (0,3 mm). All the quartz grains are recrystallized, cemented

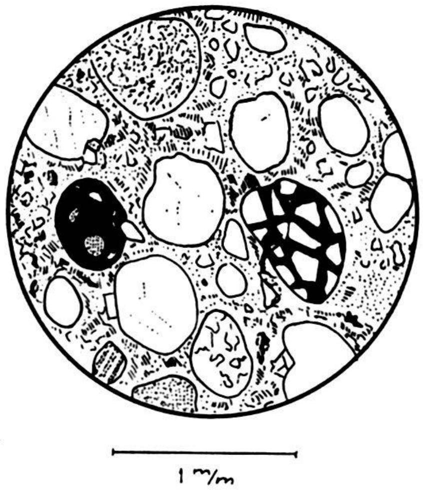

Fig. 7. Red Jasper with sand grains. Thin section. Note well rounded quartz grains with round grains of iron quartzite (iron ore = black) and rounded fragment of microbreccia (quartz and haematitic cement). Orinduik falls. British Guiana–Brazil border.

by quartz in optical continuity, leading to well developed crystal faces. The thin slides reveal further, that the original grains have been *perfectly rounded*, a fact emphasized by a fine dust rim, outlining the grain size prior to its recrystallisation (Fig. 8 and 9). This primary, perfect roundness of the quartz grains is of considerable importance in connection with the genesis of the Roraima formation. We may also recall, that the quartz grains in the coarser jasper beds are, if not broken, very well rounded. They have *not* been recrystallised (Fig. 7).

The quartz crystals show practically no undulatory extinction. In addition to the predominant quartz, occur rarely some altered feldspar grains. Iron oxide dust causes the pinkish colour of the rocks.

The top part of the upper member is again formed by thinner bedded sandstone horizons, partly reminiscent of the middle member. Intercalated, occur well bedded, sandy, siliceous shale horizons, mostly of a reddish colour. The top of the Wei Tepui is formed by whitish, sugary, medium grained sandstones. They are the youngest horizons in the Roraima formation observed by the writer. The thin bedded upper part of the upper member is approximately 300 m thick (Wei Tepui).

d) The Basic Intrusions in the Roraima Formation

(Ref. Fig. 1)

In the Roraima area, gabbroid intrusions have entered the Roraima formation in form of sills, dykes and large laccolites. In the region investigated by the writer, large laccolites and smaller sills were found in the Wailan formation underlying the Roraima sandstones, as well as dykes in the lower Roraima member. For the large laccolite of Mt. Roraima and other outcrops in the Gran Sabana of Venezuela, I refer to Aguerrevere (1939) and Lopez (1942) (see also Panorama, Plate IX, fig. A). All occurrences seem alike and undoubtedly have the same origin and similar age of intrusion. They are therefore discussed together.

Fig. 8

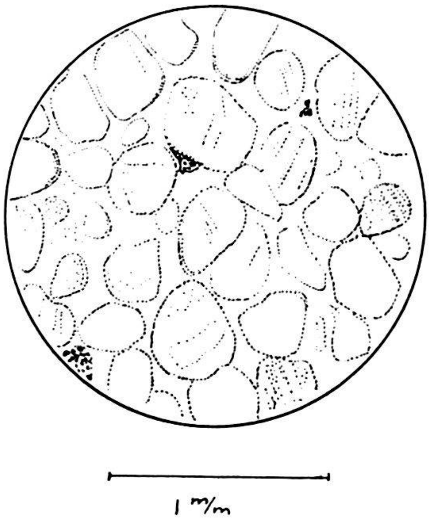

Fig. 9

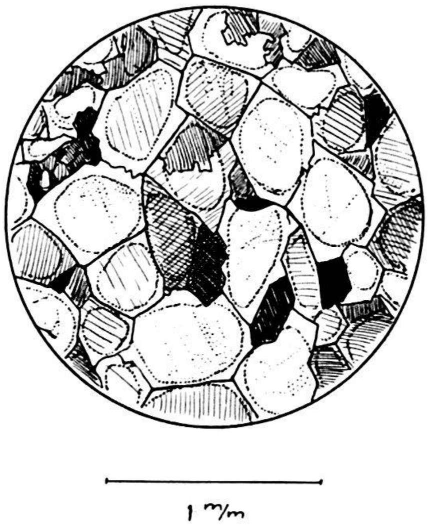

Fig. 8. Light pink quartzite. Thin section. Well rounded quartz grains with haematitic-limonitic dust inclusions. Ordinary light, with no recrystallisation visible. Upper Roraima Member. Wei Tepui W wall. Venezuela–Brazil border.

Fig. 9. Light pink quartzite. Thin section. Well rounded quartz grains, recrystallized in optical continuity. Crystal faces of grains visible at crossed nicols. Upper Roraima Member. Wei Tepui W wall. Venezuela–Brazil border.

The Tumong Augite Gabbro dykes: The gabbro dyke on the British Guiana side of the Ireng river, at the mouth of the Tumong river, has been mentioned in the survey of British Guiana (Bracewell 1927). The writer found three separate dykes of variable thickness. They continue into Brazil striking WNW. The thin slides reveal an ophitic intergrowths of labrador-plagioclase laths with ordinary augites. Myrmekite and some free quartz are somewhat unexpected and may be explained by assimilation of quartzites. Magnetite is frequent. Some hornblende and green biotite appear as secondary minerals formed from augites. The Tumong dykes have intruded into the lower member of the Roraima formation.

The Wailan Noritic-Gabbro sills: The basic gabbro sills in the Wailan area are quite a consistent feature, intruded into the Wailan shales just below the basal Roraima conglomerate. They may be connected with the Tumong dykes, though a direct connection has not been observed in the field.

The thin slides show a strongly ophitic intergrowth of labrador plagioclase laths with complex augites. The larger pyroxenes are hypersthenes, sometimes with a border of ordinary augites. Smaller pyroxenes are predominantly monoclinic augites. Both have frequently an uralitic alteration border. Associated with ordinary augites are often diallages. Biotite and chlorite are secondary alteration products. Magnetite is frequent. Some free quartz and myrmekite is still present. Except for the orthaugites, the composition of the Wailan sills is strikingly similar to the Tumong dykes. However, the latter are of a finer grain and often resemble diabases.

The Wailan Gabbro laccolite: The visible base of the Wailan shales is formed by a large intrusive mass of predominantly gabbroid rocks. I observed that south of Wailan, the lower member of the Roraima formation is repeated, and that the gabbro intrusion may have followed a major fault zone, along which the south part has been down thrown (see Map Plate X). The large gabbro mass has caused an unexpectedly marked contact metamorphism on the Wailan shales, already described above. The border zones of the main gabbro mass are of a finer grain and slightly more basic than the main mass. Under the microscope, some small olivine crystals were noted. Frequent are orthaugites, always intergrown with ophitically arranged plagioclases. The latter are zonar, with a more basic core of labrador and a rim of labrador-andesin.

The main gabbro mass (Biotite-Quartz-Gabbro) consists predominantly of labrador plagioclase and ordinary augites, partly replaced by diallage. Hypersthene, very common in the border zone and in the smaller sills and dykes, was not noted. Brown biotite is rather frequent. Free quartz, partly with myrmekitic reactions, is present. Magnetite and ilmenite are quite common. Chlorite as secondary mineral has been formed from altered biotite, which seems to constitute a primary mineral.

Along the lower Wailan river, at the rapids called locally Pescaduik, the main gabbro mass has a more acid appearance. Plagioclases and quartz increase together with biotite, leading to dioritic rocks. Within the observed intrusive mass, proper diorites are however rare, though the central part of the laccolite seems more acid than the border zone. In the Wailan area, the gabbro laccolite is several hundred meters thick. The lateral extension is large, its limit however has not been investigated.

All the observed basic rocks are relatively uniform in composition. They were found intruded in the Roraima rocks as well as in the underlying Wailan formation. They have most likely the same age. Since they have been observed as intrusions between the Middle and Upper Roraima Member (Mt. Roraima) they are thus younger than the deposition of the Upper Roraima Member.

The basic igneous rocks, intruded into the Roraima formation, may have its counterpart in the widespread basic intrusiva and extrusiva of the northwestern part of S. America, where an Upper Cretaceous and early Tertiary age has been established (GANSSER 1950).

Tuffaceous layers in the Middle and Upper Roraima members reported from the Venezuelean side (AGUERREVERE 1939, LOPEZ 1942) may be related to antecedent volcanisme, of which however nothing is known so far.

2. The Eastern Part of the Roraima Formation in British Guiana

(Ref. Fig. 1)

In recent years, geologists of the Geological Survey of British Guiana investigated the Roraima sediments in the Mazaruni and Cuyuni rivers areas (mainly MARTIN KAYE 1950, 1952).

Here we are particularly interested in differences of facies between the eastern outcrops of the Roraima sediments and the areas described above (Central area).

The Roraima sediments studied in the Cuyuni and the Mazaruni river areas are tentatively subdivished into a lower bench, middle bench and upper escarpment. This threefold subdivision may roughly correspond to the lower-middle and upper member described above. Within the middle bench and at the base of the upper escarpment occur gabbro sills.

The sediments of the Cuyuni section are considerably coarser if compared with the region S of Roraima. The middle bench however consists of well bedded quartzitic sandstones contrasting with the irregular thick bedded conglomeratic lower and top horizons. This fine grained and well bedded zone suggests a similarity with the middle member of S Roraima. No basal conglomerate is reported from the lower bench. The latter is approximately 260 m, the middle bench 250 m and the upper escarpment 300 m thick. Most probably the upper escarpment in this area does represent only a part of the upper Roraima member.

3. The Roraima Formation in SE Venezuela (Gran Sabana)

(Ref. Fig. 1)

A comprehensive lithological description of the Roraima-sediments and their basic intrusions in SE Venezuela (Gran Sabana) has been published by AGUERREVERE (1939) and later by LOPEZ (1942). Some information on the Auyan Tepui was published by TATE (1938). A basal conglomerate has been observed in various sections not exceeding however 10 m in thickness. The fact may be emphasized, that, contrasting with the basal conglomerates mentioned from S of Roraima (Brazil) and part of British Guiana, subangular to rounded, irregular, porphyritic pebbles reworked from the underlying volcanic group are quite frequent. The conglomerate transgresses directly the volcanic rocks without intercalations of shales of the Wailan-Haimarakka type, the latter not having been observed in Venezuela. Well rounded pebbles of a banded haematite-quartzites (itabirite) are of particular interest, the more so, since the quartzites seem to have been strongly folded prior to their redeposition. They recall the itabirites from the Imataca range, which may have been deposited and folded long before the Roraima sedimentation. Other conglomerate layers are mentioned from stratigraphically higher levels of the section. They consist only of white, well rounded quartz pebbles, and recall the conglomerate layers mentioned from British Guiana (MARTIN KAYE 1950). Some jasper beds are reported, predominantly of a green colour, and assumed to be of tuffaceous origin.

From the available information it seems difficult to subdivide the total section of Roraima sediments. Thin bedded horizons seem predominant in the basal layers

(Auyantepui). Judging from available photographs, the upper member, recognized already in the areas SE of the Roraima Mt. and described above, has increased considerably, in particular in the impressive cliffs of the Auyantepui at the famous Angels fall.

The total thickness of the Roraima formation is given as 2400 m in the Auyantepui, probably representing the largest preserved sedimentary relic. From the Mt. Roraima 500 m are mentioned to occur above the gabbro laccolite, a figure probably on the conservative side.

4. The Roraima Formation in SW Venezuela (Upper Orinoco)

(Ref. Plate XI)

Based only on fragmentary observations, the Roraima sediments can be followed along the Venezuelan/Brazilian border (the watershed between the Orinoco and Amazon basins) westwards into the table mountain of Cerro Duida, the various table mountains in the upper Ventuari river and the block like uplift of the Cerro Sipapo. This vaste area between the upper Orinoco and the Rio Caroni in the NE is geologically very little known.

One of the most impressive relics is probably the Cerro Duida in the Upper Orinoco, visited and described mainly geographically by TATE and HITCHCOCK (TATE 1930). Most interesting informations have been obtained during a more recent expedition organized by W.H. PHELPS Jr. into the Rio Ventuari region (HITCHCOCK, 1947). From the attached map of HITCHCOCK's report, drawn with the help of aerial photographs, a structural pattern is visible in the basement and the distribution of the relictic table mountains is discernible. Following HITCHCOCK's description, the table mountains consist of sandstone formations, not unlike the outcrops of the Gran Sabana. Conglomeratic intercalations were observed in the lower part of the section, with pebbles consisting predominantly of pinkish quartzites, with a moderatly quartzitic cement. The sandstones are coarse to fine grained, locally silicified, and pinkish to gray in colour. Crossbedding seems characteristic, and locally current ripples were observed. Fine sandstones were found locally contorted, and syngenetic slumping is assumed. We may recall similar features from the Roraima formation previously described.

Judging from the photographs attached to HITCHCOCK's paper, the sandstone scarps seem rather uniform, resembling already the table mountains of the Colombian Llanos, and representing probably the upper Roraima member. At Cerro Yavi, 800–900 m of sediments have been observed.

Apart from the Rio Ventuari and Cerro Duida area, the remainder of the vaste territory between the Orinoco and Caroni rivers is very little known, and the extension of the Roraima type formation, such as indicated on the sketchmap, Plate XI, must be regarded as rather unreliable. On the other hand, there remains little doubt, that the impressive table mountains such as Cerro Duida, Cerro Yavi and part of the Sipapo uplift are vestiges of a western continuation of the main Roraima formation.

5. The Roraima Equivalent in the Colombian Llanos

(Ref. Fig. 1 and Plate XI)

Further to the West, the basement of the Guiana Shield gradually disappears under the extensive Alluvial and Pliocene deposits of the Colombian Llanos. Except for two very doubtful occurrences of Roraima type sediments in NW Brazil between Rio Negro and Rio Vaupes, a wide gap exists before reaching the impressive table mountains between Rio Vaupes and Rio Guaviare in Colombia, particularly the mesas of Mapiripan, Yambi and Inirida (Plate XI). Further westward, in the San José region, Roraima type sediments overlap an uplifted Guiana Shield basement and a similar uplift, capped by such sediments, occurs at Araracuara in the South.

A certain intermediate position between the Guiana Shield and the orogenetic belt of the Andes is occupied by the Macarena block (ref. Plate IX, fig. B). It leads to Shield elements, which have been completely involved in the Andean folding phases, such as the Garzon massive. Both, the Macarena block and the Garzon massive consist of Precambrian and Paleozoic, and are capped by sandstone sediments not unlike the Roraima formation, most likely of Cretaceous age.

The relation of the Garzon massive and its sedimentary cover with the Macarena block and the more eastern outcrops of San José, Araracuara to the S and the mesas of Inirida, Mapiripan and Yambi is of outstanding importance in connection with the age evaluation and origin of the Roraima sandstones.

Exploratory work of Oil Companies has covered this area and delivered a considerable amount of information. But inspite of these, unfortunately unpublished data, opinions vary as far as the correlation of the sedimentary sandstone-cover is concerned. The main reasons for dispute are evidently the lack of fossils, the scarcity in characteristic and correlative heavy minerals and most important, the reduced number and discontinued nature of the outcrops.

The only fossiliferous sediments underlying the Roraima type formation were observed in the area of the Macarena block and the Garzon massive. The faunas range from Uppermost Cambrian to Ordovician (TRÜMPY, 1943). A questionable Devonian fauna was found in the Central Macarena. Where it has been observed in the Macarena, the Paleozoic formations are lithologically quite different from the transgressively overlying sandstones and quartzites.

In the southern and western Macarena block as well as in the San José region, the Roraima equivalent transgresses over Precambrian igneous and metamorphic syenitic rocks. In the mesas of Yambi, Mapiripan and Inirida, the basement does not outcrop. Somewhat contrasting with the Roraima formation of the Central Shield, conglomeratic beds are seldom developed in the basal horizons. Instead, kaolinic depositions, hardened to white splintery "porcellanites" form basal or intermediate intercalations. Kaoline also occurs frequently between the quartz grains, mainly formed from altered orthoclases and microclines. The "porcellanites" suggest a concentration of this kaolinic material. It may be derived from an old basement peneplain. In my opinion, a certain similarity between the already discussed jasper beds and the "porcellanites" seems evident.

In the southern Macarena and the San José region, the quartzitic sediments are devided into an upper and lower member by intercalations of silty red beds. In the mesas of Yambi, Mapiripan and Inirida the sediments are more compact resembling much more the upper member of the Roraima type region.

The top layers of the Roraima sediments in the Macarena block often contain thin bands of conglomerates consisting of well rounded, white quartz and black chert pebbles, mostly with diameters of 1–3 cm. These fine conglomerates may however indicate a new sedimentary cycle, leading to an Eocene age of these deposits, since above follow gray green banded clay-shales, which, in some places, contain a poor arenaceous foraminiferal fauna, of Oligo-Eocene age. I have seen similar clay shales overlying the San José quartzites. They have been observed also in the Araracuara region (verbal communication by H. HUBER) with intercalated thin carbonaceous layers. They are covered by a 10–30 m thick gritty sandstone, overlain by gray green shales with an Oligo-Miocene fauna of ostracods and molluscs (Fig. 1).

The average thickness of the Roraima type sediments in the northern and central Macarena block amounts to approximately 300 m increasing towards the southern Macarena. A similar thickness can be observed in the San José region and in the isolated mesas to the E, though the latter do not expose the total section.

The Roraima type sediments underlying the above mentioned clay shales in the Araracuara hills and transgressing the cristalline basement do not exceed 250 m (HUBER).

6. The Roraima Equivalent in Surinam (Dutch Guiana)

(Ref. Plate XI)

Apart from some doubtful outcrops along the boundary of British and Dutch Guiana, Roraima type sediments have been discovered and discribed by IJZERMAN (1931) from the Table Mountain in the central part of Surinam. The formation consists predominantly of fine grained sandstones, light pink, and well bedded in its basal part. The contact with the underlying basement has not been clearly established, but a basal conglomerate seems to be missing. Conglomerates are reported from the top mesa. The quartz grains, usually smaller than 1 mm, are rounded and cemented by quartz in optical continuity, similar to the quartzites of the upper Roraima member in the Wei Tepui. Except for a silicified tuffaceous intercalation, no indications of basic intrusions were observed. The tuffs were, on the other hand, reported as loose blocks.

The sandstones seem to cover approximately 70 square km, but the unexpected thickness of over 600 m indicates that the original cover of the sandstone formation must have been of considerable extent.

Additional field work in the interior of Surinam will probably discover further relics of sandstones of the Roraima formation, furnishing a link with the extensive deposits further to the N and NW.

IV. Some suggestions for the age of the Roraima Formation

So far, all investigations dealing with the Roraima formation failed to find direct paleontological proof for the age of the sediments. Until such time that a lucky geologist discovers a conclusive fauna, indirect evidences must help to bring this most interesting problem nearer to its solution.

First of all, the evident question arises: are all the various sediments described above representatives of the Roraima type formation, and do they actually belong to the same sedimentary cycle, which deposited the clastic rocks forming the Cerro Roraima?

Based on my own observations and the available reported facts I am rather confident that the various mentioned sections of predominantly quartzitic sandstone sediments belong to this same cycle. A definite correlation will always be handicapped by the lack of continuous outcrops, and therefore each case has to be judged by its local stratigraphical and lithological position.

If we accept the wide spread occurrence of Roraima sediments as belonging to one and the same cycle, the next step is to narrow down the stratigraphical gap within which these sediments occur.

In the central part of the Guiana Shield, fossil evidence, even for the total of the underlying and overlying sections, is missing. Only along the southern limit of the Shield, bordered by the wide depression of the Amazon valley, occur fossil-bearing formations, ranging from questionable Cambrian to Upper Carboniferous. These, mostly marine sediments, form a normal cover of the southern Guiana Shield. Westwards, they disappear under the subrecent infill of the Amazon basin. No relation with the Roraima sediments can be directly established, since so far no vestiges of the latter have been observed in the south. The youngest rock *underlying* the Roraima sediments in the Central Shield area are the Volcanics and the Haimarakka formation. The latter undoubtedly offers the best chance to find fossil evidence to limit the lower age range of Roraima sediments. Since however no fossils have been found so far, it is temping to correlate the Volcanics and Haimarakka shales with depositions of a similar facies and of known age, outcropping in the orogenetic belt surrounding the shield. A logical equivalent to the Volcanics and the Haimarakka formations could be found in the Giron and/or La Quinta formations in the Colombian and Venezuelean Andes and possibly in the Chapiza-Misahuallin of eastern Ecuador. Local marine ingressions have delivered fossils which place these predominantly red beds and volcanics into the Trias-Jurassic (Trümpy 1943, Tschopp 1948). As long as no other evidence is found, I am inclined to suggest a similar age for the Volcanics and Haimarakka formations, thus limiting the lower age of the Roraima sediments, unconformably transgressing the former, to *Post-Jurassic*.

The *upper limit* of the Roraima sediments *in the Central Shield* is only documented by the so called "White Sand Series" in British Guiana, which have been considered late Miocene to Pliocene (Bracewell 1946, 1947). Eastward, towards the coast of British Guiana the "White Sand Series" increase considerably in thickness and become lithologically quite complex. Over 2000 m (Berbice formation) were found in the Rose Hall deep test by the Central Mining and Investment Corporation Ltd (Kugler 1944), where they consist of irregular clays, sands and gravels. It is noteworthy that apart from some conglomeratic horizons at the base, this great amount of sediments is practically unconsolidated. They transgress directly on weathered quartz feldspar porphyries (Rose Hall well). No typical Roraima sediments were observed except that some of the harder conglomerates at the base of the Berbice formation may represent a conglomeratic facies of the former (suggestion by BRACEWELL in KUGLER, 1944). On the other hand, it was suggested (KUGLER, 1944) that the lower part of the Berbice sediments have been derived most likely from deposits corresponding to the Roraima formation. The facts remain however, that the seismic survey indicated a relatively high velocity for the lower conglomerates which overly the basement, contrasting with the velocities of the upper, less- and unconsolidated deposits. The discovery of a conglomeratic facies type of the Roraima formation in this area would be of great importance for its general distribution and origin.

In the Western Guiana Shield where it merges with the Andean orogenetic belt, we have the best opportunity to narrow down the lower and upper age limit of the Roraima type sediments, but even here considerable work has still to be done in the Colombian Llanos, in order to obtain more accurate information. In my opinion, the key area includes the Guiana Shield block of the Macarena and the eastern foothill belt of the Andes in Central Colombia. Both areas have been investigated by various oil companies, without however enlarging upon possible correlations with the Guiana Shield sediments. This, obviously, was not of immediate importance during the more economical investigations. Further more, only a few of the many interesting results have been published so far. An up to date investigation dealing with the sandstone facies and its distribution in predominantly Cretaceous sediments is thus highly warranted.

Based on my own experience during geological investigations in the areas of interest, a few tentative suggestions are forwarded.

If we accept, as already outlined, the correlations of the various Roraima type sediments in the Colombian Llanos, then we arrive at the following stratigraphical conclusions:

In the Macarena block, the Roraima type sediments transgress fossiliferous Silurian and doubtful Devonian. Except for some basal Eocene sandstones they are overlain by shaly sediments with a poor Oligo-Eocene fauna. The latter have also been reported from the Araracuara and San José regions. The Roraima type sediments in the western Llanos region would thus fall into the gap between Devonian and Lower Tertiary.

A direct connection of the Maracena block with the Andean foothills does not exist. Of considerable importance is the Garzon uplift in the foothill belt, a Shield element affected by the Andean folding. Fossiliferous Silurian covers the basement (TRÜMPY, 1943). The former is overlain by approximately 1000 m of quartzites, locally reported as Ambica quartzites. They are covered by fossiliferous Middle Cretaceous. Further to the N, along the Andean foothills, the Albian and particularly the Cenomanian is developed in a sandstone facies, the Une sandstone of the Shell Oil Co. These sandstones clearly increase from W to the E, that means towards the Guiana Shield. They cover Aptian limestones and, further E, even lowermost Cretaceous shales. Similar to the Une sandstone, the uppermost Cretaceous sandstone facies also increases in thickness from W to E, toward the Shield. The Ambica quartzites and the Une sandstones are lithologically not unlike the quartzitic sandstones representing the Roraima sediments. Ambica quartzite and Une sandstones are however of different age, the former Pre-Aptian, the latter Post-Aptian. In my opinion the Ambica quartzite does represent part of the Lower Cretaceous, not unlike the Pre-Aptian and Post-Jurassic Hollin sandstone (quartzite) of eastern Ecuador (TSCHOPP, 1948).

There is little doubt that all these sandstone facies increase in thickness towards the E, that is towards the Guiana Shield. One can easily conceive that further E, the *various Cretaceous sandstone horizons merge into one, though complex, sandstone formation, and that this sandstone formation represents the wide spread deposits, culminating in Cerro Roraima.* This, I fully realize, is a conception, which still needs considerable stratigraphical detail work for its ultimate proof. Of particular importance is the region of the Garzon massive, and the lateral extensions and correlations of the Ambica quartzites.

Based on the above, somewhat cursorely discussions, we may now conclude, that the Roraima sediments are:

a. transgressing a volcanic, pyroclastic sedimentary formation, not unlike the wide spread volcanic facies in the Andean Belt of mainly Triassic-Jurassic age.
b. They are normally covered by Lower Tertiary sediments.
c. The regionally uniform quartzitic sandstone facies is characteristic for the Cretaceous Andean sediments bordering the Guiana Shield, which may become condensed into one complex sandstone formation covering the Shield itself and impressively represented in the Roraima mountains.

Until further evidences are obtained I consider the greater part of the Roraima formation to be of Cretaceous age.

In the published literature the Roraima formation has been variously placed from Pre-Cambrian to Eocene. It is noteworthy that Brazilian correlations (OLIVEIRA 1938) favor a Pre-Cambrian age (Serie de Lavras) partly based on the fact that both formations contain diamantiferous basal conglomerates (see origin of Roraima sediments, below). Authors, dealing with andean sediments favor a Mesozoic age (LIDDLE, KUGLER, HEDBERG and others).

More recent investigations discussing the age of the Roraima sediments (AGUERREVERE 1939, LOPEZ 1942, KUGLER 1953) tend to correlate the sandstones with the Giron-La Quinta formations of Colombia and Venezuela (Trias to Jurassic). One of the main reasons given, the lithological analogy, is in my opinion not at all conclusive. A considerable difference exists between the two types of sediments. As mentioned above, a lithological correlation of the Giron-La Quinta sediments with the Haimarakka (Wailan) and Volcanic formations is much more likely. The very uniform intrusive rocks found in the Roraima sediments seem to belong to a quite different cycle than the wide spread, syngenetic volcanic rocks of the Giron-La Quinta beds.

Already in 1928 LIDDLE correlated the Roraima sediments tentatively with the Lower Cretaceous of the Andes, and more particularly with the Barranquin sandstones of NE Venezuela. This suggestion falls in line with my correlations mentioned above.

For the rapidly developing age determination by radio activity, the age of the Roraima sediments is certainly a most interesting problem to solve. The Roraima gabbros are being investigated by the Helium method (with Magnetite) and it is hoped that some conclusive results will be soon available.

V. A possible origin of the Roraima Sediments

More uncertain than the age of the Roraima formation is the origin of its uniform sediments.

In order to solve this most interesting problem, facts covering two important items should be available. Firstly, we should know the lithology of the rocks composing the Guiana Shield and its surrounding provinces. Secondly, concise informations regarding the sediment-petrological qualities of the Roraima deposits. The detailed lithology, grain size, roundness, mode of deposition etc. are of paramount necessity. For both items, data so far available are insufficient. The Roraima sediments have never been systematically investigated and wide areas of the Guiana Shield, in particular the western Pacaraima Mountains, the Parima range and the head-waters of the Orinoco are hardly touched geologically.

If in the following I venture to express some ideas, it is done in order to sponsor the interest in these problems by giving an opportunity to discuss the rather scanty facts and emphasizing the prime necessity for further investigations in the field.

As far as I have personally observed, and based on the available literature, the sediments of the Roraima formation are remarkably uniform. They belong, apart from local intercalations such as the shaly members, the jasper beds and conglomeratic layers, to *the sandstones*, *the quartz sandstone* and, *locally*, *quartzites*, less frequent to the feldspatic sandstones (Luepa region, Venezuela), without reaching however real arkoses. The cement of the sandstones is predominantly siliceous, and a regrowth of the quartz grains with quartz cement in optical continuity is quite frequent. The primary grains are very well rounded. Except for the more conglomeratic parts, the grains are well sorted.

The presence of cross-bedding, ripple marks and local slumping, such as already described, indicate sedimentation in shallow water without excessive currents over the greater part of the sedimented area. Some wind blown sediments may also be present, but indications are inconclusive.

The very well rounded grains suggest a distant source, or, what is more likely, *a secondary deposition*. Thus the original rock types forming the source of most of the Roraima formation may have been predominantly *sediments*, rich in quartz grains.

A further fact of considerable importance is the lithology and distribution of conglomerates. As already mentioned, conglomerates are not frequent. In the Roraima region they form a conspicuous basal conglomerate and occur again higher up in the sequence in the Gran Sabana region (AGUERREVERE 1939). They have been reported from British Guiana in the N and NE. The thin conglomerates (2 to 10 m), transgressing directly the volcanic rocks of the Santa Elena region, contain pebbles from the underlying formation. There is no doubt, that these pebbles, often only badly rounded, are directly derived from the eroded volcanics. Together were observed well rounded ferrouginous quartzite pebbles, not present in the underlying formation. Conglomerates, higher than the basal beds do not seem to contain volcanic nor granitic, nor even metamorphic components, but again ferrouginous quartzites in addition to frequent white quartzes. The pebbles of those conglomerates are perfectly rounded.

The conglomerate horizons described from the Cuyuni river, British Guiana, (MARTIN KAYE 1951) are similar, except that a real basal conglomerate seems to be missing. The higher pebble horizons are however more frequent than in the more western deposits. Basal conglomerates with reworked volcanics are reported from the scarp SW of the Mazaruni river (Kurupunung river DIXON, 1949).

In the Colombian Llanos, conglomerate horizons seem rare, or absent. Basal conglomerates were observed in the Araracuara region, consisting, locally, of reworked granosyenitic basement (HUBER.) The thin top conglomerates in the Macarena block may already belong to a higher sedimentary cycle. The paucity of conglomerate in this westernmost part of the Guiana Shield seems to be in line with a change of the fluviatil terrestrial sandstone facies into marine sediments. This lithological change would indicate a source of the Roraima sediments *lying in the E.*

The most conspicuous pebble in the conglomerates, besides the perfectly rounded quartzes, are the ferruginous quartzites, often consisting of laminae of quartz grains and haematite. They resemble the Imataca formation of eastern Venezuela, or, more remote, the itabirites of the Brazilian Minas formation.

Another important fact concerning the origin of Roraima sediments, is a probable *association of diamonds with the basal conglomerate* of the Roraima formation. So far, diamonds have been observed only in quarternary deposits, derived directly from the basal Roraima sediments or indirectly from reworked white sand deposits (Late Tertiary?) which again originated from Roraima sediments. The diamond works are particularly rich near the basal Roraima escarpment (basal conglomerate) such as along the Mazaruni and Potaro rivers in British Guiana, the upper Santa Elena region in SE Venezuela and the headwaters of Rio Branco in Brazil (BRACEWELL, 1946, 1947).

Diamond works do not surpass the zone of basal conglomerates, and except for some local occurrences in the headwaters of the Potaro river (British Guiana), no diamonds have been found yet within the Roraima sediments. The Upper Potaro diamonds may have been derived from higher conglomerates or from old quaternary deposits originating from a southern source (Pleistocene of Ireng river?). The possible relation to Gabbro intrusions is doubtful. The frequent gabbro laccolites elsewhere in the Roraima sediments cannot be considered a source for secondary diamond deposits, so, admittedly, very little is known so far in this respect.

In recent years small scale exploration, mostly by few individual diamond miners, increased considerably, particularly in the headwaters of Rio Branco in Brazil covering also the border zones with British Guiana and to some extent in the southern border zone of the Gran Sabana in Venezuela. Unfortunately very little information is seeping out from such investigations. However, a wealth of new facts must be available from this source regarding the distribution of diamond deposits, and it would be a most valuable and certainly fruitful undertaking, if such new information could be put on record and compiled in the scientific literature. However this information must be collected on the spot.

The writer visited some new diamond works on the Brazilian side of the Ireng river, below the basal conglomerate of the Roraima sediments. The river has cut the E extension of the massive Wailan gabbro, and has formed irregular deep channels and pools. Since 1936, the diving helmet has been introduced in this area, and it may be of interest to give a short description of this mining method: The work is carried out usually on a very small scale, by a group of normally not more than half a dozen men. After the selection of a suitable stretch of river (slow flowing, deeply and irregularly eroded into bedrock), ropes are stretched over the river with a canoe

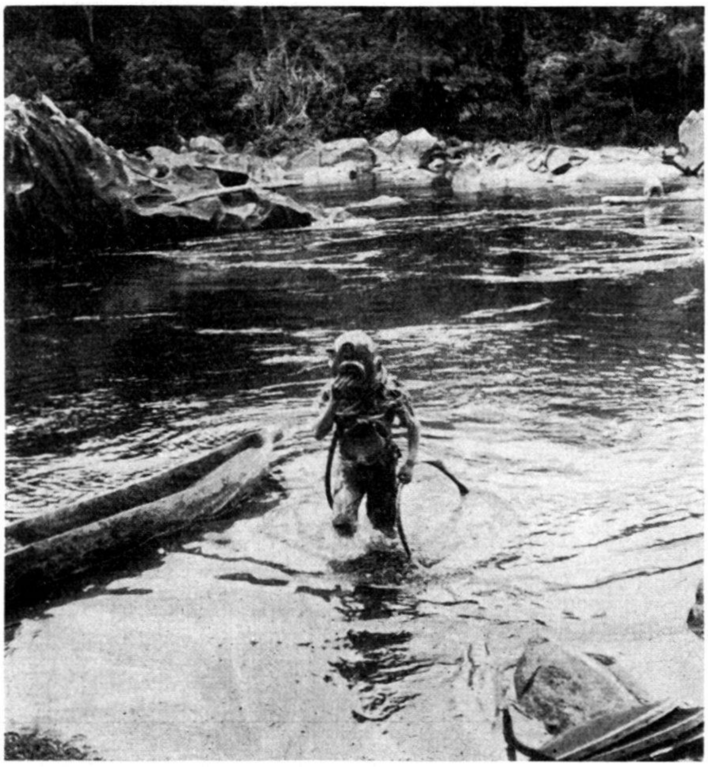

Fig. 10. Diamond works on Ireng river. Diver returns after one hour diving. The river is slow flowing but very deep. British Guiana-Brazil border.

being attached to it over the spot to be investigated by the diver. Equipped with diving helmet, lead weights, connected to a hand pump on land and attached by a rope to the canoe, the diver enters the river and walks down to the deepest potholes in the bedrocks. With a short plate-like shovel, sand and gravel is filled into a small bag and attached to the rope of the canoe. The filled bag is pulled into the canoe, emptied and sent down again to the diver who continues the operation until the canoe is filled. This may take from half to well over one hour, after which the diver emerges quite exhausted (Fig. 10). The canoe is pulled to the shore and its content is subsequently placed into circular sieves (washing pans) of 60 cm in diameter with meshes of approximately 1 cm, half a cm and one millimeter. The sieves are placed one on top of each other, the finest at the bottom. They are hand panned under the water and then each sieved fraction is placed on a flat spot on the shore.

Here a special man investigates each fraction for the content of diamonds. It is most remarkable with what a rapidity this investigation is carried out, but apparently no diamonds are being missed by the highly trained eye.

With this method of diving into the deep potholes of the rivers, quite a considerable amount of diamonds has been discovered. The work is however very strenuous and dangerous. The remoteness of the areas precludes the use of mechanized equipment. During my visit, the various rivers flowing into rio Branco have not yet been explored beyond the basal Roraima conglomerate, and it was thus not possible to verify if diamonds are related only to this part of the Roraima formation, or if some relation exists with other horizons of the formation, or even with the basic intrusions.

It has been generally supposed that originally the Guiana diamonds have been derived from a distant source. If this is so, the origin of the diamonds should also give some ideas about the origin of the Roraima sediments. No diamonds have so far been reported in situ from the basement formations, nor from secondary deposits derived only from the basement.

Attention should be given also to minerals found associated with diamonds in the concentrates. Gold is often present, but many local sources for gold are known and thus it seems of little value for tracing the origin of the sediments. Topaz, euclase in clear crystals, black turmaline, anatas, and rutil, the latter usually well rounded, are some of the more important associated minerals. Most of them seem to be known in the diamantiferous deposits in the Brazilian Pre-Cambrian, the Sopa formation (State of Minas Geraes).

To derive the Guiana diamonds from such a distant source does not comply with at least one fact which in my opinion is difficult to explain. Most of the diamonds found in the Guiana Shield occur as sharp idiomorphic crystals. The writer has seen diamonds from the Ireng river which were beautifully sparkling octahedrons. Can those diamonds retain their sharp crystal feature after being transported, sedimented again, reworked, transported and redeposited? Have they been fractured along their octahedron cleavage, but then some rounded forms should also be present? Does it not rather suggest a source not very far from its present deposition similar to the volcanic pebbles in the basal conglomerate?

These questions cannot be answered in this present issue. I have stressed this problem with the hope that some day it will be followed by new facts from the field. Before additional data are known regarding the formation, origin and transport of the Guiana Shield diamonds, I hesitate to regard them as a possible indication for a very remote southern source of the Roraima sediments.

Based on Plate XI we may, concluding, glance at the regional distribution ot the Roraima sediments. The main extention is clearly from E to W. Westwards, the Roraima clastics grade apparently into marine sediments of predominantly Cretaceous age. No source from this direction can conceivably be expected. North- and southwards the limit of the Roraima sediments is erosional, but indications hint to a decrease of the deposits in both directions. Eastwards, a clear increase in thickness of the sediments is evident. Conglomeratic intercalations increase, and are, as far as the regional information indicates, best developed in British Guiana, that means to the E. The greatest thickness of sediments was observed in the Auyantepui–Roraima–Wei Tepui ranges. The eastern to northeastern limit of the Roraima sediments is an erosional scarp, representing only part of the total sedimentary section, the thickest top layers probably being eroded. This fact is supported by the step like scarps rising towards the Pacaraima range (Cerro Roraima). The primary sedimentation may probably even surpass the visible thickness of Auyantepui. SE-wards, the few relictic sediments may indicate again a decrease of the original sedimentation. On the other hand Post-Roraima erosion must have been quite considerable in this area, since it coincides with the highest elevation of the Pre-Cambrian basement in the Kanuku Mountains (nearly 1000 m). The age of this basement was established through the occurrence of Euxenit, present in pegmatites traversing the gneissose granite. The age for this radio active mineral was calculated to be over 1000 million years (BRACEWELL 1946). The considerable extension of "White Sand deposits" NE of this basement uplift seems further to support a strong erosion of Roraima sediments. The White Sand deposits are decreasing however in Surinam (Dutch Guiana).

The most significant pebbles from the Roraima conglomerates are haematite-quartzites, similar if not identical with the itabirites outcropping in the Imataca range which borders the Orinoco delta. The Imataca range strikes clearly NE, and certainly continues into the sea (see structural discussions below). The itabirite pebbles may thus indicate a NE source of at least part of the sediments.

Considering all these, admittedly still scanty facts and implications, *an eastern source for the bulk of the Roraima sediments* is suggested.

This conception implies evidently that the sediments are traced into an area, covered presently by the sea. The suggestion leaves us completely in the dark as to the type of the "mother rocks" yielding this enormous amount of uniform quartz sediments, which cover a great part of the visible Guiana Shield.

Structural considerations will show us that the present Guiana Shield certainly extends considerably towards the ENE. The interesting results from the Rose Hall well (KUGLER, 1944) at the coast of British Guiana near New Amsterdam, where about 2000 m of practically non consolidated sediments were drilled through, indicate a very young subsidence of the Shield basement.

B. Some Structural Aspects of the Guiana Shield

(Ref. Plate XI)

The Guiana Shield is by no means a stable area which has kept tectonically quiet since early Paleozoic times. The recent investigations by the Geological Survey of British Guiana clearly disprove such earlier assumptions. During my travels I was impressed by the effects of diastrophisms having deformed Shield elements at various geological stages. Orogenetic movements of Andean intensity have evidently not taken place, but it will be shown how regional tectonical trends expressed by Andean folding are comparable to the structural pattern of the Guiana Shield.

I am fully aware that my attempt of a tectonical analysis of the Guiana Shield is based on very few observed facts indeed. Structural investigations have been greatly neglected, and over the greater part of the Shield area no corresponding information is available. This fact is the more depressing, since parts of the Shield have been covered by aerial photographs, the most important tool necessary to furnish convincing structural data from these vast and geologically little explored regions. For various reasons, aerial photographs of the Guiana Shield were not available and the following suggestions are intended to invite future regional studies based on photogeological investigations, with a view to outline the tectonical pattern of the Guiana Shield. The striking, though preliminary results obtained in the Imataca range of Venezuela (LOPEZ 1946) just prove what can be achieved with the help of this method.

Plate XI represents a structural analysis of the Guiana Shield and the surrounding orogenetic belts. It is based on published results and my own observations. Shown on this sketch map is the approximate extension of the Roraima formation, the structural trends depicted from fold axis, thrusts and faults produced by Andean orogeny and the structural lineament of the Shield. This lineament may have formed the initial structural pattern from which most of the Andean trends have developed. For a description of the term "lineament", I refer to the important analysis by R.A. SONDER (SONDER 1938).

The characteristic trends of the Andean orogeny in the northern part of S America consist of two main and one superimposed secondary direction.

The main directions are NE–SW (NNE–SSW), trend A, and NW–SE (NNW–SSE), trend B. The secondary trend is mostly E–W orientated, trend C. Anyone familiar with the tectonic outline of northern S America can recognize, how most, if not all, important structural expressions are related to the one or the other trend, or reflect a combination of one, two and/or three. The most classical example of such a combination is the outstanding block of the Sierra Nevada de Santa Marta in N Colombia. My own observations in this Sierra have confirmed these structural trends in many instances.

Trend A is clearly developed in the Eastern Cordillera near Bogotá, in the northern Central Cordillera, in the coast ranges SW Branquilla, in the Cordillera de Perijà, the Cordillera of Merida in Venezuela, and in most of the structural trends in the basin of Eastern Venezuela. It is again well outlined in the apparently EW trending Coastal Cordillera of Eastern Venezuela and well reflected in the structural trends in S Trinidad, in the Central Range and in the core of the Northern Range of Trinidad. The main structures of Tobago reflect trend A as well as the structural features of Barbados.

The above cited examples show that trend A is mainly outlined by the direction of *folding*. Trend A seems to some extent the primary (older) structural outline of Northern S America.

Trend B is reflected by faulting and folding in the E Cordillera bordering the Middle Magdalena Valley, by the W border of the Sierra Nevada de Santa Marta (6000 m deep graben), by faulting and some folding in Central and Eastern Venezuela. It is further reflected by faulting and thrusting with considerable horizontal displacement in the E Venezuelan coast range and in southern Trinidad. Trend B which is mostly characterized by faulting, seems to have acted subsequent to Trend A.

Trend C is affecting the northern part of the Sierra Nevada de Santa Marta and, W of it, the fault trend in the Maracaibo area, occurring again as a marked fault trend in the northern part of the Coastal Cordillera in Central and E Venezuela and along the borders the Northern Range of Trinidad. A considerable amount of horizontal displacement seems characteristic. In my opinion, trend C is the youngest tectonical feature, superimposed on the structural trends A and B. As will be seen, trend C seems not well reflected by the structural elements of the Guiana Shield.

Contrasting with the three structural trends mentioned above is the island arc of the Lesser Antilles. This very young tectonical element, characterized by subrecent to recent volcanism, has been variously interpreted (ref. also SCHUCHERT, 1935). If we project this arc towards the Coastal Cordillera of Northern Venezuela, this latter structural trend with characteristic "A" elements and younger superimposed "C" faultzones is intersected by the Antille arc at Carúpano. There I was able to observe a most peculiar andesitic plug, of a very young aspect and unlike

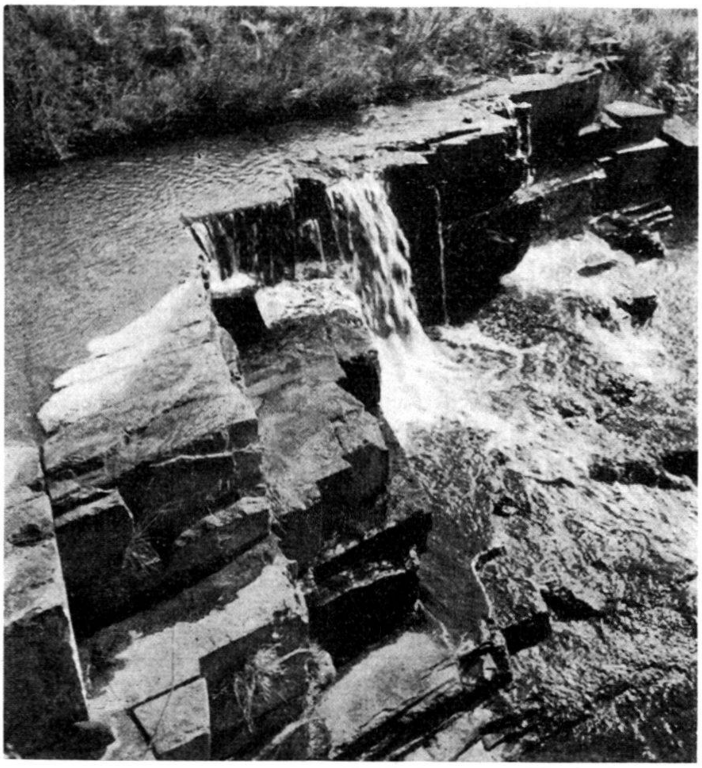

Fig. 11. Typical main fracture lines (lineaments) in fine quartzitic sandstone of the Middle Roraima Member. W side of Wei Tepui. Venezuela–Brazil border.

other products of igneous activity in this part of the Coast-Cordillera. This plug may be related to the young volcanism of the Antillean arc, which, in my opinion, is a quite separate element from the structural trends of the American main land. "A" trends persist in Trinidad and Tobago and apparently even in Barbados, striking in a NE direction into the Atlantic, *without any indications of bending into the Antillean arc.* These regional observations admittedly need more confirmation in the field. The most valuable Caribbean Research Project of the Princeton University will eventually cast a more definite light on the origin of the Antillean arc, and its structural relation with the main land (HESS 1953).

The lineaments of the Guiana Shield, as far as they can be depicted from scattered observations, follow the same main trends observed in the Andean orogenetic belts. The predominant lineaments are again NE–SW directed ("A" trend) and NW–SE directed ("B" trend). These trends are most characteristic in the cristalline basement and in the marginal parts of the sedimentary blocks. (Ref. Fig. 11.) On the other hand the gently folded Roraima sediments expose a lineament, which is more irregular than the regional picture. Many measurements which I carried out in the Roraima region, and of which the average picture is given in Plate X and XI indicate the "A" trend as a main direction, but vary somewhat as far as the second trend ("B") is concerned. A structural analysis based on the detailed topography of the top table of Cerro Roraima (Venezuelan Boundary commission, 1932) shows a somewhat variable pattern (Fig. 12). The regional warping of the Roraima sediments undoubtedly is reflected in the pattern of the respective lineament. Any structural analysis should consider this, but much more facts should be known regarding the folding of the Roraima formation.

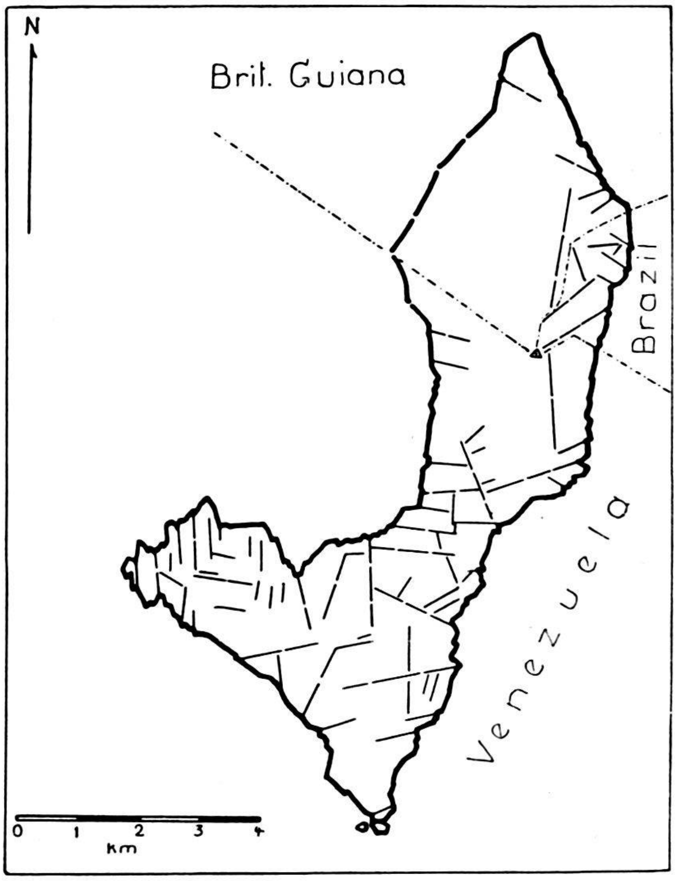

Fig. 12. Main fracture lines (lineaments) of the top mesa of Cerro Roraima. Reconstructed from detailed topographical map of Venezuelan boundary commission.

Folding in the basement has been intense. Foliation, syngenetic and subsequent intrusions, in particular dyke intrusions, frequently followed a pattern reflected by lineaments corresponding to the "A" and "B" trends. The field work by the Geological Survey of British Guiana has outlined this pattern clearly. Observations in this respect were most instructive during a flight from Georgetown to the Ireng river on the Brazilian border in connection with my field expedition.

The steep folding of the Imataca range is a further excellent example of an activated lineament, reflecting the predominant "A" trend. The parallelism of the Imataca structures with the tectonical features in Eastern Venezuela and Trinidad is most striking, in spite of the considerable age difference of the orogenetic phases. These facts have undoubtedly practical implications. A careful analysis of this northern part of the Guiana Shield would certainly yield most valuable structural informations applicable to the subsurface of the oil belt in Eastern Venezuela. The fault trends ("A" trend) found by geophysical methods in the Greater Oficina and Temblador fields confirm this suggestion to some extent.

Renewed volcanism resulting in the deposition of the *Volcanic group*, tentatively correlated with the Giron volcanics of the Andean orognetic belt, have initiated a Pre-Roraima orogenesis, folding the Haimarakka formation. The deformations of the latter follow a trend parallel to the NE and probably S rim of the Roraima formation, regionally dipping under the sandstones and striking roughly NW–SE ("B" trend). In the Wailan formation (probable equivalent of the Haimarakka) dips up to 30° towards NE have been observed, the strike being clearly NW–SE (Map of Plate X).

Subsequent to the volcanic activities and the folding of the Volcanic group, conditions were initiated, responsible for the widespread deposition of the Roraima formation, with a slowly rising hinterland most probably in the ENE.

Subsequent to the deposition of the Roraima sediments and accompanied by probably syngenetic gentle folding, followed the intrusions of gabbroid masses. The latter, by warping the sediments, may have accentuated in some cases the regional uplifts of the Roraima formation, giving origin to the saucer like table mountains surrounded by basic igneous rocks, well documented in the Gran Sabana of Venezuela. Gabbroid intrusions and regional folding again followed the original Shield lineament, reflected by the extension of basic rocks underlying the Cerro Roraima ("B" trend).

The blockfault pattern affecting the Roraima sediments follows the initial lineament of the Shield. A classical example is the impressive and complex fault block of the Macarena in the Colombian Llanos as well as the other table mountains emerging over the extensive plains. The NNW–SSE trend ("B") of the Macarena block contrasts in a particular way with the "A" trend of the East Cordillera. Anybody flying along the foothills is surprised by this remarkable mountain range, which suddenly and unexpectedly stands in one's way. The activation of the Shield lineament could not be better examplified than by this mountain block, with its over thousand meters of steep, fog bound cliffs (see panorama Plate IX, fig. B). Secondary block faulting, representing the "A" trend, also is quite frequent in the Macarena. The same fault trends are visible in the more eastern block of San José where the Roraima formation transgresses nepheline syenites. Block faulting, representing reactivated main lineament trends is again well represented in the Sipapo mountains E of the Upper Orinoco (Venezuela). Seen from the W, they appear not unlike the Macarena block with which they compare in extension and height, except that the Roraima sandstone cover has been removed by erosion over the greater part of the uplift. The Cerro Duida, SE of the Sipapo mountains, in the Upper Orinoco forms again an impressive tectonic block fitting the main lineaments. The writer is convinced, that if once the greater yet unknown part of the Guiana Shield between the Orinoco and the Caroni rivers can be structurally analysed, a wealth of additional informations conforming to the main structural trends will be obtained.

While dealing with the origin of the Roraima sediments, the possibility of an ENE source was ventilated, which would imply a considerable extension of the Shield element into the present Atlantic Ocean. Our structural analysis seems, in my opinion, to support such an assumption. The parallelism of the main lineaments of the NE, rather well known part of the Shield with the tectonical trends of the Venezuelan Coast Range, the E Venezuelan basin, the tectonical trends of Trinidad and Tobago, and to some extent even of Barbados, seem to indicate that the old Shield elements must have continued for a considerable amount towards the E. The reason for the present coast line is a subrecent down buckling of the Shield, more or less conform to the present shore line. A proof for this downbuckling are the 2000 m of practically unconsolidated sediments found in the Rose Hall deep test in British Guiana. The rapid subsidence probably occurred after the greater part of the Roraima sediments had been removed by erosion.

The assumption of an eastward extention of the Guiana Shield would further preclude the much discussed off shore oil possibilities of British Guiana. The oil distribution of Eastern Venezuela, with its producing fields and its tar belt, would most likely, continue in a ENE direction conform to the main regional structural trend, and not, as would be necessary for off shore prospects in British Guiana, conform to the present Atlantic shore line of the Guiana Shield.

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MAPS:

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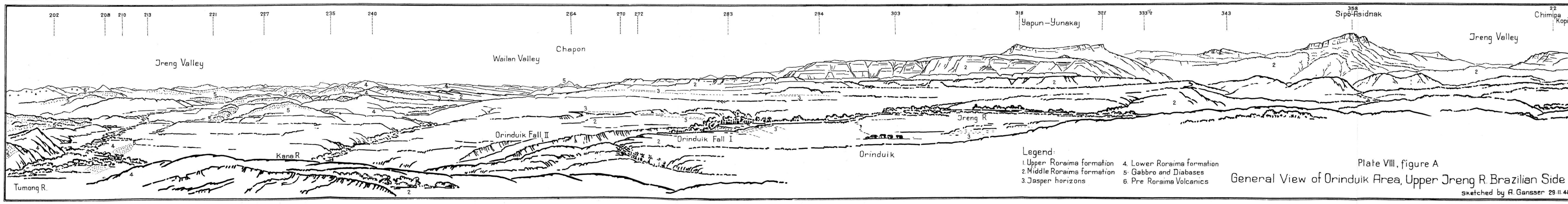


Plate VIII, figure A

General View of Orinduik Area, Upper Jreng R. Brazilian Side

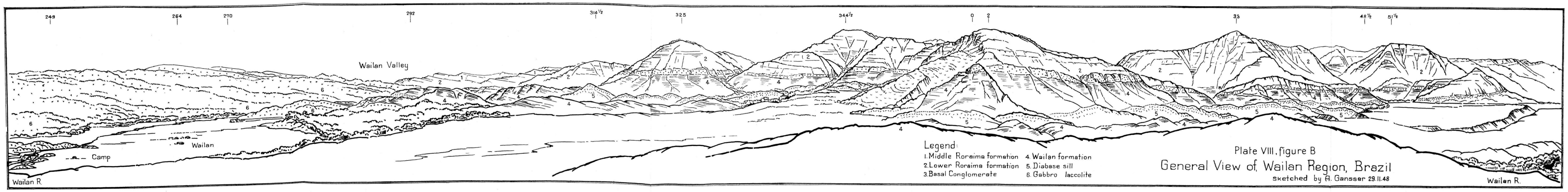


Plate VIII, figure B

General View of Wailan Region, Brazil

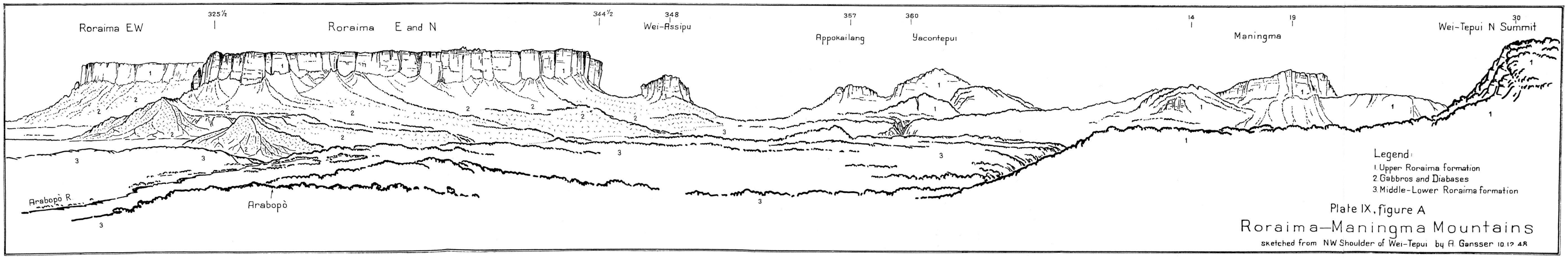


Plate IX, figure A
Roraima—Maningma Mountains
sketched from NW Shoulder of Wei-Tepui by A. Gansser 10 12 48

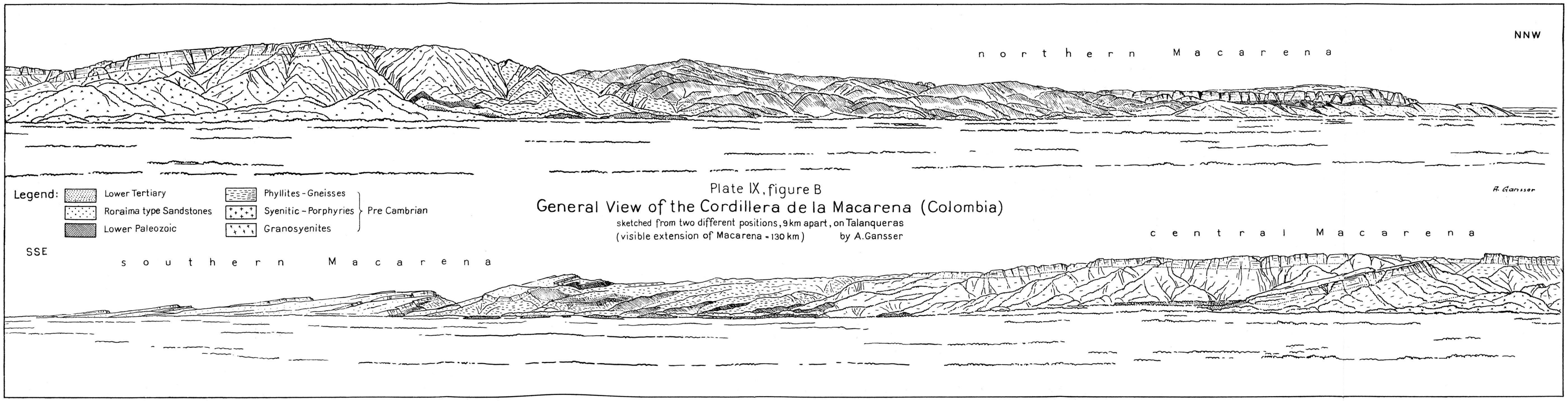
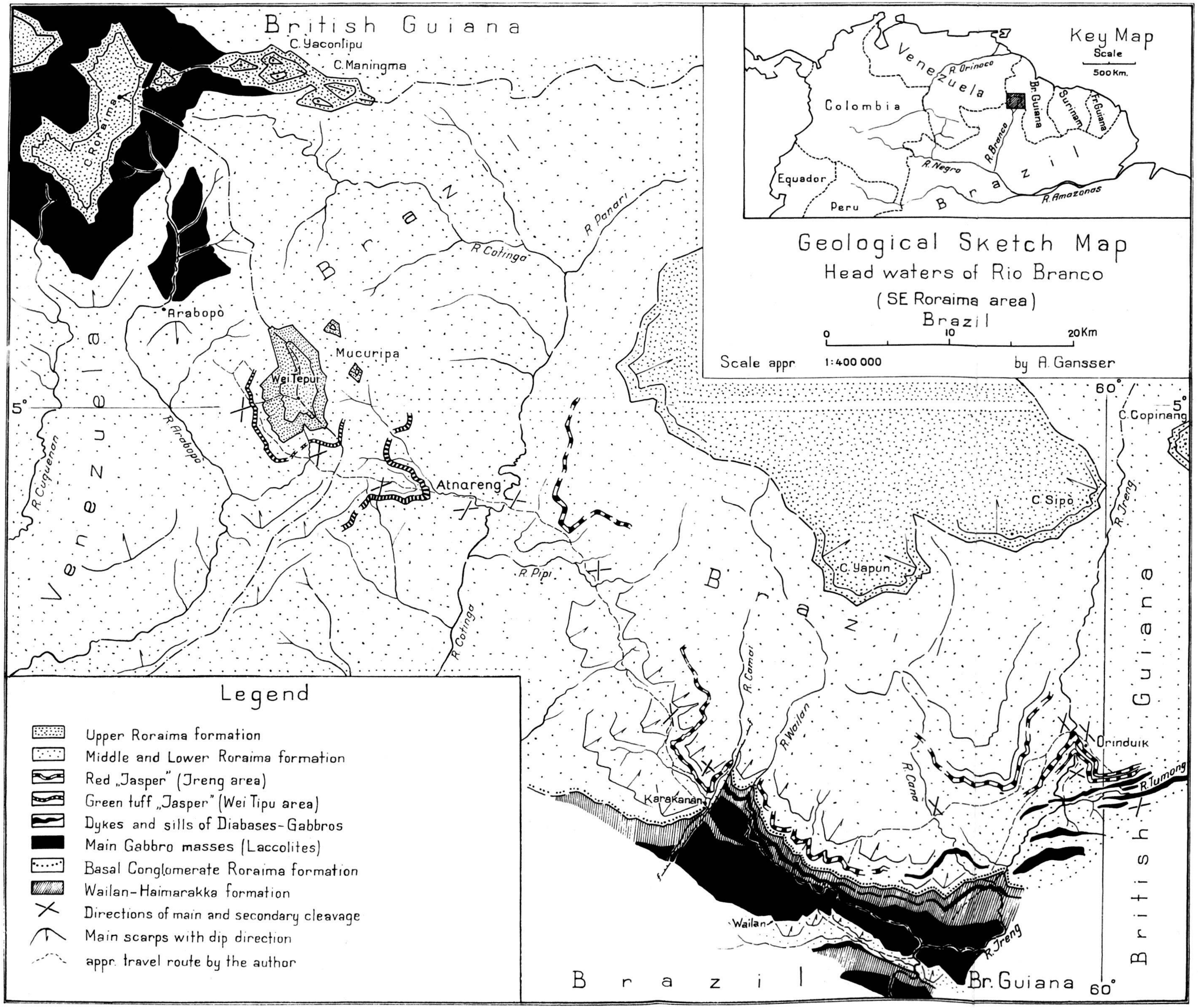
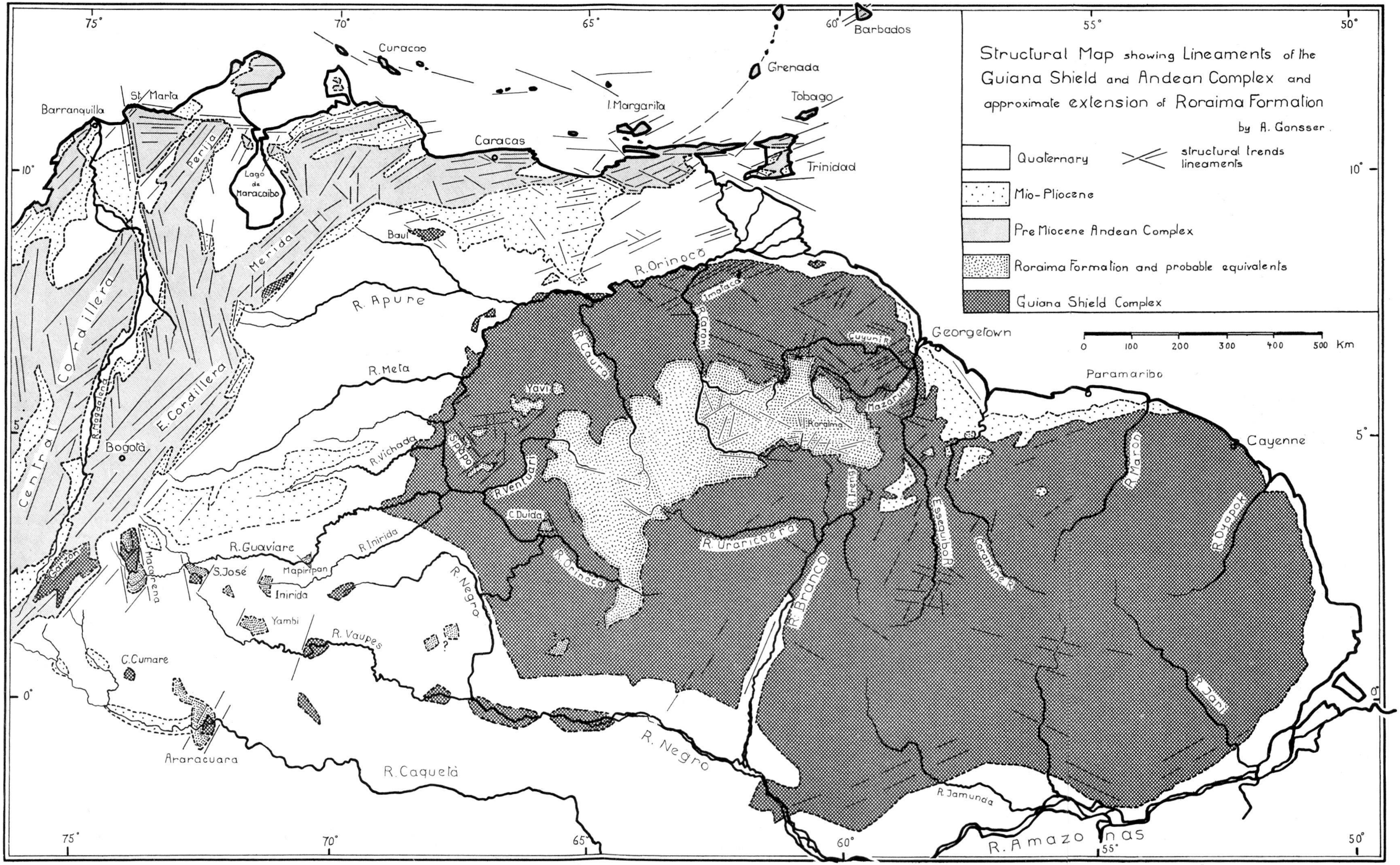


Plate IX, figure B
General View of the Cordillera de la Macarena (Colombia)
sketched from two different positions, 9 km apart, on Talanqueras
(visible extension of Macarena = 130 km) by A. Gansser


Geological Sketch Map
Head waters of Rio Branco
(SE Roraima area)
Brazil
0 10 20Km
Scale appr 1:400 000
by A. Gansser
Key Map
Scale
500 Km.
Venezuela
Colombia
Equador
Peru
Brazil
Br. Guiana
Surinam
Fr. Guiana
R. Orinoco
R. Branco
R. Negro
R. Amazonas
British Guiana
C. Yaconlipu
C. Maningma
C. Roraima
Arabopò
Mucuripa
Wei Tepui
R. Arabopò
R. Cuquenan
Venezuela
Brazil
R. Panari
R. Cotinga
Atnareng
R. Pipi
C. Copinang
C. Sipò
C. Yapun
R. Jreng
R. Camai
R. Wailan
R. Cana
Orinduik
R. Tumong
Karakanan
Wailan
Br. Guiana
5°
60°
Legend
Upper Roraima formation
Middle and Lower Roraima formation
Red „Jasper" (Jreng area)
Green tuff „Jasper" (Wei Tipu area)
Dykes and sills of Diabases-Gabbros
Main Gabbro masses (Laccolites)
Basal Conglomerate Roraima formation
Wailan-Haimarakka formation
Directions of main and secondary cleavage
Main scarps with dip direction
appr. travel route by the author


Structural Map showing Lineaments of the Guiana Shield and Andean Complex and approximate extension of Roraima Formation
by A. Gansser
Quaternary
structural trends lineaments
Mio-Pliocene
Pre Miocene Andean Complex
Roraima Formation and probable equivalents
Guiana Shield Complex
0 100 200 300 400 500 Km
Barbados
Curacao
Grenada
Tobago
Trinidad
I. Margarita
Caracas
Barranquilla
St. Marta
Perija
Lago de Maracaibo
Merida
Baul
R. Orinoco
R. Apure
Georgetown
Paramaribo
Cayenne
Imataca
R. Caroni
R. Caura
Cuyuni R.
Mazaruni
Roraima
Yavi
Sipapo
R. Ventuari
C. Duida
R. Uraricoera
R. Ireng
Essequibo R.
Corantijne R.
R. Maroni
R. Oyapok
R. Jari
R. Branco
R. Orinoco
R. Meta
R. Vichada
Cordillera
Central
E. Cordillera
Bogotà
R. Magdalena
Garzon
Macarena
R. Guaviare
R. Inirida
S. José
Mapiripan
Inirida
Yambi
R. Vaupes
R. Negro
C. Cumare
Araracuara
R. Caquetà
R. Negro
R. Jamunda
R. Amazonas
75°
70°
65°
60°
55°
50°
10°
5°
0°