Geology of the northern part of the province Santa Clara, Cuba

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M. G. RUTTEN

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PROEFSCHRIFT

TER VERKRIJGING VAN DEN GRAAD VAN DOCTOR IN DE WIS- EN NATUURKUNDE AAN DE RIJKS-UNIVERSITEIT TE UTRECHT, OP GEZAG VAN DEN RECTOR MAGNIFICUS Dr. C. W. VOLLGRAFF, HOOGLEERAAR IN DE FACULTEIT DER LETTEREN EN WIJSBEGEERTE, VOLGENS BESLUIT VAN DEN SENAAT DER UNIVERSITEIT TEGEN DE BEDENKINGEN VAN DE FACULTEIT DER WIS- EN NATUURKUNDE TE VERDEDIGEN OP
MAANDAG 24 FEBRUARI 1936,
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DOOR

MARTIN GERARD RUTTEN
GEBOREN TE DJOMBANG

DEZE DISSERTATIE VERSCHIJNT TEVENS ALS No. 11 VAN DE PHYSIOGRAPHISCH-GEOLOGISCHE REEKS DER GEOGRAPHISCHE EN GEOLOGISCHE MEDEDEELINGEN

U, Hoogleeraren der Wis- en Natuurkundige Faculteit, dank ik hierbij zeer voor de vriendelijkheid en het geduld, waarmee U mij gedurende mijn studietijd steeds voortgeholpen hebt. In het bijzonder geldt dit natuurlijk mijn Vader en Promotor.

CONTENTS.

INTRODUCTION.

This paper describes the geology of the northern part of the Province of Santa Clara in middle Cuba. The boundary towards the South is drawn over Central Caracas, Guayos, San Juan de los Yeras, Central Pastora, Provincial, Baez, and at the crossing of the Rio Calabazar with the Carretera Central.

The fieldwork was done, and the material collected, during an expedition from the University of Utrecht, Holland, under the leadership of my father, Prof. L. M. R. RUTTEN, with six members, Mr. H. J. MAC GILLAVRY, Mr. A. A. THIADENS, Mr. L. W. J. VERMUNT, and the author, all students of geology at the Utrecht University; Mrs. C. J. RUTTEN-PEKELHARING and Miss A. RÖNTGEN.

We worked in Santa Clara province during the second half of February, the whole of March, and the first half of April of the year 1933, during which time we surveyed both the northern and the southern part of the province. All material, notes and samples, bearing on the northern half of the province were turned over to me, to compile a geologic description of this district. Mr. A. A. THIADENS will describe the southern part of the province.

Maps: We had at our disposition the military Cuban maps on the scale of one inch to a mile, whilst at home we could make use of the maps of the Carretera Central a new highway over the axis of the island, and the nautical charts of the American Navy.

The Cuban military maps were very bad, and not to be relied upon. Instead of these we surveyed our own courses by taking directions with an ordinary hand-compass and measuring distances by counting our paces. The rough maps got in this way were more reliable than the official Cuban maps. At home, the different courses were plotted, and put into position. As can be seen from the map I had the disposition of numerous triangles, and with the help of these I could correct major differences between various courses. The maps of the Carretera Central, at the scale of one to twenty thousand, proved reliable enough as to distances and directions, although sometimes the North-indication was wrong. The map thus obtained, could be controlled with the U. S. Navy chart, as both La Isabella and Caibairien were indicated on the chart. The distance between La Isabella and Caibairien on my map was 3 % the smaller, which could be corrected by a slight change in direction of the long, straight road from Sagua la Grande to La Isabella. For publication with this paper two different maps were prepared, one to show the geology, the other to indicate the localities and find-spots mentioned in the description of the district. For the sake of an easy comparison of both maps, the geologic boundaries are drawn on the second map also. For the geologic map we had to choose between two ways of indicating our observations. The area surveyed is by no means covered by observations, but we surveyed a number of sections only, these form together a maze with openings of varying width. I could have indicated only the geology along the courses surveyed, e. g., the results of direct observation. This was not done, as, during our field-work and the latter period of laboratory work, we got a definite conception of the geologic structure of the district, and by this interpretation could, with a certain measure of security, combine the boundaries and other data found at the individual courses and so make a geologic map, covering the larger part of the area surveyed. The geologic map published with this paper thus is the combined result of direct observations and their interpretation. To show the amount of direct observation, and to show the widths of the openings the maze of observations leave, all courses surveyed are indicated on both maps, so that everyone can see at a glance if certain features are only interpretation, or also supported by direct observations. As this was the first detailed geologic description of the northern part of Santa Clara Province, it was thought necessary to give also a find-spot map, together with a detailed description of several of the major courses, thus producing definite controllable evidence for the statements made in the general part of the paper.

A difficulty arose, with the recording of the different strikes and dips on the geologic map. In the heavier and more irregularly folded regions it was impossible to draw all strikes and dips observed, and only a certain number could be selected, the selection of course being wholly subjective. Possibly the abnormal strikes, occuring in the field only in a small number, are reproduced in a relatively larger number on the map. This is not, however, of vital interest, as, with the scarce and widely apart courses surveyed, we did not succeed in finding a definite structure in these heavily folded regions, so that no statements about the structural build are deduced from the relative importance of the regular or abnormal strikes.

Acknowledgments: I am indebted for help and advice of various kinds to a large number of people,

The 'MOLENGRAAFF-FONDS' and the 'BATAAFSCHE PETROLEUM MAATSCHAPPIJ' gave financial support to our field work.

I have been largely helped by the fact that all observations and field work done in the district by the other members of the expedition were placed at my disposition, whilst, during the working out of the Rudist collections made, I had much help from Mr. H. J. MAC GILLAVRY's extensive knowledge of this subject.

At Cuba the Government and the SOCIEDAD GEOGRAFICA DE CUBA have furthered our interests in every possible way, and we shall long remember the agreeable help of Cuban private residents, especially the ever-active interest and aid of Ingenior FÉLIX MALBERTI. Mr. POLIAKOFF, of the

Compañia Shell Mex. has also been of great assistance to us, whilst the long discussions on Cuban geology we had with Dr. TSCHOPP, geologist of the Shell Mex., in the field, were of vital interest for our studies. To Dr. TSCHOPP I am furthermore indebted for the fossil locality H. 550, between La Esperanza and Santa Clara, where many beautiful Rudists were found.

To Prof. TRAUTH of Vienna and Prof. JAWORSKI of Bonn, I am indebted for their assistance, they having taken over the separate study of our collections of Aptychi and Ammonites.

Mr. VAN DIJK of the Utrecht laboratory executed all drawings and micro-photographs necessary for the publication of the paper with pain-staking accuracy and neatness.

My cousin Mrs. BREUNING-WILLIAMSON kindly revised with me the English text of the manuscript.

To Prof. J. I. J. M. SCHMUTZER I am indebted for his careful revision of the microscopic thin-sections, and to Mr. W. VAN TONGEREN for the making of the chemical analyses and advice in petrochemical matters.

Prof. H. GERTH, of Amsterdam determined the corals found, and kindly permited me to publish the results in this paper.

Chapter I: **SUMMARY AND GEOLOGIC HISTORY.**

The district described, the northern part of the Province of Santa Clara, middle Cuba, is formed by a structural high, and bounded at the western and eastern side by large synclinoria, with the younger sediments chiefly exposed.

Geologic history begins in Lower Cretaceous times, with the sedimentation of the Aptychi Limestones and the lower parts of the Tuff Series. These two elements are of the same age, and only form different facies. But whereas the Aptychi Limestones only contain fossils of Lower Cretaceous age, the Tuff Series are found to range higher up in the geologic column, and locally contain fossils of lowest Upper Cretaceous (Turonian-Emscherian) age. Generally speaking, we find the Aptychi Limestones in the northern and eastern part, and the Tuff Series in the southern part of the district. The difference is, however, gradual, and a close alternation of layers of the different facies has been observed. The Tuff Series comprises volcanics — spilites, diabases and porphyrites, with glass-tuffs, crystal-tuffs and tuff-breccias of the same composition — and cherts, sometimes with *Radiolaria*. Limestone-beds are sometimes intercalated, and rarely macro-fossils — Ammonites or Caprinids — are found. The Aptychi Formation is formed by greyish, monotonous, well bedded limestones, and intercalated cherts. Locally they carry abundant *Radiolaria-* or Smaller *Foraminifera*. Scarce macrofossils found comprise remains of Ammonites and their Opercula. Specific determination of these Opercula places the Aptychi Limestones into the Lowest Cretaceous.

Following the sedimentation of these formations came orogenetic activity, with the intrusion of large masses of peridotites, and slightly younger dikes of gabbroid composition, followed by the intrusion of dikes from a dioritic magma. The peridotites nowadays are found as large and smaller massifs of Serpentine. Within the Serpentines we find many foreign inclusions that may be divided into two groups. The first group shows only slight metamorphism, and comprises diabases and spilites, closely allied to and derived from the Tuff Series. To the second group belong schists, amphibolites and garnet-rocks, with a meso-zonatic metamorphism, that are parallelised with older, jurassic, schists, known from other parts of the island.

In the Uppermost Cretaceous, parallelised with the Maastrichtian of Europe, there followed the sedimentation of the Habana Formation. In the southwestern part we find limestones, tuffaceous limestones and tuffs, indicating a continuous volcanic activity, with a characteristic fauna of Orbitoids and Rudists. In the northern and eastern part we find mostly

Geologic History of northern Santa Clara Province, Cuba.

	Time:	southern facies:	northern facies:
Tertiary		Vertical uplift of Guines Limestone.	
	Oligo-Miocene	Guines Limestone.	Guines Limestone.
	Orogenesis	Gentle folding.	Strong folding, perhaps faulting.
	Oligocene	Orbitoidal limestones.	
	Upper Eocene	Orbitoidal limest., marls, tuffaceous limest., basal conglomerate.	Limestones and marls Smaller *Foraminifera*.
	Orogenesis	Gentle folding.	Strong folding, perhaps faulting and overthrusting.
Cretaceous	Maastrichtian	Habana Formation Limest. with Orbitoids and Rudists, tuffaceous limest., glass-tuffs, intrusions of porphyrites, basal conglomerate.	Habana Formation Breccia-limestones, scarce Orbitoids and Rudists.
	Orogenesis	Gentle folding.	Gentle folding.
		Intrusion of diorites, diorite-porphyrites, aplites and malchites. Intrusion of gabbroid dikes. Intrusion of peridotites with inclusions from the Tuff series and from older formations, at present unknown in the district.	
	Lower and Middle Cretaceous	Tuff Series. Spilites, diabases, porphyrites, glass-tuffs, crystal-tuffs, tuff-breccias, cherts, *Radiolaria*, Ammonites.	Aptychi Limestones. Limestones, cherts, *Radiolaria*, Smaller Forams., scarce Ammonites and *Aptychi*.

breccia-limestones, sometimes with characteristic Orbitoids or Rudists, and a much smaller amount of volcanics.

Between the Maastrichtian and the Upper Eocene a second orogenesis took place, followed by the sedimentation of the Upper Eocene and Oligocene beds. In the southwestern part we find marls and limestones, occasionally conglomeratical or with tuffaceous elements, that are transgressive with a basal conglomerate over the older formations. The fauna comprises locally abundant Larger *Foraminifera*, *Radiolaria* and several corals. In the northern facies marls and fine-grained oölithical limestones are found, the fauna mainly comprising Smaller and Arenaceous *Foraminifera*, locally with *Radiolaria*.

Following the sedimentation of the concordant Upper Eocene and Oligocene beds, came a third orogenetic phase. In the southwestern part it resulted in the formation of gentle, undulating, structures, in the northern and eastern part the Upper Eocene beds were heavily folded, and synclines with monoclinal build were formed.

The horizontal Guines Limestone of Oligo-Miocene age marks the end of the orogenetic activity in the district.

It must be noted that the difference in facies found in the Lower Cretaceous Tuff Series and Aptychi Limestones, roughly characterised by a decrease of volcanic matter towards the North and East, is also found with the younger formations.

Parallel to this difference in facies is a difference in tectonic style. In the southwestern part we find simple, large structures, that are replaced towards the North and East by an imbricate structure, formed by narrow wedges bounded by overthrusts. These are found mainly at the contacts of the Serpentines with the Tuff Series or Aptychi Limestones.

Chapter II : **STRATIGRAPHY.**

Tuff Series.

General: From the map we may see, that this formation is found, for its larger part, to the South of the Serpentine-belts. In an uninterrupted zone, it runs along the southern boundary of the district, from San Juan eastward. We find it here in its typical facies, being built up by volcanics and cherts. More to the North, we find it again, closely associated with the limestones from the Aptychi Formation. South from Camajuani for instance, we find the rocks from the Tuff Series with occasional intercalated beds of limestone, not to be distinguished from those of the Aptychi Formation, and South of San Andres we find Aptychi Limestones closely alternating with layers of tuffs and porphyrites, in the neighbourhood of M. 479. Moreover at L. 535, between Bernia and Santa Clara, and at M. 604, West of Placetas, well bedded Ammonite-bearing limestones are intercalated between rocks from the Tuff Series.

The Tuff Series consists largely of green or greenish rocks and thereby is easily distinguished in the field. We find spilites, diabases and porphyrites, with tuffs — occasionally brecciaceous — and cherts. Spilites and diabases are mostly without any trace of bedding, the porphyrites may occur in rather thin sills or lava-sheets ; the tuffs and cherts are well bedded.

Age: Although the only fossils commonly found in this formation are the *Radiolaria* from the cherts, we may safely assume a Lower Cretaceous age for its lower parts, from the interbedding at various localities of Tuff Series and Aptychi Limestones. But, in contrast with the Aptychi Limestones, where the fossils found all indicate a Lower Cretaceous age, the Tuff Series ranges higher up in the geologic column. This is proved by the Ammonites found at M. 604 and L. 535, which, according to Prof. JAWORSKI can not be parallelized with those from the Aptychi Limestones, but are of lowest Upper Cretaceous (Turonian-Emscherian) age; and also by abundant rests of Caprinids, found just South of the district on the road from Santa Clara to Manicaragua, in limestones intercalated in the Tuff Series. The Ammonites will be described separately by JAWORSKI, together with other Ammonites, collected on the island by us, and the Caprinids will be described by Mr. A. THIADENS, in his description of the southern part of Santa Clara Province.

Spilites: The spilites are mostly very weathered and difficult to sample. Less weathered specimens are green to dark green, fine grained rocks. Microscopically they consist of acid felspars and augite, with their decomposition products ; together with magnetite in fine grains or small crystals. The felspars form short laths, not exceeding 0,3 mm. They are strongly clouded by very small inclusions ; too small to determine their nature, and vary in composition from albite-oligoclase to oligoclase-andesine. Most laths are twinned, without, however, forming lamellar twins.

They are grouped irregularly, lying in all directions. In the places between the felspar-laths lie small and large grains of augite with an occasional larger crystal, thus making the texture of the rocks truly ophitic. Mostly the amount of felspar is much larger than that of augite but in some cases they are almost equal. The felspars decompose into zeolites (mainly prehnite) and zoisite or chlorite, whilst also sericitisation occurs. The augites are transformed to green, fibrous amphiboles, thereby forming uralite-spilites. The amphibole is altered into chlorite, which mineral also originates directly from the augites, and sometimes the aggregates of chlorite are altered into secondary quartz. Between Guaracabulla and Placetas we found spilites that differed in texture from the common type, and were formed by small felspar-laths placed in beautiful spherolites with many very small grains of augite, irregularly strewn between the felspar-spherolithes. Several rocks show transitions toward the porphyrites. The texture becomes coarser, with phenocrysts of plagioclase. The felspar, however, is cloudy, with an albite-oligoclase composition, contrasting with the more calcic felspars from the diabases and porphyrites (see pl. I, fig. 1).

Diabases and Porphyrites: The diabases and porphyrites mainly are harder, less weathered, rocks. When in the neighbourhood of bedded tuffs or cherts, they are seen to occur in concordant beds. Pillow-structure is met with sometimes, but not predominant. The rocks are mostly green, fine-grained, crystalline, with small white spots from the felspar-phenocrysts. Sometimes their colour varies to brown or grey. Microscopically, they consist of felspar and augite, with magnetite in small crystals always present in a small quantity, and sometimes apatite. The porphyrites grade into coarse diabases and normal diabases, by a gradual diminishing in size of the phenocrysts, whilst the intersertal texture of the groundmass becomes coarser. Diabases and most porphyrites are holocrystalline, but porphyrites with vitreous groundmass also occur. Phenocrysts are formed by clear, twinned felspars; of a composition that varies from labradorite to bytownite; and colourless augites. Both components are also found in the crystalline groundmasses. Occasionally we find crystals of a light-brown to greenish-brown pleochroitic amphibole.

The felspars decompose into zeolites, chlorite or zoisite, and the augites are often altered to green fibrous amphiboles, thereby forming uralite-diabases and uralite-porphyrites ; or to green, irregular, aggregates of chlorites.

Spilite Problem: The relation of the diabases and porphyrites with a true gabbroid composition to the more acid spilitic rocks is not clear. As the spilites are always more weathered than the porphyrites, with a larger amount of secondary minerals, we might consider them as normal decalcified diabases. In favour of this view is the fact, that we find some cases, where the clear calcic felspars of the porphyrites show more cloudy patches that also have a more acid composition, thus indicating a decomposition from the clear calcic felspars of the porphyrites toward the cloudy acid felspars of the spilites. On the other hand the felspar-laths of the spilites are almost invariably twinned, which seems unreasonable in a secondary mineral, and we also may ask why the spilites should have their plagioclase decomposed, whilst the porphyrites and diabases with which they alternate have unaltered felspars.

The literature on the problem is rather large, and views as to the origin and even as to the definition and limits of the term 'spilite' differ widely [1]). I cannot say anything definite as to the causes which led to the formation of the Cuban spilitic rocks. I have used the term to denominate rocks with a diabase-like habit, differing from the true diabases by their acid felspars. If used in this sense, the term comprises rocks, that for the greater part have the same geological habit and environment, and are widely met with in the Cretaceous of the Antillean region.

Tuffs and Cherts: The tuffs range from coarse, somewhat brecciaceous, elements; with fragments of porphyrites and phenocrysts; over finer grained crystal-tuffs to glass-tuffs. These often carry *Radiolaria*, that sometimes become abundant, or get silicified, thus grading towards *Radiolaria*-bearing and *Radiolaria*-free cherts.

The bedding, that is bad in the coarser porphyrite-tuffs, improves as the sediments become finer grained, and is good with the finely-bedded cherts. The coarser tuffs are built up almost entirely by fragments of crystals and rock, carrying very little cement which gives them a brecciaceous appearance. Glass as cement increases with the decrease of the dimensions of the constituents, whilst it predominates in the glass-tuffs proper, that carry only a small amount of crystal-fragments, of diminutive dimensions.

The coarse crystal- and porphyrite-tuffs are generally heavily weathered, greenish in colour, weathering to brownish-green. Sometimes we find fresher rocks, with lighter (grey or brown) colours. Microscopically, they are seen to vary over a wide range and to carry constituents, we can parallelize with both the spilites, and the diabases and porphyrites. Principal among the fragments of phenocrysts are felspars. Some rocks carry cloudy specimens, which have an acid composition of albite-oligoclase; whilst in other rocks clear calcic plagioclases are found; showing beautiful lamellar twinning or zonal structure, and with a composition that varies from labradorite to bytownite. As a rule we find the acid cloudy felspars with the weathered soft rocks, and the basic types with fresher and harder rocks, but exceptions of this rule occur. We find other crystal-fragments of colourless augite, of magnetite and sometimes of a light-brown to greenish-brown pleochroitic amphibole. The fragments of porphyrites found in the coarsest

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[1]) A discussion of the literature of this subject can be found in 'Keratophyres of eastern Oregon and the spilite problem'. By GILLULY, J., in the American Journal of Science, Fifth Series, XXIX, 171, 1935.

tuffs, the porphyrite-tuffs, are lumps of groundmass from true porphyrites, with small laths of clear, basic, felspars, with much glass in some cases, or with grains of augite, placed intersertally, in other cases.

As in the extrusive rocks, the clastic tuffs often have their components strongly altered. The felspars then undergo chloritization, zoisitization and sericitization, whilst the pyroxenes are altered into uralite or chlorite. Moreover in several cases calcitisation is apparent.

The glass-tuffs are dark-green rocks, weathering to a brownish-green colour. Their structure is dense, dyscrystalline, and in the field they are friable, soft, mostly rather strongly weathered. Microscopically they consist of dusty glass, mostly clouded by minute, or slightly larger, inclusions of chlorite and limonite. Its refractive index is always lower than 1,54. Small angular fragments of felspars, of varying composition, are included in varying amounts and sometimes, if the amount of felspar-fragments is high, we find occasional fragments of augite. They often contain remains of *Radiolaria;* even globular forms with diameters varying from 75 μ to 200 μ.

They grade into the well bedded, dense, hard, green or bluish black cherts, that often carry *Radiolaria* and sometimes are almost built up by these fossils.

Aptychi Limestones.

General: This formation is mainly found in the northern and eastern part of the district, where it usually forms the ridges of low hills that cross the country with a general Southeast—Northwest strike. It is called Aptychi Formation or Aptychi Limestones, as it is for the larger part built up by greyish limestones and marly limestones, that in several localities contain ammonite Opercula, and sometimes remains of Ammonites.

The collections of Opercula made by us in this and other parts of the island were sent to Prof. F. Trauth, of Vienna, who was so kind as to determine them specifically for us (Bibl. 13). The collections of remains of Ammonites were sent to Prof. E. Jaworski at Bonn, the results of his determinations will be published in due course.

Age: According to Trauth, the ammonite Opercula found all indicate a Lower Cretaceous age for the Aptychi Limestones, which view is also held by Jaworski, after a preliminary examination of the ammonite remains (Jaworski, in litt.).

Petrography: The Aptychi Formation is built up largely by limestones and, to a much smaller extent, by cherts, whereas locally marls and sandstones, or intercalated layers of tuffs occur. The limestones are monotonous, dull, grey or greyish-blue, sometimes reddish, dense, and well- to finely-bedded. Intercalated are layers and lenses of dark dense cherts. In some localities occur grey-brown, fine-grained, sandstones, built up by fragments of crystals of clear quartz, basic plagioclase felspars and muscovite in small tabular crystals, with rarely some fragments of micropegmatitic quartz-felspar-intergrowths. The components of these sandstones resemble those of the Diorite-intrusions. We might surmise that they were formed by detrition of these Diorites, but abundant evidence proves the Diorites to be younger than the Tuff Series and the Serpentines. So the components of these sandstones are derived from older sources, perhaps from the equivalents of the Pinar schists, from Pinar del Rio, or the schists from the Sierra de Trinidad, in southern Santa Clara, which carry a considerable amount of quartz.

Fauna: The only macro-fossils found are Ammonites and their *Opercula*. The Aptychi are scarce and the Ammonites are rare, the state of preservation of the Ammonites is bad. The fossils are usually found at places, where the limestones are very finely-bedded, and not in the coarser banks. Besides these we locally find abundant micro-fossils. In some rocks Smaller *Foraminifera*, mostly related to the genus *Globigerina* are found in abundance, but usually the *Radiolaria* are the commonest, and also found in more localities. We found radiolarian cherts and limestones. In the last-mentioned rocks the silica of the radiolarian-tests has been completely replaced by calcite. Remains of plants occur sometimes, but are nowhere predominant.

Facies: The facies of the formation, characterised by the fine-grained or dense, well-bedded, monotonous layers, and the occurrence of Ammonites and ammonite *Opercula* as the only macro-fossils suggest a deep-sea sedimentation.

Palmer (8) reaches the same conclusion, but states that the sedimentation must have taken place well within the continental shelf because of the occurrence of plant remains in the formation. These might be transported over larger distances by former sea currents, but the sandstones found intercalated at different localities in the Aptychi Limestones also indicate a sedimentation close to adjacent landmasses. The *Radiolaria* and *Globigerina* found do not give a definite indication, so the evidence available points to a sedimentation of the rocks in a deeper sea, well within reach of former landmasses.

The monotony of the stratigraphy, coupled with the scarcity of macro-fossils makes it impossible to distinguish index horizonts. The beds of this formation are usually strongly and irregularly folded and faulted and the absence of index horizonts made it impossible to find anything definite as to the internal structure of the lime-stone ridges.

Differences with the Tuff Series: As has been stated before, the Aptychi Limestones are a facies-equivalent of part of the Tuff Series. The Tuffs are mainly built up by volcanics and cherts, and the Aptychi Formation by limestones and cherts. The difference is, however, a gradual one, as we find intercalated layers of tuffs in the Aptychi Formation and also limestone beds in the Tuff Series. Moreover, we often find a small amount of volcanic matter within the limestones of the Aptychi Formation, consisting of small angular fragments of plagioclase felspars, so that we find evidences of volcanic activity in the northern facies also. The Caprinids found intercalated in the Tuff Series, South of Santa Clara, indicate a littoral sedimentation of the Tuff Series. The facies of the Aptychi Limestones thus differs from that of the Tuff Series by a very considerable — in many layers even a total — reduction of the volcanic matter, together with the sedimentation taking place in deeper water. This feature explains the monotony of the beds of the Aptychi Formation, contrasting with the irregular and varied sediments of the Tuff Series.

Serpentines.

General: Serpentines and associated rocks form one of the common features of the district and are mainly found in its central part. Although sometimes occurring in large, unbroken territories e. g. in the Sierra Alta de Agabama southeast of Santa Clara ; and in the country between Santa Clara and Encrucijada, we find them also in narrow strips, outcropping between other elements and following their general structural trend. The Serpentines are dark-greenish rocks, with many veins of lighter-green rocks, with veins of carbonates, with abundant foreign inclusions, comprising more or less altered igneous rocks and strongly metamorphic schists, and with dikes of younger intrusives. The country where Serpentines are exposed, is readily recognised by its vegetation, which varies from almost nil to so-called sabanas, badlands, with typical palms and a thorny undergrowth. The rocks usually are well exposed and not weathered.

Owing to the low elevation of most of the country under discussion, no natural sections, offering views of the contacts of Serpentines with the other formations, were found. In several places, however, we see how the boundaries between the Serpentines and the other formations, cut across the bedding in these formations, indicating a tectonical contact. This is the case to the North and South of the Sierra Alta de Agabama, at L. 619, and East of Provincial. In other places, traces of asfalt or oil at the contact between the Serpentines and other formations, also indicate a tectonical contact. For instance near Santa Clarita and at the asfalt mine Anna Maria, Southwest of Placetas. Finally we find direct evidence of a tectonic contact between Aptychi Limestones and Serpentines at H. 423 and H. 535, East of Santa Clara, where a limestone-serpentine-breccia is formed at the contact between the two formations (See p. 13, fig. 1; pl. I, fig. 2); and in the Serpentine-zone South from Camajuani, which is here so heavily sheared, as to simulate a stratified structure parallel to the contacts between the Serpentines and the other formations. With these evidences of a tectonic contact between Serpentines and older formations at many places, I assume that everywhere, where we find in this district a sharp boundary-line between these formations, without any indication of contact-metamorphism, the contact is a tectonical one, formed by overthrusting. The only locality where this seems not to be the case is North from Santa Clarita. Here, from North to South, we find Serpentines, with inclusions of diabases from the Tuff Series at M. 371 ; which inclusions increase in number and volume

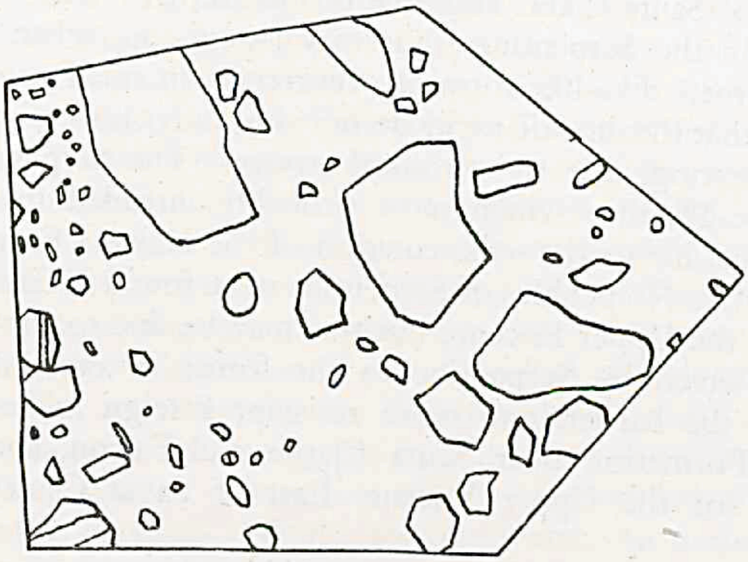


Fig. 1. Polished surface of red limestone with many angular fragments of serpentine of varying dimensions, from the Aptychi Limestone-Serpentine breccia at H. 535. $\times$ 1/1.

until we reach M. 374 ; where no Serpentines are found any longer and only porphyrites and diabases from the Tuff Series are exposed.

Age: In the geologic column, the Serpentine rocks are placed above the Tuff Series and their equivalent the Aptychi Limestones, and under the Diorites and Habana Formation. Evidence of this age runs as follows. As seen above, near Santa Clarita, the Serpentines are in contact with the rocks from the Tuff Series and carry inclusions from this series. These inclusions are slightly metamorphosed, we find here uralite-diabases, contrasting with the diabases with unaltered pyroxenes, found at M. 374, within the Tuff Series proper. Although this is the only place, where we find metamorphosed rocks from the Tuff Series close to the contact between Serpentines and Tuff Series, more or less metamorphosed rocks from the Tuff Series are found within the Serpentines at many other localities. In these cases the geographical relationship to the Tuff Series is not so clear, but the petrographical relationship is apparent. These rocks comprise more or less uralitized spilites and diabases that can not be distinguished petrographically from the uralitized rocks, found within the Tuff Series itself, whereas spilites and diabases, showing stronger uralitization, are also found as inclusions within the Serpentines, together with true uralite-rocks, where uralite and some chlorite have replaced all other mineral consituents.

The Serpentines are older than the Diorites, as we find, along the Carretera Central between Placetas and Falcon, several dikes of dioritic rocks in the Serpentines, here clearly exposed in cuts made for the new highway, the Carretera Central.

In numerous other places in the country we find Dioritic rocks within the Serpentines. The largest patches are those along the Carretera Central between La Esperanza and Santa Clara and in the hills direct Southwest of the town of Santa Clara. Here we do not actually see that these rocks are intrusive in the Serpentines, but may assume so, when we take into consideration their dike-like form of occurrence, in small patches, together with the fact, that the dioritic rocks do not show any signs of metamorphism other than shearing, due to tectonical stresses. The Serpentines thus are older than the Diorites which most probably intruded in Upper Cretaceous times, just before the sedimentation of the Habana Formation during the Maastrichtian. No pebbles of Serpentine were found in either the Habana Formation or the Upper Eocene, but this may be due to the small amount of resistance given by Serpentine to the forces of erosion, as we find pebbles from the harder, and more resistant foreign inclusions, both in the Habana Formation near Santa Clarita and Falcon, and in the basal conglomerate of the Upper Eocene, East of Santa Clara and West of Conyedo.

Serpentines s.s.: The serpentine-rocks proper are practically all of 'Schillerfels'-habit, dark-green, with greasy glance, showing large patches of bastite. Under the microscope they appear to consist of antigorite, which has its short fibres arranged in small quadrangular, or rectangular, patches. These patches may be rather regularly arranged. Between the antigorite we find large even fields of bastite. Magnetite is always present, often in a considerable amount, in very small grains arranged along the contours of the antigorite-quadrangles, accentuating their structure by thin black lines formed by many small grains of this mineral. The serpentines have clearly originated from harzburgites, the olivines being decomposed to antigorite with a residue of magnetite accumulating along the cracks of the olivine-crystals, whilst the rhombic pyroxenes are altered into the patches of bastite. We did not succeed in determining exactly when the serpentinisation took place.

Other rocks: With the Serpentines, we always find foreign rocks: older inclusions and younger dikes. The inclusions from the Tuff Series and the dikes of Dioritic rocks have been mentioned already, and the difficulty of determining, if a rock is really intrusive, has been stated with the discussion of the Dioritic dikes. One only finds sections through the Serpentines along some of the railroads and along the Carretera Central. Otherwise, the country is not very accentuated and slopes are smooth. Although no weathering residue of any importance covers the rocks in a Serpentine area, and we find the bare rock exposed almost everywhere, we never see deeper than the surface rock. In most cases the safest way to determine if a given rock is an inclusion or a dike, is by way of microscopical examination. As a rule the inclusions have either undergone considerable metamorphism, or can be compared with known rocks from other formations of this region, whilst the dikes are not metamorphosed; and have only, in various cases, been sheared to a certain extent through tectonic stresses.

We find dikes of two kinds. Firstly those, belonging to a dioritic magma, that are also found as dikes in the Tuff Series, and will be reviewed separately, and secondly dikes from a basic gabbroid magma that are only found within the Serpentines. These last vary from gabbro, through olivine-gabbro, to peridotitic rocks, as harzburgite, lherzolite and diallage-peridotite.

Gabbroid dikes: The gabbros are white and green medium-grained crystalline rocks, that contain clear lamellar-twinned felspars, of a composition varying from labradorite-bytownite to bytownite, and large and small crystals of beautifully cleaved diallage. Locally either of the two constituents show their own crystallographic forms, but mostly both have a granular appearance, whilst the dimensions of the individual crystals of both constituents vary widely. Occasionally we find poicilitic brown amphibole in large crystals without any crystallographic limits, and in the olivine-gabbros large and small crystals of olivine are added. Magnetite is always present in a large number of small crystals, apatite is rare. Most rocks are fresh, with unaltered constituents, but sometimes alteration is commencing. This is indicated by a serpentinisation of the olivines, a uralitisation of the diallage and a zeolitisation or sericitisation of the plagioclases. Quartz and chlorites may also be formed.

The more basic dikes, occurring in a much smaller number, are green and black, fine to medium-grained rocks, mainly differing from the serpentines by the lack of the greasy glance. They are peridotites, with several kinds of pyroxene-minerals, thus harzburgites, lherzolites and diallage-peridotites are found. On microscopical examination, all show a beginning of serpentinisation of the olivines, along the irregular cracks through these crystals.

The age of these dikes must be younger than that of the serpentinisation of the larger areas of peridotites, as the olivine-crystals from the dikes show only the beginning of serpentinisation. On the other hand, the fact that we only find these dikes, within the present geographic distribution of the Serpentines, indicates that their intrusion occurred before, or with, the beginning of the stronger tectonic disturbances. We saw before how the boundaries between the Serpentines and the older formations, are largely of a tectonical nature and formed by overthrusts. These thrusts alter the geographic place of the formation-boundaries, and if the intrusion of the gabbroid-peridotitic dikes had followed the overthrusting, we should expect them to intrude sometimes on the wrong side of the boundary also. Another argument for the pre-orogenic age of these dikes is the fact, that we found within the Serpentines several amphibolites, differing from the more common amphibolite-inclusions carrying albite and epidote-zoïsite. The first mentioned amphibolites are formed by basic plagioclases, with diallage and occasional brown amphibole in allotriomorphic granular structure, showing, however, strong linear foliation with occasional sutured texture of the constituents. These amphibolites clearly have originated from the gabbroid dikes through shearing under orogenetic forces.

Foreign inclusions: The foreign inclusions can be divided into two groups, those that have undergone slight metamorphism, the products formed reaching not deeper than the epi-zone, and those that are more strongly metamorphosed, with products belonging to the meso-zone.

In the field, the rocks from the second group are the most apparent and consist for a large part of schists, that occur locally in large masses, extremely plicated and foliated, and without any connection with the surrounding Serpentines. The other components of the second group, chiefly the non-schistose amphibolites and pyroxene-rocks, although of common occurrence, are not so often met with, nor do they give the Serpentine-country such a striking appearance as do the schists. The dimensions of these inclusions vary widely, from little fragments of several cm. to large packets of several tenths of meters, whilst in the Sierra Alta de Agabama, Southeast of Santa Clara, small hill-tops may be entirely formed by the more resistant foreign inclusions.

The division made in epi-zonatic rocks and meso-zonatic rocks also holds true in relation to the origin of the inclusions. In the first group we find the more or less uralitized volcanics, parallelized with rocks from the Tuff Series, whereas the rocks from the second group have no obvious connection with other rocks from the district, and must have originated from a deeper underground, at present unknown in the district.

Slightly metamorphosed group: In this group are reckoned uralitized spilites, diabases and porphyrites, with occasional uralite-tuffs, ranging into uralite-rocks, where green fibrous amphibole with chlorites have almost completely replaced the primary mineral constituents. The spilites are greenish, either fine-grained or dense rocks, which on microscopical examination appear to consist of acid plagioclase felspars and secondary minerals, of which uralite is always present.

The felspars, in short laths that lie irregularly in all directions, are very cloudy and have an acid composition, of albite or albite-oligoclase. The green, fibrous uralite is here no longer confined to the spaces between the felspar-crystals, but its broom-like bundles often grow across the older crystal-limits. Other secondary minerals commonly found are prehnite or zoisite and epidote, formed out of the felspars, chlorites and quartz. The uralite-diabases and uralite-porphyrites, distinguished by texture only, often have much clearer and more basic plagioclases. These are however subject to decalcification also, as we find crystals with a clear basic core and a cloudy, acid outer layer. Here also we find the pyroxenes completely altered into green fibrous uralite, whilst prehnite and sometimes secondary quartz are common minerals also, and chlorite, epidote, and zoisite have been found. On three occasions we found green, uralitized, chloritized and silicified inclusions which under the microscope show a clastic structure and are considered as altered tuffs. The rocks from the first group, with low metamorphism can thus be parallelized with rocks from the Tuff Series. In fact the more uralitized members we find with the Tuff Series can not be distinguished petrographically from the uralite-spilites and diabases found as inclusions in the Serpentines. We may attribute this uralitisation to a regional metamorphism, which attacked both Serpentines and Tuff Series. In some cases this was accentuated by low contact-metamorphism and this led to the forming of heavier uralitized rocks. This contact-metamorphism has always been very gentle, otherwise we should find inclusions from the Tuff Series with a stronger metamorphism, and the outer layers of the inclusions would show a metamorphic aureole. This feature was nowhere observed.

Meso-zonatic metamorphosed group: The inclusions which show stronger metamorphism — which metamorphism is found throughout each inclusion, without any indication of a metamorphic aureole even in the largest inclusions found — must have been metamorphosed already to a meso-zonatic grade before they were included by the peridotites. For the metamorphism brought about by the peridotites is low, and cannot reach a meso-zonatic grade as is demonstrated by the Tuff Series inclusions. If we therefore want to compare them with autochthone rocks from the neighbourhood, only formations, with regional, meso-zonatic metamorphism are to be considered. We find such rocks in the schists from the Isla de Pinos, described in detail by L. RUTTEN, (10) and in the Sierra de Trinidad in the southern part of the Province of Santa Clara. It is probable that the rocks from the second group have originated from a formation in the deeper underground of the province, which is the equivalent of the schist-formations mentioned.

In this group the most common rocks are various schists and amphibolites, mostly carrying albite, epidote or zoisite, whilst also eclogites and pyroxene-rocks are found.

The schists fall into two groups, the coarse linear foliated actinolite-schists, and the fine-grained, banded closely foliated glaucophane- and muscovite-schists.

The actinolite-schists are green, coarse-grained rocks wholly built up by large, fibrous crystals of green actinolite. The parallel arrangement of the crystals, which occasionally attain a length of several cm., brings about the linear structure of the rocks. Sometimes a varying amount of green chlorites is found to replace the amphibole, ranging to almost pure massive chlorite-schists.

Glaucophane- and muscovite-schists are not quite so common. They are fine-grained and closely foliated and occur in irregular packets, which always show evidence of strong tectonic disturbance in the close and irregular folding of the different layers. The glaucophane-schists carry quartz or quartz-clear albite in small irregular, sutured grains, and small needles of glaucophane, with rigorous linear arrangement. The rocks are built up by closely alternating darker and lighter zones, according to the abundance of the amphibole-needles, which are completely lacking in some and predominant in other parts of the rocks. The muscovite-schists carry medium-grained to fine-grained muscovite-leaves, together with chlorites and epidote, or titanite as accessories.

The amphibolites, when fresh, are medium- to fine-grained white and green rocks. Under the microscope they sometimes show linear, or parallel, structure but this is never very distinct, so that it usually is not seen macroscopically. Many of the rocks do not show any parallel arrangement of their constituents whatever. They are built up by amphibole, with albite, zoisite, epidote and muscovite in varying amounts. The amphiboles are light- to dark-green, pleochroitic needles and prisms, with good cleavage and without a trace of the fibrous texture of the amphiboles in the uralitized rocks. In some rocks we find a small amount of glaucophane together with the green amphibole. The epidote and zoisite occur in small grains or larger crystals, which then mostly take the form of short prisms. The albite is formed in those places, where the texture of the rocks becomes coarser and forms very large, allotriomorphic, untwinned absolutely clear poicilitic crystals. The muscovite, which never plays an important part, is found in small plates. The amounts of the different constituents vary widely. We find rocks almost wholly built up by amphiboles and only accessory zoisite or epidote ; rocks with amphibole and a considerable quantity of one of these two, or of both of these minerals ; together with rocks where the albite plays a very important part. These last may locally vary into rocks, that are almost exclusively built up by clear, untwinned, albite with here and there some needles of green amphibole.

We found several rocks carrying garnet, some massive and some with schistous structure. Their mineral constituents place them with the eclogites. Apart from the idiomorphic crystals of garnet decomposing into chlorite and quartz, small always allotriomorphic crystals of a green pyroxene, larger more or less idiomorphic prisms of green or blue amphibole, and muscovite in small tables or leafs are found. Titanite and ore form accessories, but in one rock the titanite was found in large quantities, occurring in large idiomorphic crystals, attaining 4 $\times$ 1,5 mm.

Diorites.

General; Age: Rocks of dioritic parentage are found outcropping in the Tuff Series and in the Serpentines. In cuts along the Carretera Central between Placetas and Falcon we can easily observe the true intrusive nature of these rocks, which occur in small dikes. Elsewhere the exposures are not good enough to yield direct results as to the age of the dioritic rocks and the surrounding Tuffs or Serpentines. We may, however, consider the silicification of diabases and spilites from the Tuff Series, which nearly always accompanies the dioritic rocks when found within the Tuff Series, as a contact metamorphism, due to the intrusion of the Dioritic rocks.

These thus are younger than the Tuffs and the Serpentines, and, on the other hand, older than the transgressive Habana Formation of Maastrichtian age, which contains pebbles of dioritic rocks. The dioritic intrusions took place between the intrusion of the peridotites and the sedimentation of the Habana Formation, and are of Upper Cretaceous age.

We find diorites, quartz diorites, diorite-porphyrites and porphyrites, also plagiaplites, albitites and malchites. The diorites are found within the larger intrusions, along the Carretera Central between La Esperanza and Santa Clara, Southwest of Santa Clara (A. 391—399), between Guaracabulla and Falcon and Guaracabulla and Placetas, to the South of the Serpentine-ridge, at M. 407 and V. 212, and in the neighbourhood of San Andres. The diorite-porphyrites and the leucocratic and melanocratic rocks from the many small dikes, are found throughout the area covered by the Tuff Series and the Serpentines, whereas they also occur within the larger intrusions mentioned.

Most rocks have a cataclastic structure, which varies in intensity and is sometimes predominating. We find broken phenocrysts of felspar and quartz with bent or twisted columns and leaves of amphibole and biotite, or even whole shearing-zones, where all larger crystals have been ground to small pieces. Just as the Serpentines, the dioritic rocks must have undergone considerable tectonic stresses.

Diorites s. s. The diorites and quartz-diorites are medium- to coarse-grained, white-green rocks that are chiefly built up by plagioclases, with quartz and amphibole and sometimes biotite or pyroxene. The amphibole is idiomorphic, in prisms, light-green to greenish-brown pleochroitic. It sometimes decomposes locally into green fibrous uralite. The plagioclase, in more or less idiomorphic crystals, often with lamellar twinning or zonal structure, when fresh, has the composition of labradorite, and is clear. Sometimes we find cloudy crystals, with a composition ranging from albite-oligoclase to oligoclase, and in several cases within these acid cloudy crystals, a clear calcic core is found, denouncing the cloudy crystals to be decalcified clear ones. The quartz is found in large clear allotriomorphic crystals. Sometimes we find a close intergrowth of quartz and plagioclase, and the rock becomes a diorite-pegmatite. By their outstanding character, the diorite-pegmatites, when found as pebbles in the younger formations, are the easiest indicators that these formations are transgressive over the Diorites.

Brown biotite sometimes is found in small leaves, and colourless augite in short prisms. Apatite, titanite and magnetite are accessories.

Diorite-porphyrites. The diorite-porphyrites have the same mineral constituents as the diorites, and differ only by their holocrystalline porphyritic texture. Quartz may or may not occur as phenocrysts, distinguishing between quartz-diorite-porphyrites and diorite-porphyrites.

Leucocratic dike-rocks: The leucocratic dikes, formed by albitites and plagiaplites, are small-grained to dense white or light-green rocks, with a hypidiomorphic or indistinct porphyritic texture. They are formed by heavily clouded acid plagioclases, short, sometimes twinned, laths and tables, with a composition varying from albite to oligoclase-andesine, and by allotriomorphic clear quartz. Sometimes we find several green needles of amphibole, whilst apatite, titanite and sometimes a very small amount of magnetite are accessories.

Melanocratic dike-rocks: The melanocratic dikes are formed by malchites, very fine-grained white-and-green or dark-green rocks. They are formed by plagioclase and amphibole in about equal quantities, with pan-allotriomorphic granular texture, and with a small amount of quartz. The plagioclase is clear, twinned labradorite or labradorite-bytownite. The amphibole is coloured green or brown, with small pleochroism. Magnetite in small crystals is always present. Moreover, one dike of spessartite has been found.

Contact metamorphism: With the larger Diorite intrusions through the Tuff Series we often find traces of contact metamorphism. We probably should have found more direct evidence, had it not been that the Diorites and the rocks from the Tuff Series usually were rather weathered, and the contact between the two formations not exposed. The spilites and diabases from the Tuff Series near the contact are silicified to a certain extent. Between the laths of the felspars, where in fresh rocks we find the grains of augite that often are seen to uralitize or chloritize, are found irregular clear grains of secondary quartz, that are grown together with other secondary minerals, e. g. chlorite, epidote and uralite, thereby proving their secondary nature. In several of the normal spilites and diabases with a strong decomposition of the pyroxenes and a consequent large amount of secondary minerals we also find some quartz and it looks as if this process — the decomposition mainly of the chlorite to quartz — has been accelerated by the nearby intrusions of the Diorites.

This phenomenon was typically observed in rocks of the Tuff Series close to the Diorite intrusions between Guaracabulla and Falcon (M. 402—M. 407 and M. 416), between Guaracabulla and Placetas (Near V. 215) and South of General Carillo (A. 501), in the eastern part of the district.

The Habana Formation.

General: Palmer (9) was the first writer on the geology of Cuba, who gave a good account of this formation, as it outcrops in the vicinity of the town of Habana. Although the petrographic characters in the district under discussion are distinct from those found near Habana — in fact there is strong variation within the district itself —, its age and fossil content is the same. Layers of this age, but varying locally in petrographic and lithologic character, are found at many places in Cuba and it is thought best to give them all the same formational name, whilst the different, sometimes intergrading characters are described separately for each locality.

This is thought better than giving a new name to the many local variations.

Age: The age of the Habana Formation is Uppermost Cretaceous, as it can be parallelized with the Maastrichtian of Europe by the occurrence of Larger Foraminifera of the genera *Lepidorbitoides* and *Omphalocyclus*.

It is transgressive over the Diorites and Tuff Series and their equivalent, the Aptychi Limestones. Pebbles of diorite-porphyrite and quartz-diorite-pegmatite are found, together with *Vaughanina cubensis* and fragments of Rudists, at H. 482 and at L. 617, East and West of Falcon; whilst pebbles from the Tuff Series and the Aptychi Limestones are found at different localities. In the southwestern part the structural discordance is clearly indicated on the map, where we see the layers of the Habana Formation transgressive over various older formations. For instance near Falcon over Tuff Series, Aptychi Limestones and Serpentines; and along the northern limit of the Bernia-syncline over Tuff Series and Serpentines.

Just as with the Tuff Series and the Aptychi Limestones, we find a strong difference of facies in the Habana Formation, between the northern and the southern part of the district; the line of larger Serpentine-bodies roughly indicating the boundary-line. Together with this change in facies we find an intensified tectonic structure, when passing from South to North.

Southern facies: Typical for the Habana Formation in the southern part of the district is the great syncline of Bernia to the South and Southwest of the town of Santa Clara, and the exposures to the Northeast of this town along the road to Remedios in the neighbourhood of Capiro. We find here light-green glass-tuffs, crystal-tuffs, tuffaceous limestones, Rudist- and Orbitoidal-limestones. The different layers vary strongly parallel to the strike and are only found over short distances, when they taper out, to be replaced by others, in an irregular way. The whole lithology, the rapid thinning out of layers, the angular crystal-fragments in the tuffs and the tuffaceous limestones, together with the local abundance of Rudists and Orbitoids, is evidence of a littoral sedimentation. Although we find abundant evidence of volcanic activity during the sedimentation of the formation in this part of the country, we only found igneous rocks at two localities, A. 127 and H. 213, both between San Juan and Pastora, where porphyrites outcrop.

Differences with the Tuff Series: In the field the formation is easily recognised when it carries Rudists or Orbitoids, but those sections where glass-tuffs, tuffs and tuffaceous limestones are found, resemble to a certain extent the layers of the older Tuff Series. The glass-tuffs from the Habana differ, however, from those of the Tuff Series by their light-green or whitish colour, which is much lighter than the usual colour of the older glass-tuffs and tuffs. Moreover as a rule they have a much smaller specific weight and a fresher appearance. Moreover in most cases smaller and larger intercalations of limestones occur not unfrequently. These limestones contrast by their white or yellowish-brown colour with the grey or blue-grey limestones, sometimes found intercalated within the Tuff Series, and can also be distinguished by their coarser texture, which usually is granular and may be finely conglomeratic or brecciaceous.

Under the microscope we find dense light-green glass-tuffs, which only consist of clouded glass, and that are difficult to distinguish from those of the Tuff Series. But the coarser glass-tuffs and the tuffaceous limestones, that vary from limestones with volcanic material towards tuffites with calcareous cement, can be recognised by a number of features. They carry fragments of porphyrites whose texture varies from hyalopilitic to holocrystalline, fragments of phenocrysts of plagioclase, quartz, sometimes of augite, and crystals of magnetite. The plagioclases are always clear, with lammellar twinning or zonal structure and are rather basic, with a composition of labradorite. They contrast with the plagioclase-fragments of the

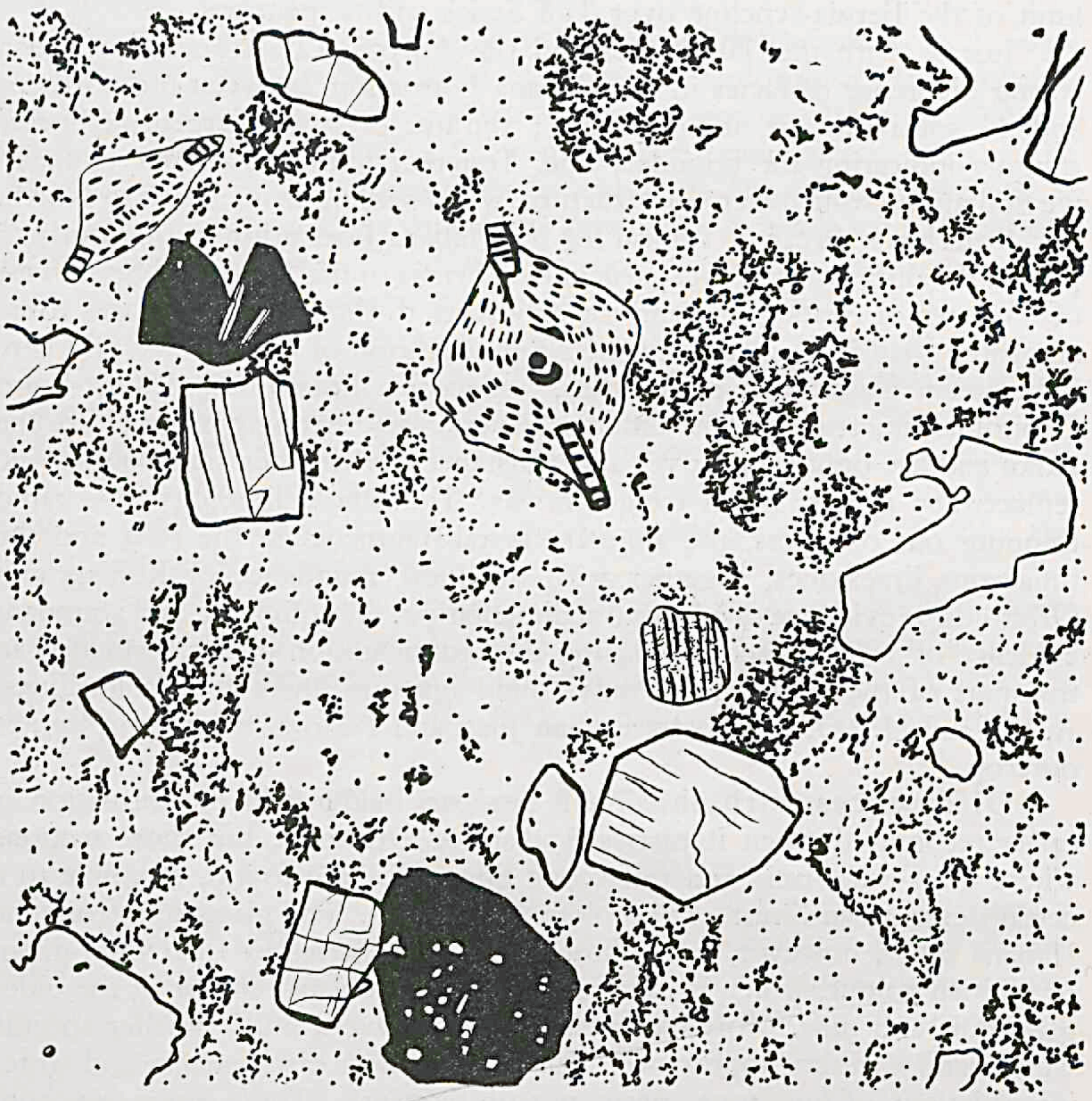


Fig. 2. Tuffaceous limestone from the Habana formation, × 26, with specimens of *Vaughanina cubensis* Palmer, fragments of dark, hyalopilitic porphyrite-groundmass, fragments of clear, cleaved plagioclase, of a dark, cleaved augite and absolutely clear, allotriomorphic quartz.

tuffs from the Tuff Series by their clearness, twinning, zonal structure and basic composition. These features are also sometimes found with older tuffs, but always with the tuffs from the Habana Formation. Moreover the almost constant occurrence of fragments of clear quartz-crystals is a distinguishing feature, as we almost always find quartz in the tuffs of the Habana Formation, and never in tuffs from the older formations. In the tuffaceous limestones, moreover, we often find fragments of Orbitoids, or of *Vaughanina cubensis*, which at once determine the age of the rocks under question, and lastly in this part of the island *Radiolaria* are rarely met with in the Habana Formation. This characteristic does not hold good, however, for the whole island, as PALMER (8) describes abundant radiolarian deposits from this formation in other parts of the island, and therefore it should only be used in combination with the other characteristics mentioned.

Intrusions of Porphyrites: The porphyrites found are dark-brown and black, dense rocks. They carry phenocrysts of plagioclase and augite. The plagioclase occurs in large tabular crystals with lammellar twinning or zonal structure, mostly clear, sometimes slightly cloudy, that vary in composition from andesine-labradorite to labradorite-bytownite. The augite is colourless, and the crystals have the form of short prisms. Magnetite, in smaller and larger crystals, is present. The fine-grained, partly vitreous groundmass contains basic plagioclases, with some pyroxene and magnetite.

Petrography: As we have seen, one of the differences between the volcanic elements of the tuffs from the Habana Formation and those of the Tuff Series, is the occurrence in the Habana, of a considerable amount of primary quartz. The parentage of the effusives thus is more dioritic than gabbroid. In agreement with this fact, the chemical composition of a glasstuff from the Habana Formation is that of a granite. (Analysis 17). The intrusive augite-porphyrites seem to have a more gabbroid parentage by their mineral constituents, but the chemical analysis of one of them also reveals a close resemblance to a granitic magma (Analysis 16). When we take into consideration the intrusions of Diorites and dioritic rocks into the older formations, it is highly probable that the volcanic activity that furnished the material for the tuffs of the Habana Formation, and for the porphyrite-intrusions in the Habana Formation, was allied to the igneous activity which led to the intrusions of the dioritic rocks. We may consider the volcanic activity, during the sedimentation of the Habana Formation, as the waning of the igneous activity that formed the earlier Diorite intrusions.

Northern Facies: The difference in facies in the Habana Formation between the northern and southern part of the district, is parallel to that found between the Tuff Series and Aptychi Limestones. We see a considerable decrease in volcanic matter, which in the northern facies of the Habana Formation is almost non-existent. There are also indications that part of the formation was sedimentated in a somewhat deeper sea. Whereas in the

South and Southwest, we found a perfect littoral lithology, in the northern facies we find only scarce layers with Rudists or Orbitoids. These, together with the coarsely brecciaceous elements indicate littoral sedimentation too. Over large distances, however, dense, non-brecciated limestones, sometimes with many Smaller *Foraminifera*, are evidence of uniform conditions of sedimentation, and it is probable that this sedimentation took place in a somewhat deeper sea.

The northern facies of the Habana Formation is characterised by white and yellow brecciaceous limestones, white and yellow dense limestones, and white or greyish finely conglomeratical limestones. Sometimes we find breccias of Rudists, or fragments of Orbitoids, by which the limestones can be determined, but mostly they are sterile or the Smaller *Foraminifera* can not be prepared out of the rocks for determination. The coarse limestone-breccias and the dense yellowish limestones can be separated, without fossils, from the older Aptychi Limestones, on their petrographic characters, but with the finely conglomeratic or brecciaceous limestones, it is difficult to say whether rocks belong to the Habana or to the Aptychi Formations ; and often only the finding of Orbitoids or *Radiolaria* can decide the question. It is therefore possible, and even probable, that in the northern ridges of Aptychi Limestones, beds of limestones of the Habana Formation are folded and faulted together with the Aptychi Limestones. As we can not say anything definite on the structure of the Aptychi Limestone-ridges, more detailed work may show them to contain smaller or larger synclines of Habana Limestones alternating with anticlines of Aptychi Limestones.

In the northern part, owing to the stronger influence of the post-cretaceous orogenesis, the structural discordance between the Habana Formation and the older beds is not so apparent from the map, as it is in the South. At several localities we found, however, pebbles of rocks from the Tuff Series or the Aptychi Limestones, as evidences of a structural discordance between these two formations and the transgressive Habana Formation. We found pebbles of Aptychi Limestones at L. 451, between Placetas and Remedios ; pebbles of porphyrites, tuffs and Aptychi Limestones at A. 369, between Placetas and Camajuani ; and lastly pebbles of radiolarian cherts and glass-tuffs at L. 501, West of San Antonio.

Upper Eocene.

General: We find the Upper Eocene over a large part of the south-western portion of the district, and again in the north- and north-eastern part. As with the older formations, the facies in the two regions is different, as is the tectonic structure, and a separate discussion is desirable.

The age of the formation is established beyond doubt, by the occurrence of Larger, and some Arenaceous *Foraminifera* of the genera *Camerina*, *Lepidocyclina*, *Helicolepidina*, *Discocyclina* and *Dictyoconus*.

Southwestern facies: In the southwestern region we find for the greater part white marls and limestones, often sterile, sometimes with Smaller *Foraminifera*, that could not be prepared out. The northern boundary of this territory is formed by a range of limestone-hills which begins to the North of La Esperanza, near Coneydo, and passes with an approximate northwestern strike South of San Diego del Valle. It is here transgressive over Serpentines and Tuff Series and locally carries abundant pebbles from these formations and from the Aptychi Limestones. Near Santa Isabel and Jicotea we also find conglomeratical limestones and marls, with many well-rounded, small pebbles of the older formations. The structures formed hereabout are gentle, the dipping of the beds is low. Although we have not found pebbles from the Habana Formation in sediments of the Upper Eocene, the stratigraphic unconformity is apparent by the lack of fossils from older divisions of the Eocene. The structural discordance between Habana and Upper Eocene is clearly seen between San Juan and La Esperanza; where the gently folded Upper Eocene transgresses across the synclinal of Bernia.

North of La Esperanza a tongue of Upper Eocene stretches eastward, transgressing over various older formations, to well East of Santa Clara town. We are here between the larger massifs of Serpentines, where, in earlier times, strong tectonic disturbances have taken place, contrasting with the more gentle structures formed in the southwestern region of the district. This difference also holds true for the post-Eocene orogenesis, as the beds from La Esperanza eastward, have been folded more heavily than those to the West of La Esperanza. East of Santa Clara near the end of the transgression of the Upper Eocene over Tuff Series and Serpentines, we observe a number of alternating synclines and anticlines, locally with very steep dips. Just as to the northwest of Conyedo, the Upper Eocene has here a basal conglomerate with smaller and larger pebbles, mainly from the Tuff Series and the Aptychi Limestones.

Here we also find several tuffaceous limestones, indicating a low volcanic activity in Upper Eocene times. This activity was low, compared to that during the Habana period, as the tuffaceous limestones are much rarer in the Eocene than in the Upper Cretaceous. Moreover the amount of volcanic matter in the limestones is smaller in the younger sediments, whereas the crystal-fragments often are somewhat rounded off; and we never find true crystal-tuffs, practically without calcareous matter, as is the case in the Habana Formation. The volcanic matter present is, however, of quite the same habit — basic clear plagioclases, quartz and occasional pyroxenes and fragments of porphyrites —, so that the tuffaceous limestones from the Upper Eocene can only be distinguished from those of the Habana Formation by their fossil content. Fragments of *Discocyclina* commonly occur within the Upper Eocene limestones, so usually this presents no serious difficulties.

Fauna: The fauna of the Upper Eocene in this region consists for a great part of Larger *Foraminifera*, with some corals. Locally we find abundant specimens of species of the genera *Camerina*, *Lepidocyclina* and *Discocyclina*. This contrasts with the fauna of the northern facies, where we find abundant Smaller *Foraminifera* of Rotalid parentage, with specimens of the genus *Dictyoconus*. Specimens of the genus *Discocyclina* are the only Larger *Foraminifera* found here, and they are rare, compared with the numbers found in the southern facies.

Northern facies: The northern facies of the Upper Eocene for the greater part comprises limestones. We find white and grey dense limestones, but also many well bedded, fine-grained conglomeratical or oölithical, white or greyish-brown limestones, that locally vary into brown calcareous sandstones. These alternate with grey or light-green marly limestones. The dense and fine-grained limestones often carry abundant Smaller *Foraminifera* and also many specimens of *Dictyoconus* and fragments of *Discocyclina*. The texture of these rocks distinguishes them in the field from the dense or brecciaceous, non- or badly bedded limestones of the Habana Formation. The marly limestones of Upper Eocene age, in contrast to the beds of the Habana Formation, locally carry abundant *Radiolaria*.

The Upper Eocene Formation in this region has been subject to a strong post-Eocene orogenesis, as can be seen from the strong folding, which has resulted in steep, sometimes vertical dips of the beds, and, West of San Antonio de las Vueltas, we even find synclines of monoclinal build.

Although — probably through these effects of the post-Eocene orogenesis — the structural discordance between Upper Eocene and Habana Formation is not apparent in the northern region of the district, we find the same stratigraphical gap between Maastrichtian and Upper Eocene as we found in the Southwest ; so we may assume that an unconformity between these two formations exists over the whole district.

Oligocene.

Beds of Oligocene age were only found at two localities in the southwestern part of the district, where they overly conformably the beds of Upper Eocene age and are folded in gentle structures, with low dips. We find white sterile marls, or marly limestones and yellowish-brown orbitoidal limestones, sometimes with small pebbles from the older formations. In petrographic character and tectonical structure these beds thus are not to be distinguished from the underlying beds of Upper Eocene age. We may separate them by their fossil content only. In the two localities mentioned typical Orbitoids of the subgenera *Nephrolepidina* and *Eulepidina* were found. The tectonic concordance of Oligocene and Upper Eocene proves that the post-Eocene orogenesis— which in the southwestern part of the district was rather weak, but grew in intensity towards the North and East —, took place during younger Oligocene times.

Guines Limestone.

Palmer (9) gives a full discussion of these limestones of Oligo-Miocene age, characterised by unfolded horizontal beds of white or brownish limestones, with a very singular, cavernous, habit, caused by the weathering out of abundant *Gastropoda* and other fossils. Their moulds and casts can be recognised everywhere, without, however, permitting a specific determination of the fossils after which they were formed. We only found it South of Quemado de Guines, whilst perhaps the horizontal limestones with jagged surface, found between Sagua la Grande and the coast at La Isabella, belong to the same formation. Palmer gives the jagged surface, which in extreme cases forms the 'Dientes de Perro', as a distinguishing feature of the limestones of this formation. We did, however, repeatedly find the same 'Dientes de Perro' structure with the massive limestones from the Habana Formation, South and West of Remedios.

Chapter III : TECTONICAL NOTES.

Orogenetic phases: Three different phases of orogenesis can be distinguished in this part of the island, namely the first one during the Upper Cretaceous, before the sedimentation of the Habana Formation in Maastrichtian time; the second during the Middle or Lower Eocene; and the third after the sedimentation of the Upper Eocene and Oligocene sediments. These have all caused a folding, and sometimes faulting, of the beds affected. Since the last orogenetic phase during the Oligocene no horizontal movements have taken place, as is evidenced by the horizontal beds of the Guines Limestone, and we find evidence only of a vertical uplifting of the Guines Limestones over large areas.

The first, pre-Maastrichtian, orogenesis was comparatively gentle, and we find no great discordances between the Habana Formation and the underlying Tuff Series or Serpentines. It is proved by the occurrence of pebbles of rocks from the Diorite intrusions, and from the Tuff Series, in layers of the Habana Formation and by the overlap of the Habana Formation over the older layers. We see this last feature very clearly Southwest of Santa Clara, where Habana overlies Serpentines near La Esperanza and Tuff Series more to the Southeast, near Bernia; and also West of Falcon. During this orogenesis the intrusion took place of the large amounts of peridotites and the somewhat younger diorites.

During the two following phases of orogenesis the structures formed by the first phase were accentuated, and the large overthrusts, together with the monoclinal build of the interjacent wedges, — producing an imbricate structure of the whole country northward from the Serpentine-massifs — were formed. We can not now distinguish between the share each one of the two last phases had in the forming of this structure, as sediments of Upper Eocene age are wanting over the larger part of the heavily folded country.

Difference between northern and southern part. The sections given, clearly indicate the difference in tectonical structure between the southern and the northern part of the district. In the syncline of Bernia we find even gently folded layers and a large, comparatively smooth structure. This is even more the case to the West of the syncline of Bernia, where the transgressive Upper Eocene sediments form gently undulating structures, with low-dipping beds. Contrasting herewith are the narrow wedges with steep dips, bounded by overthrusts, and the Upper Eocene synclines of monoclinal build, found in the northern and eastern part.

This difference in tectonic structure can not be explained by the facies-differences between the northern and southern parts only, for these facies-differences are gradual, and we find layers of southern facies intercalated within those of northern facies and vice versa. We can only explain it by a general growth of tectonic activity towards the North and East. The facies-difference between the Tuff Series and the Aptychi Limestones of Lower Cretaceous age, which difference is parallel to that found in younger layers, indicates that the difference between northern and southern part, existed already in Lower Cretaceous times, and survived throughout the three different orogenetic phases.

Thickness of formations: As will be noted I have not stated the thickness of the different formations. This is omitted for various reasons. The Tuff Series, along the southern boundary of the district, only shows the northern end of a large area as it outcrops also to the South of the district so that the thickness of this series can not, at present, be given.

The Aptychi Limestones are found only in narrow wedges with prevailing monoclinal build and bounded by overthrusts. The absence of index horizons in these limestones makes it impossible to observe a repetition of layers, which might well occur together with the imbricate structure found ; whilst on the other hand, the overthrusts at the contacts may conceal large parts of the formation. By the first feature one would be inclined to give an exaggerated idea of the thickness of the limestones, the second feature produces a contrary result. As we know nothing about the relative importance of these two features, we can only guess as to the thickness of the Aptychi Limestones. The sections given illustrate the geographical extent covered by beds of this formation, and give an idea of the rougher dimensions of its vertical extent.

The Habana Formation and younger sediments in the southwestern part are transgressive, with a variable lithology and thickness. This is illustrated by the section I, through the syncline of Bernia, where the Habana Formation is much thicker in the southern flank of the syncline than it is in its northern flank. This can be explained by a wedging out of the layers towards the Northeast. The younger formations elsewhere on the island — in the structural basins — attain a considerable thickness (Palmer, Bibl. 9), whilst they are found in this district only as a thin cover. Computed values given for their thickness in this part of the island thus are not representative for these formations.

In the northeastern part of the district the Habana and Upper Eocene Formations do not exhibit such a variable lithology, but here they are strongly folded, with overthrusts formed in several places at the contacts between Aptychi Limestones and Habana Formation, so that here also a computation of the formation's thicknesses remains very uncertain.

Chapter IV : **PETROLOGICAL NOTES.**

From a number of Cuban rocks Mr. W. van Tongeren of Utrecht kindly made chemical analyses, so that the chemical properties of the rocks from the different formations can be discussed. The analyses are given below, together with seven analyses from other Cuban rocks, given by Schürmann (Bibl. 12), that were also executed by Mr. van Tongeren.

The Niggli-values were computed, and a differentiation-diagram was drawn. Niggli (Bibl. 7) gives yet another method by which the quantities of normative minerals in molecular proportions can be easily drawn in a triangular projection. From the three angles of a triangle we put down the quotient of the normative molecular amount of free silica with the total molecular amount of silica, Qs, secondly the quotient of the normative molecular amount of silica used by the molecular normative leucocratic components and the total amount of silica, Ls, thirdly the quotient of the molecular amount of silica used by the molecular normative melanocratic components with the total molecular amount of silica, Fs. The sum of Qs, Ls and Fs is always the unit, and therefore we may use the triangular projection. Ls and Fs are computed with the supposition that molecules with the highest grade of silicification are formed. If this is really not the case, we find this expressed by a negative Qs. Together with the projections of the Cuban rocks the mean values of several types of rocks, according to Niggli, are put down.

From the differentiation-diagram we see that the Cuban rocks belong to the common alkali-calc series, giving a normal differentiation diagram.

From the triangular projection we see that the rocks from the Tuff Series, analyses 10 and 8, lie between the mean values for gabbro and for syenite, thus chemically confirming the facts we had already noted with the petrographic description of the spilites and diabases.

Number 11, Tuff-Series-diabase found as inclusion in the Serpentines illustrates the close chemical parentage of these rocks with the volcanics from the Tuff Series, a parentage we have already noted with the petrographic description of these inclusions from the Serpentines. Number 9, a spilite from the Tuff Series, silicified by the intrusion of the Diorites, truly has a much more acid character than the un-altered rocks of this Series. The chemical parentage of the rocks from the Diorite intrusions and the glass-tuffs (number 17) and porphyrites (number 16) from the Habana Formation, is equally well illustrated in the triangular projection. It will be seen that these rocks, with the exeption of number 15, a melanocratic, malchitic dike-rock, have about the chemical composition of a granite.

Yet petrographically they have a true dioritic or quartz-dioritic parentage, as they never carry orthoclase felspars but always plagioclase felspars, with phenocrysts usually even of a rather basic composition. This is a general feature of the Cuban rocks in so far as we find it also with the rocks from the Tuff Series. These last mentioned rocks with their beautiful ophitic structure, their considerable amount of pyroxene, and absence of biotite or amphiboles, should have a gabbroid composition. Instead they are more acid, and intermediate in composition between gabbros and syenites. Just so with the rocks from the Diorite-intrusions, which petrographically are to be classed with the diorites, and chemically with the granites. It is hoped that examination of equivalent rocks from other parts of the island may show, if this difference is accidental, or due to a regional Cuban or Antillean feature.

The composition of the numbers 12 and 13, foreign inclusions from the Serpentines of the meso-metamorphic group, do not give any evidence as to their origin.

The analyses No. 1—7 are those, given by SCHÜRMANN (12), Numbers 1—4 are of Dioritic rocks, numbers 5—7 are of rocks from the Serpentines.

Nr. 8 is a spilite, taken at V. 211, between Guaracabulla and Falcon.
Nr. 9 is a silicified spilite, taken at M. 416, South of Falcon.
Nr. 10 is a diabase from the Tuff Series, taken at M. 374, near Santa Clarita.
Nr. 11 is a diabase, a foreign inclusion in the Serpentines, taken at M. 371, near the former locality.
Nr. 12 is a zoisite-amphibolite, a foreign inclusion in the Serpentines, South from Encrucijada, at H. 502.
Nr. 13 is a glaucophane-eclogite, a foreign inclusion from the Serpentines, taken along the Carretera Central, 11 km. East of Santa Clara.
Nr. 14 is a diorite, from the Diorite-intrusion Southwest of Santa Clara, at A. 395.
Nr. 15 is a malchite, connected with the Diorite-intrusions, from a dike in the Serpentines, at M. 434, just South of Falcon.
Nr. 16 is an augite-porphyrite from the base of the Habana Formation, at H. 213, East of San Juan.
Nr. 17 is a glass-tuff from the Habana Formation, West of Santa Clara, at L. 359.

Nr.:	1.	2.	3.	4.	5.	6.	7.	8.	9.
				Analyst : W. VAN TONGEREN					
SiO_2	74,48	67,37	63,90	60,11	50,71	48,54	39,75	55,50	56,00
Al_2O_3	12,47	15,95	14,56	16,55	16,72	12,02	0,57	15,25	19,09
Fe_2O_3	2,30	1,09	3,01	2,81	0,99	2,57	7,40	2,45	1,15
FeO	0,42	1,61	2,56	5,46	7,01	7,91	0,95	3,79	6,14
MnO	tr.	0,02	0,05	0,02	0,06	0,18	0,08	0,07	0,18
MgO	0,22	1,26	2,57	2,41	6,91	12,35	37,79	7,73	4,63
CaO	1,41	2,65	3,34	6,09	6,62	14,14	0,03	4,70	4,25
Na_2O	2,88	5,40	4,23	4,08	4,72	0,68	0,14	5,60	4,27
K_2O	4,51	1,90	2,85	0,84	0,28	0,20	tr.	0,68	1,32
H_2O^+	0,39	1,25	1,63	0,52	4,67	0,86	12,10	2,54	1,45
H_2O^-	0,48	0,54	0,43	0,20	0,96	0,13	0,78	0,86	0,77
TiO_2	0,33	0,38	0,50	0,72	0,39	0,31	0,03	0,74	0,72
CO_2	tr.	0,04	—	0,05	tr.	—	tr.	—	0,03
P_2O_5	0,12	0,33	0,42	0,24	0,15	0,17	0,07	0,14	0,08
Cr_2O_3	—	—	—	—	tr.	—	0,32	—	—
Total	100,01	99,79	100,05	100,10	100,19	100,06	100,15[1])	100,05	100,08

NIGGLI-values:

si	**440**	**297**	**243**	**194**	**131**	**97**	**63**	**152**	**165**
al	43,3	40,3	32,5	31,6	25,4	14,1	0,7	24,6	33,3
fm	14,2	17,8	31,4	33,1	44,0	54,1	99,0	45,5	38,6
c	9,0	12,5	13,6	21,0	18,3	30,2	0,05	13,8	13,4
alk	33,5	28,4	22,5	14,3	12,3	1,6	0,25	16,1	14,7

[1]) No. 7 has NiO for 0,14 %.

Nr.:	10.	11.	12.	13.	14.	15.	16.	17.
Analyst: W. van Tongeren								
SiO_2	53,19	47,58	46,20	46,91	68,77	51,41	69,25	62,15
Al_2O_3	15,14	14,07	14,74	17,69	15,68	15,60	14,27	13,13
Fe_2O_3	3,84	1,33	3,56	2,65	0,67	2,18	1,83	3,06
FeO	8,25	10,05	6,28	9,43	1,42	6,46	1,76	0,49
MnO	0,07	0,12	0,09	0,06	—	0,08	0,02	0,03
MgO	2,62	3,84	8,18	4,02	1,97	7,66	0,50	1,35
CaO	6,80	13,12	12,42	9,61	2,54	11,28	3,01	3,44
Na_2O	4,57	3,47	4,81	5,36	6,80	2,60	3,78	1,63
K_2O	1,28	1,01	0,23	1,28	1,47	0,28	4,08	2,88
H_2O^+	1,80	3,29	0,83	1,26	0,60	1,07	0,28	8,03
H_2O^-	0,81	0,41	0,24	0,33	0,13	0,34	0,49	3,34
TiO_2	1,28	1,35	2,09	1,66	0,26	0,66	0,52	0,40
CO_2	tr.	tr.	tr.	tr.	0,02	0,13	0,17	tr.
P_2O_5	0,06	0,02	0,09	tr.	tr.	0,18	0,16	0,06
SrO	0,08	0,12	0,11	0,06	—	—	—	0,04
Total	99,79	99,78	99,87	100,32	100,15	99,93	100,12	100,03
Niggli-values:								
si	**151**	**114**	**98**	**110**	**288**	**121**	**322**	**317**
al	25,3	19,9	18,5	24,2	38,7	21,7	39,1	39,4
fm	39,1	36,6	43,0	37,4	18,4	43,5	16,8	24,2
c	20,7	33,8	28,3	24,1	11,4	28,4	15,0	19,0
alk	14,9	9,7	10,2	14,1	31,5	6,4	29,1	17,4

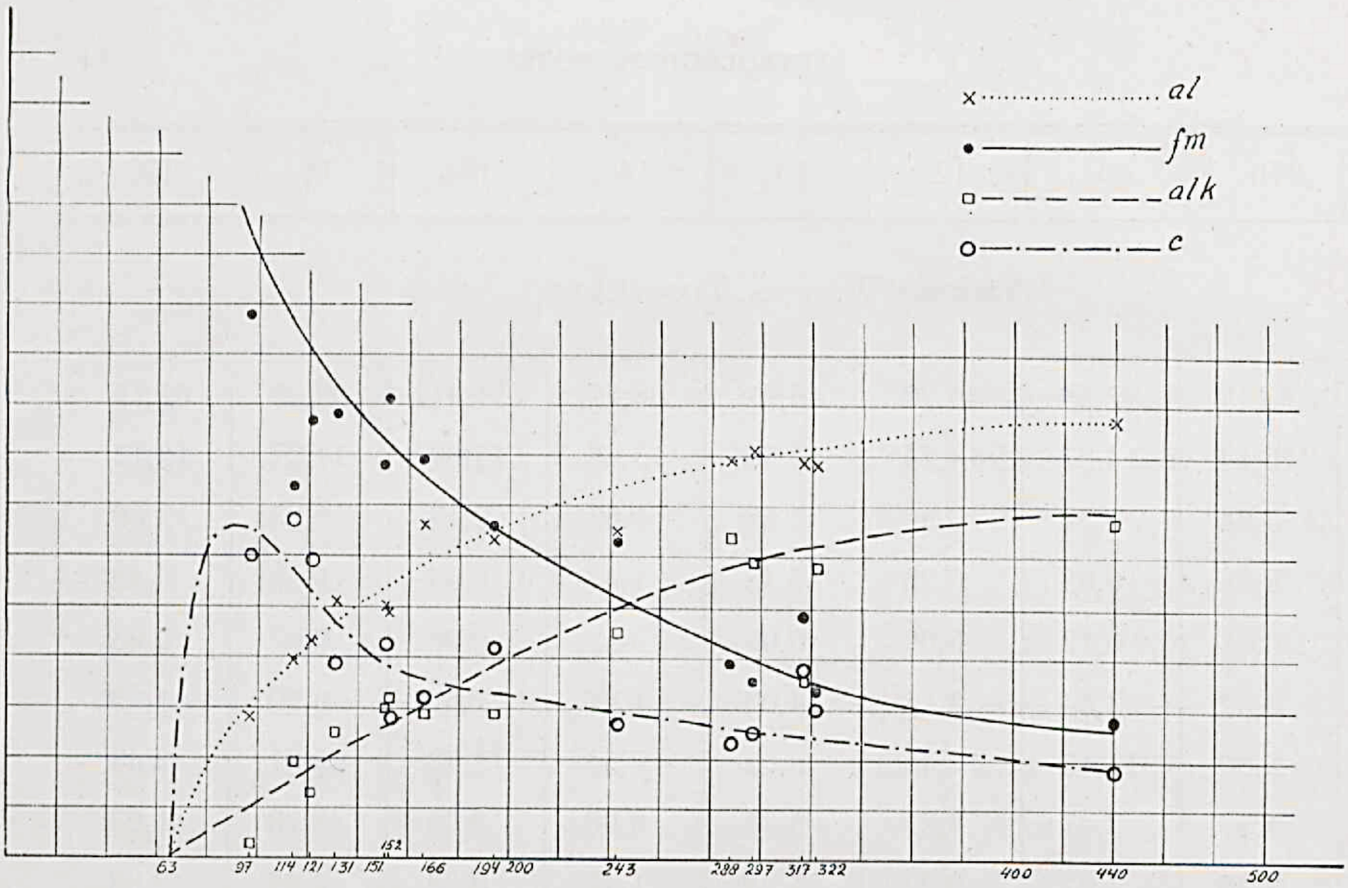


Fig. 3. Differentiation-diagram of Cuban rocks.

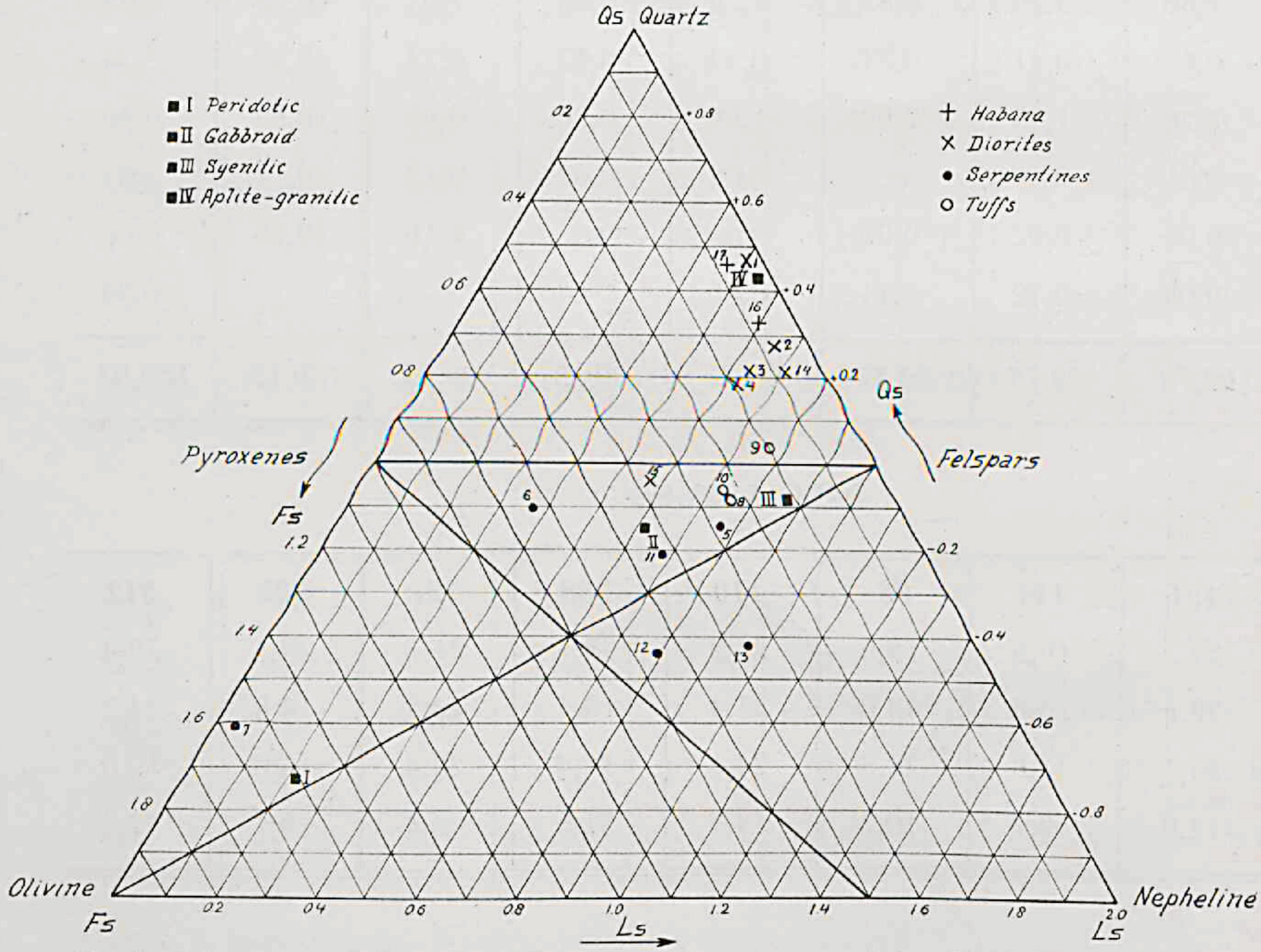


Fig. 4. Triangular projection of normative, molecular amounts of free silica (Qs), of silica needed by the leucrocratic elements (Ls) and by the melanocratic (Fs), computed from analyses of Cuban rocks, with four typical magmas, according to NIGGLI.

Chapter V : **PALEONTOLOGICAL NOTES.**

Most of the results of the work on the fossil remains, found in the northern part of the province of Santa Clara, has been, or will be, published elsewhere, to make it more accessible to purely paleontological workers. These publications will not be repeated here, and only faunal lists, with find-spots of the different fossils, will be given.

The ammonite Aptychi of the formation bearing this name have been specifically determined by Prof. F. TRAUTH, of Vienna (Bibl. 13).

The remains of Ammonites will be determined by Prof. E. JAWORSKI of Bonn. The results will be published later on, but Prof. JAWORSKI kindly permitted me to publish here the provisional results, that are of geological interest also.

The Larger *Foraminifera* of Maastrichtian, Upper Eocene and Oligocene age have been specifically determined by me (Bibl. 11).

The Rudists and Rudistids from the Habana Formation have been described by me in a paper, submitted for publication to the Journal of Paleontology.

Faunal Lists :

Radiolaria were found at the following localities :

L. 362, L. 363, L. 373, L. 407, L. 461, L. 467, L. 471, L. 479, L. 525, L. 527, H. 198, H. 394, H. 401, H. 406, H. 410, H. 545, H. 548, V. 178, *V. 182, V. 184, V. 186, V. 187, V. 193, V. 198, V. 203, V. 262, V. 313,* V. 399, V. 410, A. 143, A. 363, A. 388, A. 422, M. 327, M. 381, M. 382, M. 417, M. 420, M. 421.

With the exception of L. 373, L. 461, H. 406, H. 410 and A. 143 all these localities are situated in the Tuff Series or the Aptychi Limestones.

The age of L. 373 is not certain, the other four localities are of Upper Eocene age.

Ammonites or Ammonite Aptychi were found at the following localities : L. 362, L. 535, L. 619, H. 487—489, M. 520, M. 604.

L. 362, H. 487—489 and M. 520 are situated in the northern ranges of Aptychi Limestones and the determination of the *Opercula* by Prof. TRAUTH indicates a Lowermost Cretaceous age for these limestones.

L. 535, L. 619 and M. 604 are limestones, intercalated in the Tuff Series in the southern half of the district. The provisional determination of the Ammonites by JAWORSKI yielded the following species :

Austiniceras dibleyi Spath 1922	L. 535, L. 619.
Pachydiscus sp. indet. cf. *colligatus* Binckhorst	L. 535.
Peroniceras cocchii Meneghini	M. 604.
Peroniceras ex. aff. *tricarinatus* (Fric.) Burckhardt 1919	L. 535, M. 604.
Peroniceras sp. indet. cf. *czörnigi* Redtenbacher	L. 535.
Peroniceras sp. indet.	L. 535.
Barroisiceras sp. indet. Nr. 7 Burckhardt 1919	L. 619.
Crioceras sp. indet. Burckhardt 1919	M. 604.

The *Pachydiscus* ex. aff. *tricarinatus* (Fric.) Burckhardt 1919, together with the *Crioceras* sp. indet. Burckhardt 1919 and the *Barroisiceras* sp. indet. Nr. 7 Burckhardt 1919 are all described from the *Peroniceras-Barroisiceras* beds of Zumpango del Rio in Mexico. These beds lie at the boundary between the Turonian and the Emscherian, or belong to the Lower Emscherian. The *Austiniceras dibleyi* Spath is known from the Turonian of England and Algiers and the *Peroniceras cocchi* Meneghini from the Lower Senonian of Toscana. These determinations thus indicate an Turonian-Emscherian age for the limestone-intercalations in the Tuff Series. The oldest sediments of the Tuff Series must be of Lowermost Cretaceous age, by their interbedding in the northern half of the district with the Aptychi Limestones, but the younger elements of the Tuff Series range up to the boundary between the Middle and Upper Cretaceous.

List of fossils from the Habana Formation.

Fossils :	Localities :
Vaughanina cubensis Palmer	L. 373, L. 483, L. 505, H. 143, H. 482, H. 550, H. 640, V. 151, V. 188, V. 229, A. 330, A. 331, A. 373, M. 573, M. 793.
Orbitoids	L. 451, H. 640, V. 151, A. 374.
Orbitoides browni (Ellis)	L. 396, L. 485, L. 501, H. 153, H. 157, H. 160, V. 159, V. 252.
Orbitoides sp.	L. 505, H. 482.
Omphalocyclus sp.	H. 153.
Torreina torrei Palmer	L. 415, V. 188.
Lepidorbitoides minima H. Douvillé	L. 485.
Lepidorbitoides planasi M. Rutten	L. 485.
Lepidorbitoides cubensis (Palmer)	L. 485, H. 153.
Lepidorbitoides rooki Vaughan and Cole	L. 485, H. 153.
Lepidorbitoides aguayoi Palmer	H. 153.
Lepidorbitoides sp.	H. 143, H. 157, V. 157.
Lepidorbitoides (*Lepidorbitoides*) sp.	V. 227.
Pseudorbitoides trechmanni H. Douvillé	L. 414, L. 415, L. 417.

Fossils:	Localities:
Pseudorbitoides israelski Vaughan and Cole	L. 414, L. 415, L. 417, L. 485, H. 153.
Pseudorbitoides sp.	V. 188.
Astrararea cf. *media* Sowerby	L. 543.
Fragments of Rudists	L. 465, L. 510, H. 482, H. 509, A. 333.
Torreites sanchezi (H. Douvillé)	L. 543, H. 550.
Barrettia monilifera Woodward	L. 483, L. 543, H. 196, H. 550.
Barrettia multilirata Whitfield	H. 196.
Parastroma sp.	H. 156, H. 550.
Biradiolites cf. *lameracensis* Toucas	L. 540.
Biradiolites cubensis H. Douvillé	L. 540, H. 196, H. 550.
Bournonia sp.	L. 543.
Parabournonia hispida H. Douvillé	H. 550.
Chiapasella cubensis M. Rutten	H. 550.
Plagioptychus antillarum (H. Douvillé)	L. 540, H. 196.
Nerinea cf. *bicincta* Bronn	H. 550.

List of fossils from the Upper Eocene.

Fossils:	Localities:
Valvulinids	L. 394, L. 458, L. 459, L. 507, H. 566, V. 165.
Dictyoconus fontabellensis (Vaughan)	L. 390, H. 636, V. 255, A. 427.
Camerina macgillavryi M. Rutten	H. 636.
Camerina malbertii M. Rutten	L. 158, H. 63, H. 66.
Camerina petri M. Rutten	L. 158, H. 61, H. 63, H. 66, H. 374, H. 381.
Camerina sp.	L. 390, L. 393, V. 328.
Camerina sp. [= *Amphistegina cubensis* Palmer, pars]	H. 374, H. 381, H. 384.
Operculina sp.	L. 390, H. 61, H. 63, H. 66.
Heterostegina panamensis Gravell	H. 374, H. 392.
Gypsina globulus (Reuss)	L. 393.
Gypsina sp.	L. 507.
Lepidocyclina r-douvillei Lisson	L. 158, H. 66.
Lepidocyclina georgiana Cushman	H. 66, H. 374.
Lepidocyclina meinzeri Vaughan	H. 66, H. 374, H. 392.
Lepidocyclina supera (Conrad)	H. 66, H. 374, H. 392.
Lepidocyclina piedrasensis Vaughan	L. 158, L. 388, H. 61.
Lepidocyclina semmesi Vaughan and Cole	H. 66, H. 374.
Lepidocyclina sp.	L. 390, H. 386, A. 361, M. 556.
Helicolepidina spiralis Tobler	L. 158, H. 374.

Fossils:	Localities:
Discocyclina blumenthali Gorter and van der Vlerk	H. 63, H. 636.
Discocyclina cloptoni Vaughan	L. 393, H. 636.
Discocyclina cubensis (Cushman)	H. 63, H. 66, H. 381.
Discocyclina perkinsi Vaughan	L. 393, H. 374, V. 384.
Discocyclina (*Discocyclina*) sp.	L. 390, L. 459, H. 386, V. 328, A. 125, A. 361.
Discocyclina kugleri Gravell	H. 374, H. 381.
Discocyclina vermunti M. Rutten	H. 61, H. 66, H. 374, H. 392.
Discocyclina (*Asterocyclina*) sp.	L. 390, L. 393, L. 458, L. 463, L. 504, L. 507, L. 558, H. 374, H. 636, A. 125.
Discocyclina sp.	L. 460, V. 376, V. 408, A. 126.
Monticulastrea regularis Kühn	H. 121.
Diplochaetetes longitubus Weissermel	H. 121, H. 385.

List of fossils from the Oligocene.

Fossils :	Localities :
Lepidocyclina fragilis Cushman	L. 157.
Lepidocyclina marginata (Michelotti)	L. 156, L. 157, H. 71.
Lepidocyclina piedrasensis Vaughan	L. 156, L. 157, H. 80.
Lepidocyclina tournoueri Lemoine and R. Douvillé	L. 156, H. 71, H. 80, A. 360.
Lepidocyclina semmesi Vaughan and Cole	L. 156.
Lepidocyclina favosa Cushman	L. 156, H. 71, H. 80.

Systematic descriptions :

Genus Dictyoconus Blanckenhorn, 1900.

Dictyoconus fontabellensis (Vaughan).

(See figs 5, 7, p. 40).

Cushmania fontabellensis, Vaughan, 1928, Jour. of Pal., Vol. 1, no. 4, p. 282, pl. 44, fig. 3.
Dictyoconus fontabellensis, Vaughan, 1932, Jour. of Pal., Vol. 6, no. 1, pp. 97, 98, pl. 14, fig. 6, 7.

Small forms, with outer characters varying. In most cases the diameter of the basis is larger than the height, but sometimes they are equal. They are characterised by a rather coarse structure, the platforms are set wide apart; near the centre of the basis the distance between two platforms varies from 0,10 mm. to 0,15 mm.

Diameters in mm. of specimens of *D. fontabellensis*:

Height	1,0	1,1	1,2	1,6	1,8	2,3	2,4
Diameter at basis ...	1,8	2,1	1,8	1,6	2,4	3,7	3,0

Upper Eocene, Santa Clara Province, Cuba.

Genus VAUGHANINA Palmer, 1935.

VAUGHANINA CUBENSIS, Palmer.

(See fig. 2, p. 22).

Vaughanina cubensis, PALMER, D. K., Soc. Cubana de Hist. Nat., Mem., Vol. 8, no. 4, pp. 240—243, figs. 2, 3, pl. 12, fig. 5, pl. 13, figs. 2, 4.

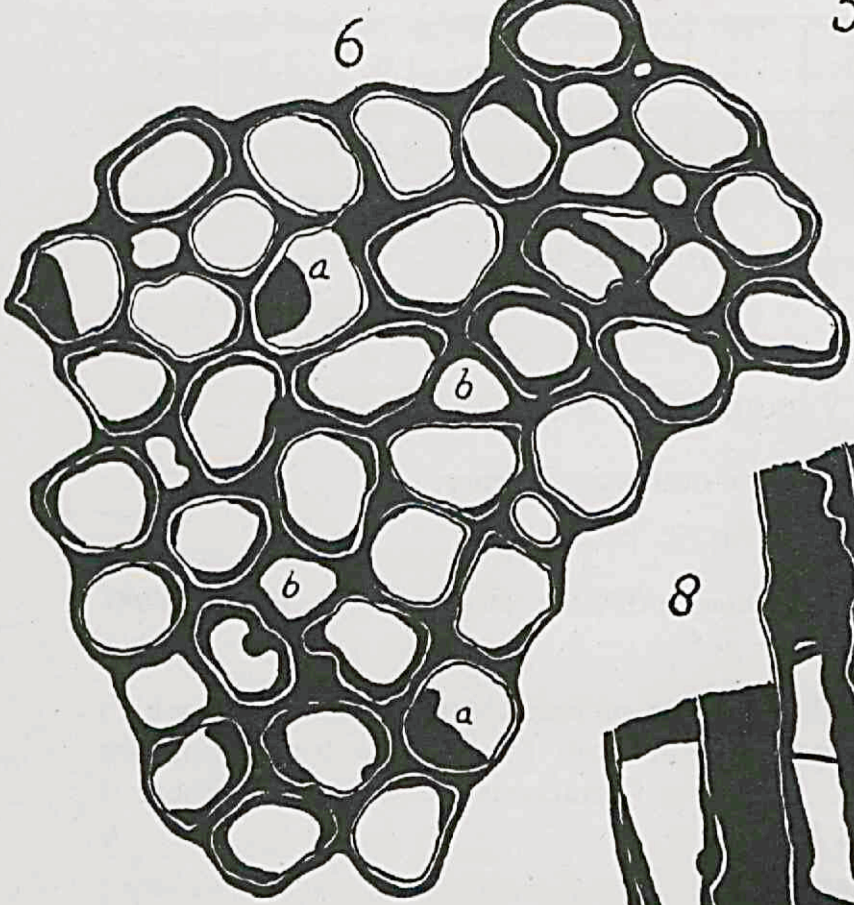
As may be seen from the number of find-spots of this fossil, which is larger than that of any other fossil from the Habana formation, this species is widely distributed in Upper Cretaceous Cuban layers, where it serves as an excellent index fossil.

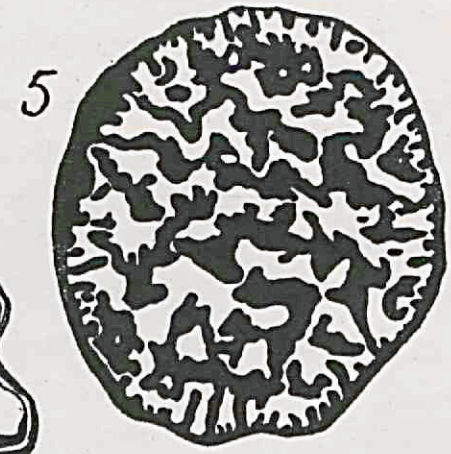
Genus LEPIDOCYCLINA Gümbel, 1868.

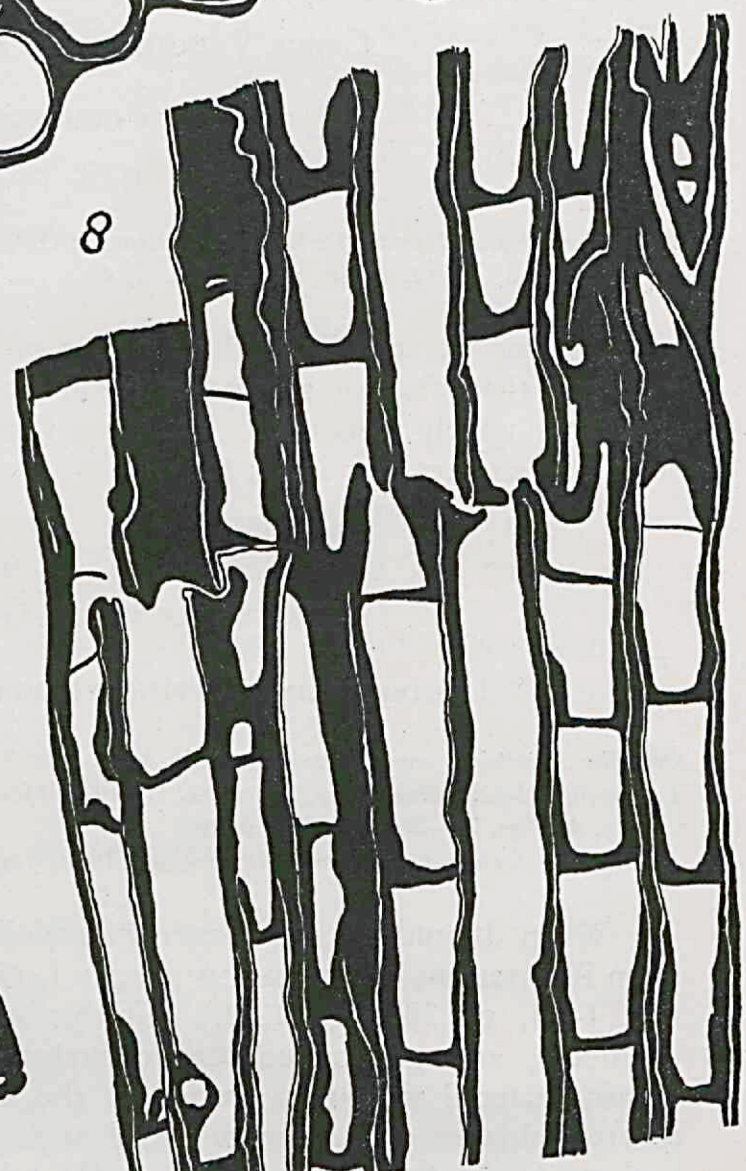
LEPIDOCYCLINA (LEPIDOCYCLINA) SUPERA (Conrad).

Orbitolites (*Orbitoides*) *supera*, CONRAD, 1865, Acad. Nat. Sci., Philadelphia, Proc., no. 2, p. 74.
Lepidocyclina (*Lepidocyclina*) *supera*, DOUVILLÉ, H., 1924, Mém. Soc. Geol. France, N. S., T. I., Mém. 2, p. 40, figs. 23—26, pl. I, figs. 9, 10.
Lepidocyclina (*Lepidocyclina*) *mortoni*, RUTTEN, M., 1935, Journ. o. Pal., Vol. 9, no. 6, pp. 538, 539.

When I studied the Larger *Foraminifera* of the district I concluded from illustrations of CUSHMANS species *Lepidocyclina mortoni* (Bibl. 1, pl. 27, figs. 1—4, pl. 28, figs. 1, 2.) that this species had hexagonal equatorial chambers, arranged on concentric circles, and identified specimens from Cuban material with this species, at the same time drawing attention to the resemblance of *L. mortoni* and *L. supera*. The same view was held by VAN DE GEYN & VAN DER VLERK, (3), who placed *L. mortoni* under the synonymy of *L. supera*. However, the extensive redescription of *L. mortoni* from the type-locality by GRAVELL & HANNA (4.), shows this species to be characterised by rhomboid equatorial chambers, arranged on intersecting, outwardly convex curves. The Cuban specimens, flat discoidal forms, with hexagonal equatorial chambers, arranged on concentric circles, with only







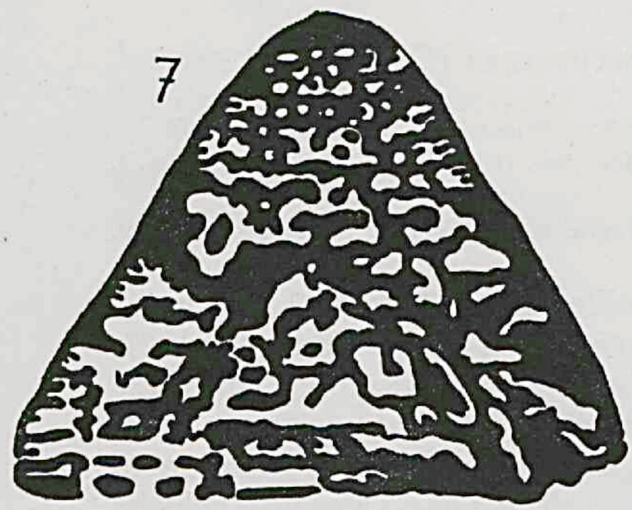


Fig. 5. *Dictyoconus fontabellensis*, horizontal section, × 30.

Fig. 6. *Diplochaetetes longitubus*, horizontal section, × 30. Partly sectioned floors at *a*, irregular cavities at *b*.

Fig. 7. *Dictyoconus fontabellensis*, vertical section, × 30.

Fig. 8. *Diplochaetetes longitubus*, vertical section, Illustrating the irregular position of the floors, × 30.

a few layers of low lateral chambers, must now be identified with *Lepidocyclina supera* (Conrad), which thus also occurs in Upper Eocene layers, and is specifically distinct from *Lepidocyclina mortoni* Cushman.

Upper Eocene, Santa Clara Province, Cuba. Hypotypes, Min.-Geol. Inst., Utrecht, D. 14035—14044.

Genus MONTICULASTREA Duncan, 1880.

MONTICULASTREA REGULARIS Kühn.

(See Pl. I, fig. 11).

Monticulastrea regularis, KÜHN, 1933, Palaeontographica, bd. LXXIX, A, 1. 3—6, p. 195, taf. XVIII, fig. 12, taf. XIX, fig. 1.

The small, rounded hills between the rows of calices are flat. The valleys with the columella have sharp edges and form rather regular hexagons. The diameter of these varies from 5 mm. to 8 mm., with a mean value of 7 mm. As in the type-specimen there are 7 to 10 septa for every 5 mm. length of columella.

Upper Eocene, Santa Clara Province, Cuba. Hypotypes, Min.-Geol. Inst., Utrecht, Coll., Pa. 1935, 302 ; D. 14431, 14432.

Genus DIPLOCHAETETES Weissermel, 1913.

DIPLOCHAETETES LONGITUBUS Weissermel.

(See figs. 6, 8, p. 40; pl. I, fig. 10).

Diplochaetetes longitubus, WEISSERMEL, 1913, Geol. Erforsch. Deutsch. Schutzg. Beitr., heft 5, pp. 84—108, textfig. 1, 2, pl. 13, figs. 1—3. ———, WEISSERMEL, 1926, in KAISER, Diamantenwüste Südwestafrikas, Berlin, bd. II, pp. 88, 89, pl. 35, figs. 1, 2, textpl. C, figs. 1—3.

The structure of these striking corals is absolutely identical with that given by WEISSERMEL, so that there is no doubt that the forms are specifically identical.

Walls double, septa wanting, horizontal diameter of calices varying between 1 mm. and 2 mm. with a mean value of 1,5 mm., floors scarce and irregularly placed. The corals grow by the division of tubes; when the space available augments. They are much smaller than those from the type-locality. One well preserved specimen has a height of 2 cm. It is flat-oval in outline, the largest horizontal diameters being 4 cm. × 5,5 cm. and it is attached to the lower tip of the colony.

Upper Eocene, Santa Clara Province, Cuba. Hypotypes, Min.-Geol. Inst., Coll., Pa. 1935, 301 ; Cb. 1933, 116 ; D. 14428—14430.

Genus Nerinea Defrance, 1825.

Nerinea cf. bicincta Bronn.
(See figs. 9, 10, p. 42).

Nerinea bicincta, Bronn, 1836, Neues Jahrb. f. Min. etc., p. 562, t. 6, fig. 14, — — —, Goldfuss, 1844, Petref. Germ., 3, p. 46, t. 177, fig. 5a, b.

Broken specimens embedded in hard limestone rock and only to be studied in sections. Horizontal diameter at the upper side varies from about 3 cm. to 6 cm. The sections through the coils reveal the simple infoldings, typical of the genus. There are three central folds, one of which is placed at the upper side of the spiral; and one lateral fold.

Maastrichtian, Santa Clara Province Cuba. Hypotypes, Min.-Geol. Inst., Utrecht. Coll. Cb. 1933, 51—53.


9.

10


Figs. 9, 10. *Nerinea* cf. *bicincta*. Locality H. 550, between La Esperanza and Santa Clara.
9. Oblique section through young specimen. × 1/1.
10. Vertical section through three consecutive windings of a large specimen. × 1/1.

Chapter VI : **ECONOMIC GEOLOGY.**

The importance of northern Santa Clara from an economic viewpoint is very small. With the Serpentines occur small bodies of iron- or chromium-ore which sometimes have been mined for a short time.

Locally the Diorites brought a small amount of gold. One abandoned gold-mine, the Mina Isel, is situated on the path from Guaracabulla to Falcon. After the conquest of the island by the Spaniards placer-gold was found in the beds of the Rio Arimao and Rio Caonao, and this led to prospecting work being done higher up in the basins of these rivers, and also in the neighbourhood of Guaracabulla, without, however, yielding much result.

In several localities seeps of asfalt are found, which is being mined now at the mine Anna Maria, Southwest of Placetas. These findspots are numerous near Santa Clarita, and here they are situated along the contact between the Serpentines and the Aptychi Limestones. The Aptychi Limestones are to a certain extent oil-bearing. We often find traces of oil along the limestone-bedding-planes or the limestones give a definite odour, when broken. We may explain the asfalt-seeps near Santa Clarita by the tectonical contact between the Serpentines and the Aptychi Limestones. If the plane of overthrusting between the two formations has a southern dip, imperforate rocks from the Serpentines overlie steeply folded, pervious limestones. Oil may accumulate against the overthrust-plane, and escape along the contact of the two formations. The economic importance of these indications is, however, practically nil, as the Aptychi Limestones are too heavily folded to present useful structures and the contacts of Serpentines and Aptychi Limestones in all probability do not offer enough space for the accumulation of larger oil-masses.

Chapter VII : DESCRIPTION OF SOME ROADS SURVEYED.

Santa Clara — Camajuani — Remedios — Caibairien.

(See Section VII).

The road leaves Santa Clara in the northeastern part of the town and it is here still in the Serpentine district. Soon it passes into the Habana Formation, where white brecciated or fine-grained limestones predominate over light-green glasstuffs. At Capiro, the limestones are well exposed in quarries to the North and South of the road (V. 157, 158). They are steeply folded and small faults occur. Near the Granja Agricola the Habana Formation is overlaid by Upper Eocene, characterised by white marly limestones and tuffaceous limestones, that form gently undulating structures. In the Rio Ochoa we find a silicified spilitic rock (V. 162a), that is likely to belong to the Tuff Formation, and over the river we pass into the Serpentines, with veins of gabbro that show a strong uralitisation and a cataclastic structure. The road then passes through the southern flank of a small hill, the Bonachea, that is formed by steeply and irregularly folded grey and red limestones and marls from the Aptychi Formation (V. 168), and again comes into the Serpentines, until after the crossing of the Rio Sagua la Chica and the railroad at Santa Fé. Before us we see here a ridge of hills with a Northwest—Southeastern trend, the Loma Santa Fé. (See fig. 11, p. 45). It is formed by limestones of the Aptychi Formation, that are steeply folded and sometimes faulted, with strikes running roughly parallel to the trend of the ridge (V. 178—186). Although the contact with the Serpentines is sharply defined, no trace of metamorphism in the limestones is found. We find here grey and bluishgrey limestones and marly limestones, with layers and lenses of dark chert. *Radiolaria* are very abundant. Several layers of tuffaceous limestone are encountered and in one place we find a brown, fine-grained sandstone, built up by fragments of quartz and plagioclase felspars, with some muscovite and calcite (V. 186). Owing to the strong folding nothing definite of the tectonic structure of the ridge can be said. In connection with the facts found at the path from Falcon to Camajuani, we may assume that the Serpentines are brought into tectonical contact with the Aptychi Limestones by an overthrust.

On the eastern flank of the Loma Santa Fé are exposed greyish marls and finely brecciaceous limestones, which, on microscopical examination, are found to contain Orbitoids and belong to the Habana Formation (V. 188). We then pass into a small zone of Serpentine that is very weathered, and recognised by the more resistent foreign inclusions. Over the railroad we

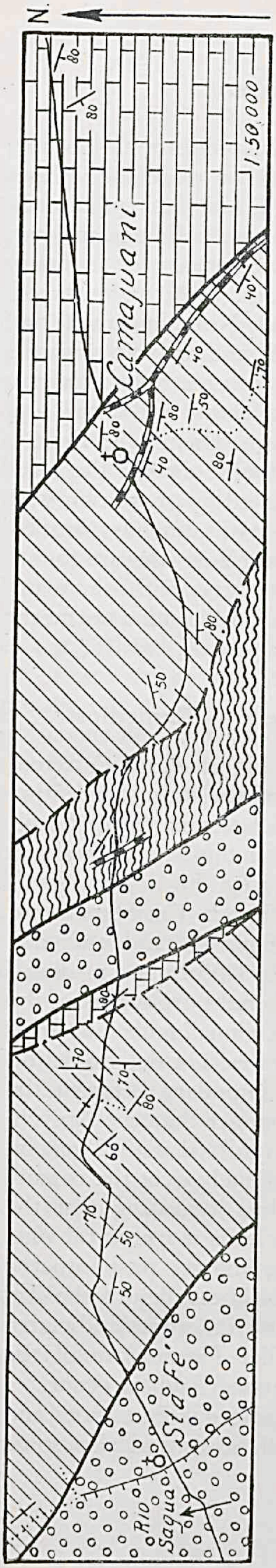


Fig. 11. Detailed geologic map of the Loma Santa Fé, West of Camajuani. Scale 1 : 50.000.

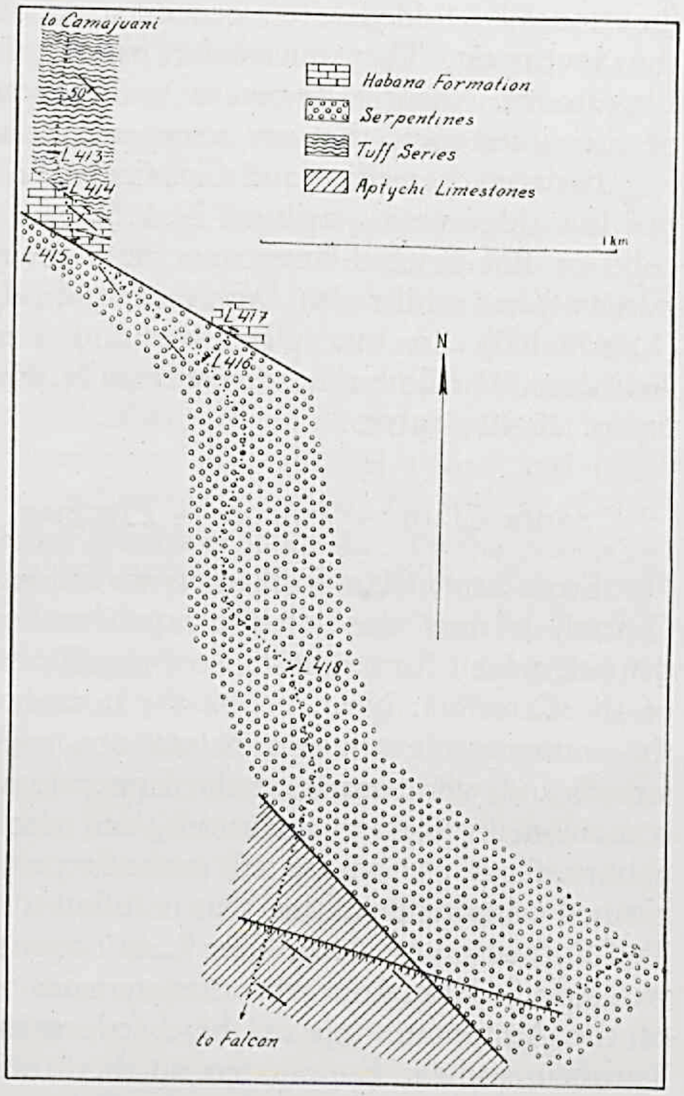


Fig. 12. Detailed geologic map of part of the road between Camajuani and Falcon. Scale 1 : 25.000.

pass into the Tuff Series, represented by glass-tuffs and prophyrite-tuffs without stratification (V. 190—192). From V. 193 till we reach the village of Camajuani, we once more cross a zone of grey limestones with intercalated dark cherts from the Aptychi Formation. Between Camajuani and Remedios, we find white and grey brecciated limestones, that contain Orbitoids of the Habana Formation near Camajuani, and fragments of Rudists of the sub-family of the *Radiolitinae* at V. 244. Near Camajuani the limestones are folded with a general strike of N. 120 E. and they dip towards the Southwest. They must lie in tectonical contact with the older Aptychi Limestones. Nearing Remedios nothing can be said about strike and dip of the limestones, that are very cavernous and form 'Dientes de Perro'.

Between Remedios and Caibairien the Upper Eocene crosses the road in a low ridge with a strike of N. 115 E. It is represented by greyish brown, solid or fine-grained limestones with many micro-fossils, mainly Smaller *Foraminifera* ; whilst also *Dictyoconus* and fragments of *Discocyclina* are found (L. 458-460). In one place we find a marly limestone with abundant *Radiolaria*. The limestones strike from N. 95 E. to N. 130 E. with a northerly dip of 25-40 degrees.

Santa Clara — Falcon — Placetas — Zulueta — Remedios.

From Santa Clara to Placetas we follow the new highroad, the Carretera Central. It runs close to the northern boundary of the large Serpentine district, which forms the hills of the Sierra Alta de Agabama to the South of the Carretera. Near V. 399 the boundary between the Serpentines and the transgressive younger formations crosses the road for a very small stretch and white marls of the Upper Eocene are found. The Serpentines contain many foreign inclusions, and also veins of normal and uralitised gabbro. At A. 341 we are still in the Serpentine but A. 340 brings a medium-grained cristallyne albitite, that is followed by weathered porphyrites of the Tuff Formation (A. 338). Near L. 619 they pass with a small fault into grey, well stratified limestones that carry remains of Ammonites. The determination of the Ammonites places these sediments at the boundary between the Turonian and the Emscherian, so they are much younger than the Aptychi Limestones further to the North. They are strongly folded with a general strike of N. 115 E.—N. 140 E. These strikes cut obliquely over the contact of Tuffs and Limestones with the Serpentines, thus indicating that the contact between the Serpentines and the older rocks is a tectonical one.

The railroad here crosses under the Carretera, and we pass into the Habana Formation, which is exposed until we reach the valley of the Rio Sagua la Chica near Falcon. It is characterised by white limestones and marls, locally carrying abundant organisms, chiefly smaller *Foraminifera* of the *Globigerina* group. *Vaughanina cubensis* and fragments of Rudists occur.

The steeply folded limestones alternate with tuffaceous limestones and breccias with fragments of porphyrites of the Tuff Series and also some pebbles of dioritic rocks. On the eastern side of Falcon we find a large quarry with white to light-green marly limestones, over a basal conglomerate with many boulders from the older formations. We found here augite-porphyrite, diabase and uralite-diabase from the Tuff Series, a uralite-rock, which most probably comes from the Serpentines, and a brecciated quartz-dioriteporphyrite from the Diorites. The rocks gently dip towards the Northeast and the patch of limestones is surrounded at all sides by the alluvial plains of the Rio Sagua and its affluents. During our fieldwork we parallelised these rocks with those of the Habana Formation found to the East and West. On microscopical examination however, some of the limestone-boulders were found to contain *Vaughanina cubensis*, whilst the greenish limestones contain abundant *Radiolaria*. If the rocks are of Maastrichtian age, the limestone-boulders must have been formed during or immediately before sedimentation. Moreover *Radiolaria* are very scarce in the Habana Formation as it is exposed in Santa Clara. There remains the possibility that we have here rocks of Eocene or Oligocene age, but without index fossils the question can not be answered. As this patch of limestones is flanked by limestones of the Habana Formation I have provisorily dated them as Habana also.

Eastward of the limestone quarry we find alluvial plains and then porphyrites of the Tuff Formation, which are replaced by steeply folded tuffaceous limestones of the Habana Formation at L. 371. To the North of the Carretera Central it is exposed as white limestones, with boulders of porphyrite and quartzdiorite-pegmatite respectively of the Tuff Formation and of the Diorites. Here it contains fragments of Rudists of the sub-family of the *Radiolitinae* and characteristic *Foraminifera*, e. g. *Orbitoides* and *Vaughanina* (H. 480, 482). At L. 369 we pass once more into the Serpentines, containing many dikes of diorite-porphyrite and gabbro. To the North, the Habana formation runs parallel to the Carretera in a series of low hills. It is found at M. 500 and at L. 364 it crosses the road for a short space, to be replaced by greenish brown or white, well bedded glass-tuffs, radiolarian tuffites and radiolarian cherts of the Tuff Formation (L. 362, 363); with a small vein of a augite-spessartite near L. 362. They pass again into the Serpentines at the next bend of the road. Strikes and dips of these beds are in no connection whatever with the boundaries between the Serpentines and the Tuff Formation, so these boundaries are formed by faults or overthrusts.

From Placetas northward we find Serpentines, until we reach the hills that are the direct continuation of the Loma Santa Fé, and are formed by steeply folded and faulted well bedded limestones with intercalated layers and lenses of chert (L. 441—443). At the railroad crossing of San José begins the Tuff Formation, with some veins of Dioritic rocks, e. g. a malchite and a diorite.

South of Zulueta we once more cross a zone of steeply folded limestones and cherts from the Aptychi Formation. At L. 447 the limestones are strongly brecciated and in places have the same habit as breccia-limestones from the

Habana Formation. The components, however, are all derived from the Aptychi Formation and comprise limestones, radiolarian limestones, and cherts, and we may consider the breccia as a mylonitic one, formed on an overthrust. This is in agreement with the fact that to the Southeast, in the direction of the strike, we find a zone of Serpentine intercalated between the Aptychi Limestones on the courses from Remate, General Carillo and Jarahueca Southward. The Aptychi Limestones are found up to L. 451, north of Zulueta, where they are replaced by white, oölithical or brecciaceous limestones from the Habana Formation with fragments of *Radiolitinae* and Orbitoids. They have a Northwest—Southeast strike and a southern dip and are thus brought into tectonical contact with the Aptychi Limestones by an overthrust. Nearing Remedios the limestones have much the same appearance as between Camajuani and Remedios. Nothing can be said about their structure and no index fossils were found.

The country between these two roads.

East of Santa Clara the boundary between the trangressive Upper Eocene and the Tuff Formation is rather well exposed. The Eocene forms three synclines and the Tuffs are exposed in the corresponding anticlines. (See Section IV). At V. 382 the Eocene rests on the Tuffs with a basal conglomerate with boulders of porphyrite, dioriteporphyrite, aptychi-limestones and cherts. The Eocene comprises white marls and limestones, alternating with tuffaceous limestones and calcareous sandstones, that grade into the basal conglomerate. The tuffaceous limestones are very similar to those from the Habana Formation, but under the microscope the foreign fragments appear much more rounded, thus forming intermediate stages between tuffites and sandstones. *Discocyclina* s.s. and *Asterocyclina* are found.

From La Movida to the Bonachea (H. 397—429) (See Section V) we start at the Carretera Central with Serpentine, with dikes of Diorite, followed almost directly by glass-tuffs and occasional radiolarian limestones of the Tuff Formation. Here also we find a dike of plagiaplite at H. 403. At H. 409 we pass a small zone of amphiboliteschists, typical inclusions of the Serpentines and then find gently folded white and grey limestones with *Radiolaria*, that can be connected with one of the Upper Eocene synclines further to the West. At H. 411 begins a band of Serpentines, with many foreign inclusions, e. g. chloriteschists, zoisite-amphibolites, glaucophane-amphibolites. At H. 411 we find a practically unaltered harzburgite. The Serpentines last till H. 424 where we cross the Aptychi Limestones in the prolongation of the Bonachea. The contact between the red and grey limestones and the Serpentines is very sharp, and we find evidence that it is of a tectonical nature. Along the southern limit the limestones are brecciated and contain sharp-edged broken fragments of Serpentine (See fig. 1, p. 13), and on the northern flank the Serpentines close to the contact, have a foliated structure with the strike of the foliation running N. 155 E., that is to say, parallel to the contact of Serpentines and Aptychi limestones (See pl. I, fig. 2). The Serpentines continue from here till we reach the road from Santa Clara to Camajuani.

From La Movida to Santa Fé we first follow the railroad of the Ferrocarril de Cuba, which passes the boundary between the Tuff Formation and the Serpentines, and then we take a path to the North. At H. 535 we find a sharp contact between the Aptychi Limestones and the Serpentines, characterised, here also, by a breccia of limestone with fragments of serpentine. North of the zone of Aptychi Limestones we find Serpentines, till we reach Santa Fé, on the road from Santa Clara to Camajuani.

From Santa Fé to the Carretera Central, we pass through Serpentines, till we cross the Rio Sagua la Chica at V. 262, where heavily folded marls, limestones and radiolarian cherts of the Aptychi Formation are exposed. These can be connected with a small ridge of Aptychi Limestones, that leave the Loma Santa Fé to the East at M. 361, but do not make a direct, fault-less connection with the Aptychi Limestones that come from the Bonachea. South of this small band of limestones we find white and green glass-tuffs and tuffoid porphyrites. The glass-tuffs contain large angular fragments of quartz which, together with their light colour, makes it probable that they belong to the Habana Formation. I have connected these rocks with true exposures of Habana along the Carretera Central (A. 331—336) and near Santa Clarita (M. 385 and 381). So we get a large patch of transgressive Cretaceous, which more or less corresponds with the plains of the Rio Sagua la Chica. To draw the real extent of this patch, the scanty data available are insufficient. Before crossing the railroad we come again into true tuffs and porphyrites of the Tuff Formation, with a dike of cataclastic diorite-porphyrite at V. 269.

From Camajuani to Falcon (See Section VIII) we begin with Aptychi Limestones that are steeply folded, with a general strike of N. 100 E. At L. 407 we pass a bed of sandstone comparable to that of V. 186. At L. 408 we pass into the Tuff Series, spilitic rocks and porphyrites with intercalated beds of limestone. At L. 414 these are covered by tuff-breccias and tuffaceous limestones, with abundant Orbitoids of the genera *Pseudorbitoides* and *Torreina* (See fig. 12, p. 45). These beds belong to the Habana Formation, and pass with a sharp boundary into a small zone of Serpentines, that clearly has been under considerable stress, as the rocks are well bedded with a strike of N. 135 E. and a steep southern dip. Just before crossing the sugar-railroad at L. 420 we reach the Aptychi Limestones of the Loma Santa Fé, and we remain in steeply folded well bedded limestones with lenses and layers of chert and many veins of calcite, until we reach the southern side of the hills near Santa Clarita, where once more the Serpentines begin abruptly. Along the contact of Serpentines and Aptychi Limestones are located various 'Chapopotes', small findspots of asphalt. These we can explain by surmising that the Aptychi Limestones are an oil-motherformation. These limestones locally carry abundant *Radiolaria* and Smaller

Foraminifera and in some places even show traces of oil. During orogenesis the limestones were folded and the Serpentines were brought into contact with the limestones by an overthrust fault, which runs along the Loma Santa Fé with a southwestern dip. Oil accumulated from the folded limestones against the overlying less pervious Serpentines, and could escape only along the plane of the overthrust.

Santa Clarita lies in the Serpentines that are found till near the Carretera Central, where we pass into the Tuff Series.

From Camajuani to Placetas, we follow the railroad over San Andres and begin with the Aptychi Limestones, but soon pass into brecciated limestones of the Habana Formation, with, at A. 369, a conglomerate with boulders of porphyrite, tuffs of the Tuff Series and Aptychi-limestones. At A. 372 we have once more crossed the boundary and find porphyrite-tuffs without stratification. To the left is a small hill, with brecciaceous white and yellow limestones of the Habana Formation, carrying Orbitoids and *Vaughanina cubensis* (A. 373, 374). The Tuff Formation is interrupted at San Andres by a large patch of Dioritic rocks (See Section IX). We find here diorites, diorite-porphyrites, amphibole-porphyrites and malchites, with occasional serpentines. All dioritic rocks have undergone considerable stress, and show strong cataclastic structure with broken phenocrysts and mylonitisation of the matrixes. Passing the Diorites we again get Tuffs until we reach the Aptychi Limestones of the Loma Santa Fé at M. 456. On a more western tracé we find the limestone-tuff boundary located a little more to the North. This may be due to small tranverse faults or to the thinning out of limestone beds. At the southern side of the Loma Santa Fé we once more find the Serpentines till we reach Placetas.

Santa Clara — Encrucijada and San Antonio de las Vueltas.

From Santa Clara we pass white marls and oölithical limestones, where we did not find any index fossils, till reaching the Serpentines. Hereafter we pass a zone of Aptychi Limestones, that are strongly folded, and again come into the Serpentines, that are replaced by Aptychi Limestones and cherts near H. 500. Here again comes a small zone of Serpentines near H. 502, whereupon we soon reach the Aptychi Limestones again. Just before Encrucijada we find calcareous sandstones and, at the northern side of the village, white brecciated limestones from the Habana Formation, with fragments of Rudists. From here northward we find white, cristalline or brecciated limestones, without fossils.

We have found on this section several alternating zones of Serpentines and Aptychi Limestones, without seeing anything definite of the structure of the limestone ranges and the serpentine fields. Although the Serpentines are the younger, there is never any sign in the limestones of a metamorphism caused by the Serpentines, which points to the fact that their contacts are purely tectonical. We might yet think that the country was built up by alternating synclines and anticlines with Serpentines in the synclines and Aptychi Limestones in the anticlines and with small overthrusts at their contacts, but then we should expect that the lateral endings of the limestone ranges were caused by axial dippings of the anticlines. If then a range of limestones ends, as it does for instance near Hatillo, the Serpentines should more or less surround the end of the limestones, as the syncline becomes wider with the dipping of the anticline. This is not the case. For instance both northeast of Hatillo, and at M. 510 Northwest of the section from Santa Clara to Encrucijada, we find the limestones ending abruptly against the Serpentines. So we must surmise that the country is built up by a series of wedges, where the older Aptychi Limestones are thrown up over the Serpentines, whilst the lateral ends of the limestone ranges are formed by tranverse faults. In most cases the direction of the dip of the overthrusts is not seen. Only sometimes, for instance near Santa Clarita, where asfalt deposits have formed at the contact between Limestones and Serpentines, we are sure that the plane of the overthrust dips towards the Serpentines.

To reach San Antonio de las Vueltas (See section VI), we leave the road for Encrucijada just before H. 513 and cross a broad zone of Serpentines, with many dikes of gabbros and with foreign inclusions, such as amphibolites. Just before crossing the Rio Sagua la Chica at L. 499, we reach the well bedded steeply folded limestones and cherts of the Aptychi Formation, that form the Loma Purial. This ridge of hills lies just in the prolongation of the Loma Santa Fé. On the eastern side of the Loma Purial, after crossing the Rio Camajuani, we pass at L. 501 directly into the brecciated steeply folded limestones of the Habana-formation, with characteristic Orbitoids and *Vaughanina cubensis*. Just before San Antonio many fragments of Rudists are found. Two small synclines, with grey marls and white or grey, finely conglomeratical Upper Eocene limestones, carrying *Discocyclina* and *Dictyoconus*, are found at L. 504 and L. 507.

If we compare the structure on this section with that found at the road from Santa Clara to Camajuani, we find the latter much more complicated. On the section through the Loma Purial we find neither a zone of Serpentine, nor a layer of Habana limestones intercalated between the Aptychi Limestones. As Loma Purial and Loma Santa Fé lie in a line with each other and parallel to the general strike predominating in the Aptychi Limestones, I have connected both zones of limestones on the map, whereas the zones of Tuffs, Serpentines and Habana Formation found to the West of Camajuani, are thought to wedge out towards the North. The possibility remains that the two limestone ridges are separated by a band of Serpentines that should run through the topographical gap between the hills and connect the large field of Serpentines to the West of the hills with the band of Serpentines found at V. 189 and L. 419. The two synclines with Upper Eocene West of San Antonio de las Vueltas cannot be traced laterally.

Santa Clara to La Esperanza.

The railroad first runs through Serpentines, that are replaced between km. 285 and km. 286 by glass-tuffs and tuff-breccias of the Habana Formation and by radiolarian-tuffites with intercalated radiolarian limestones of the Tuff Formation between km. 282 and km. 281. Just before km. 280 tertiary oölithical white limestones containing *Lepidocyclina* with a North—South strike and eastern dip cross the railroad (M. 556), to be followed in the neighbourhood of km. 280 by limestones with abundant Rudists and other fossils typical of the Habana Formation (H. 550). Limestones and lightgreen fine-grained glass-tuffs follow, till we find a patch of dioritic rocks between km. 278 and km. 277, where diorites and diorite-pegmatites are found.

About two kms. futher West we cross toward the Carretera Central that runs close to the rail and find at H. 636 large rocks of greyish, somewhat conglomeratical limestone with *Asterocyclina* and abundant specimens of *Camerina maggillavryi*. The microspheric specimens of this form attain the large diameter of 5 cm.

The Carretera Central from Santa Clara to La Esperanza runs entirely through Serpentines, with a dike of albitite at L. 351 and many dikes of olivine-gabbros between L. 353 and L. 356. Here are found Dioritic rocks, augite-diorite and albitite that probably are connected with those found along the railroad.

South of the Carretera Central are some limestone hills, where limestones, tuffaceous limestones and light-green glasstuffs of the Habana Formation outcrop. These glass-tuffs and tuffaceous limestones can be distinguished from those of the Tuff Formation by the intercalated marls and their lighter green colour, whilst under the microscope angular fragments of quartz and specimens of *Vaughanina cubensis* are found to occur. These are lacking in the tuffs and limestones of the Tuff Series, whilst radiolarian deposits, that are frequently met with in the older sediments, are not found here in the Habana Formation. Locally the limestones contain abundant Orbitoids of the genera *Orbitoides* and *Lepidorbitoides* (L. 485, H. 153).

La Esperanza — San Diego del Valle — Cifuentes — Sagua la Grande — Quemado de Guines.

The railroad from la Esperanza northward crosses low country, where white marls are exposed. At Conyedo we see to the West a hill, which is the end of a long cuesta, that forms the northern boundary of the Upper Eocene against the older formations. Here at Conyedo the age of the limestones is ascertained by corals (*Monticulastrea regularis* and *Diplochaetetes longitubus* at H. 121) and by *Foraminifera* (*Camerina* sp., *Discocyclina* sp. at V. 328). The limestones contain many boulders from the older formations, for the greater part amphibolites, actinolite-schists and other resistent inclusions from the Serpentines. From Conyedo the railway turns Northwest and follows the foot of the hill. Although no exposures were found, we may assume it runs through Serpentine, which is found in good exposures more to the East (V. 319—327). Before reaching San Diego del Valle, we pass into the porphyrites of the Tuff Series at A. 410, that are replaced by a band of Serpentines, chiefly recognised by its more resistent foreign inclusions, such as amphibolites and schists. We then pass into steeply and irregularly folded, well bedded grey limestones, with occasional beds and lenses of chert, of the Aptychi Formation. These are found till near Cifuentes, where several beds of calcareous sandstones — with fragments of quartz, plagioclase felspars, muscovite, grains of quartzite and mica-schist — are intercalated in the greyish and blue, *Radiolaria* bearing Aptychi Limestones.

Cifuentes lies in broad alluvial plains of the affluents of the Rio Sagua la Grande. North of Cifuentes, till beyond Citio Grande, we cross a low ridge of hills, formed by steeply folded, well bedded limestones and occasional cherts from the Aptychi Formation. From the railroad crossing at Corazon de Jesus onward, till we reach the Rio Sagua la Grande, we follow the northern slope of the hills just crossed. The hills are formed by Aptychi Limestones with Ammonites at H. 487—489, whereas along the road we find very weathered Serpentines and green weathered tuffaceous rocks, that on microscopical examination are seen to be uralitized diabases, inclusions from the Serpentines. On the northern bank of the Rio Sagua la Grande we find brecciaceous, white or grey limestones from the Habana Formation, with *Orbitoides browni* at V. 252 and white limestones with many organisms from the Upper Eocene, containing *Dictyoconus fontabellensis*, at V. 255. The limestones are placed vertically, with a general strike of N. 100—110 E., which strike is the same as that of a ridge of hills beginning at these two localities and extending South from the road from Sagua la Grande to Quemado de Guines.

From the northern side of this ridge over Sagua la Grande, till we reach the sea at La Isabella, we pass low lying land with horizontal, cavernous limestones, probably of Oligo-Miocene age (Guines Limestone), probably younger.

In following the road from Sagua la Grande to Quemado de Guines, we pass again the Upper Eocene, Habana and Aptychi Formations, whilst at A. 428 to the northern side of the road lie several small, isolated hills. We did not find fossils here, but through the courtesy of the 'Bataafsche Petroleum My' at the Hague I received samples of limestones with fragments of Rudists of the Genus *Sauvagesia* collected on the same spot. These prove that here again Cretaceous — and most probably Habana — Formations outcrop.

Before reaching Quemado de Guines, we pass from the Aptychi limestones and cherts into white and yellow, coarsely brecciated limestones, without fossils, that most probably belong to the Habana Formation. South from Quemado de Guines we find at L. 530 and L. 531 horizontal, white and red cavernous limestones, with a very characteristic habit, caused by moulds and casts of abundant Gastropods, whose shells have been totally weathered out. We did not find any complete fossils in this Guines Limestone, but we may place it with PALMER (9) as Oligo-Miocene.

Jicotea — San Diego del Valle.

South of Jicotea, near the cemetery, we find in an outcrop of conglomeratical marly limestones with a small northern dip, abundant larger *Foraminifera* of the genera *Camerina*, *Heterostegina*, *Lepidocyclina*, *Helicolepidina* and *Discocyclina*, indicating an Upper Eocene age of these beds.

In leaving Jicotea to the Northeast, we find marls and limestones, with occasional Orbitoids and corals. At H. 392 we are at the northern limit of the Eocene. It forms here a low hill, gently sloping to the South, but forming a cuesta toward the plains at the northern side. To the left and right, we see how this limestone-hill continues along the northern limit of the Upper Eocene, and that it is connected with the cuesta we found between La Esperanza and San Diego. In the basal parts the Eocene is conglomeratical here also, but, whereas near Conyedo most pebbles were derived from the Serpentines, we find pebbles of radiolarian limestones and cherts from the Aptychi Formation predominating here. From H. 392 onward, till we reach San Diego, we pass low lying country, with brownish green glass-tuffs and radiolarian tuffites from the Tuff Series cropping out.

The country South from the Carretera Central, between Santo Domingo and La Esperanza.

At A. 360 and in the neighbourhood of Santa Isabel (L. 156, 157, and H. 71, 80) we find specimens of *Lepidocyclina*, typical of the Olicogene; whereas at A. 361 and at L. 158, H. 61, H. 63 and H. 66 faunas of Larger *Foraminifera*, typical of the Upper Eocene, are found. Near Santa Isabel the beds are feebly folded with a general northwestern dip. Oligocene and Upper Eocene seem to be perfectly concordant, and are not to be distinguished lithologically. They consist of white marls and marly limestones, alternating with finer and coarser soft greyish conglomeratical limestones, with well-rounded small pebbles of limestones and weathered tuffoid rocks.

East from Santa Isabel, till we reach the eastern boundary of the Tertiary against the Habana Formation and Tuff Series near San Juan (de los Yeras), we find white marls and marly limestones, with low dips and varying strikes in gently undulating structures. Sometimes these rocks are sterile, sometimes they are seen to contain abundant Smaller *Foraminifera* that could not, however, be determined specifically. At A. 126 we again find specimens of *Discocyclina*, which mark the eastern limit of the Upper Eocene, as we find tuffites and glass-tuffites of the Habana Formation directly eastward (A. 138), with limestones containing abundant Rudists at H. 196.

Santa Clara — Bernia.

(See section I).

We begin with Serpentines and pass to the northern side of a large patch of intrusive dioritic rocks, that form a white hill, standing out clearly in the brownish-red serpentine country. It consists (A. 391—399) of diorites, diorite-porphyrites and albitites, that show evidences of having been under considerable stress. Several rocks have a strongly cataclastic structure, whilst in those where this is not the case the quartzes show anomalous, undulous extinction.

At L. 535 we pass into a small zone of limestones, carrying remains of Ammonites. The limestones are intercalated in rocks from the Tuff Series. These comprise green tuffs and tuffites, with a southern dip. The determination of the Ammonites by Prof. Jaworski has yielded species occurring elsewhere in the Turonian or the Emscherian, so we may date the sediments at the boundary between these two formations; that is to say, between the Middle and Upper Cretaceous. In the field the petrographic character of the well-bedded, fine-grained limestones is identical with that of the Aptychi Limestones. The latter are, however, of Lower Cretaceous age, and alternate with rocks from the Tuff Series of much deeper zones.

The highest beds of the Tuff Series are exposed between L. 538 and L. 540. They are formed by grey, thick-bedded radiolarian limestones, which are directly overlain by coarse green Habana tuffites, characterised by large fragments of clear basic plagioclase felspars and quartz, together with fragments of light-green augite and grains of magnetite, with a glassy matrix. Till South of Bernia we find outcrops of green tuffs and tuffaceous limestones, alternating with pure limestone-beds, that frequently contain Rudists. In the neighbourhood of Bernia the beds have a northern dip and consequently more to the south at H. 198 we find the porphyrites and tuffs of the Tuff Series again, that are overlaid at H. 196 by Habana Limestones with Rudists and a sill of augite-porphyrite at H. 213. We thus find the Habana limestone in a large syncline, that can also be traced further East, between Santa Clara and Seibabo (See section II) and between Santa Clara and Provincial. Here it has become much smaller, and we could not trace it further eastward. If, in the syncline at the section over Bernia, we try to connect different layers of the northern and southern flanks, we fail to do so, as the single series of observations taken is not enough. The southern flank is much thicker and we can explain this in two ways. First there might be an overthrust, in the northern flank, by which part of the Habana Formation could be concealed. This is not very probable taking into account the general appearance of the structure, which, with its gentle dips, does not suggest anything so violent as overthrusting. Secondly, we may explain the difference, by the thinning out of the beds towards the North, which is very probable in a series of beds, whose lithology (Rudists, large angular tuff fragments) suggest a littoral sedimentation, and becomes even more so in connection with the fact, that the Habana Formation is transgressive over the older Tuff Series.

Baez — Guaracabulla — Falcon.

(See section III).

From Baez to Guaracabulla, we pass through the Tuff Series and find porphyrites and, locally, well bedded tuffs, with a dike of augite-diorite-porphyrite at L. 519. In this neighbourhood the tuffs have a general strike of N. 95 E. and a northern dip.

North from Guaracabulla we find green tuffs and glass-tuffs with concordant layers of porphyrite. General strike is about N. 110 E. with a southern dip. Guaracabulla thus lies in a syncline, which most probably is the same structure as the Habana-syncline further West, although its axis here has become so high that no more Habana Formation rocks are found. From M. 402 onward we find weathered green rocks, which on microscopical examination are found to be silicified spilites. They have the same texture as the true spilites, with small, twinned cloudy laths of acid plagioclase felspar, irregularly lying in all directions. But most of the pyroxenes are altered into chlorites, whilst on many places secondary patches of quartz are seen, intergrown with chlorite, calcite and epidote or zoisite; thereby proving their secondary nature. We may regard these rocks as normal spilites from the Tuff Series, that have become silicified by the dikes of diorite, that are found at M. 407. This locality is an abandoned gold mine, the Mina Isel.

We find here Dioritic rocks, such as diorite and diorite-porphyrite, close to the same silicified spilitic rocks. The works being abandoned, nothing can be said about the underground structure, but all the waste lying around consisted of Dioritic rocks, so we may safely assume the diorites were the bearer of the ore.

Immediately North from the Mina Isel begins a bare hill, formed by Serpentines, that is to be seen running through the country, with a general East—West strike. More to the West, we find the same contact, between Tuffs and Serpentines, along the southern side of the Serpentine-formed Sierra Alta de Agabama. Here we find tuffoid rocks with strikes, that are cut off by the contact between Serpentines and Tuffs, which proves this contact to be tectonical. We may safely assume the same between Guaracabulla and Falcon, although in the spilitic rocks South of the contact no stratification is found. So the intrusion of the Diorites has followed the plane of faulting, by which the older Tuff Series and Serpentines were brought into contact.

The Serpentines are replaced by spilites from the Tuff Series before M. 412, At M. 416 these rocks are again silicified, and between M. 416 and M. 419 we find Dioritic rocks, consisting of dikes of albitites and amphibole-albitites, that account for the silicification in the spilites. Well bedded brownish or green very fine grained radiolarian tuffites, with occasional interbedded diabases or spilites follow in a synclinal structure, till we reach Serpentines, with a dike of malchite at M. 434, just before the railway station of Falcon.

More eastward, the second zone of Tuffs is also found Southwest of the Carretera Central (See section IX). Here it contains limestones with Ammonites at M. 604. The well bedded limestones are identical in petrographic character with those from the Aptychi Limestones, but the Ammonites found indicate a much younger age, e. g. the boundary between Middle and Upper Cretaceous (JAWORSKI in litt.).

In this neighbourhood we also find at M. 613 the asfalt mine Anna Maria. The asfalt is found in two main bodies, at the contact of Tuff Series and Serpentines, which stikes N. 130 E., with a steep western dip, and must have accumulated along an overthrust-plane between the two formations. The rocks of the Tuff Series, that outcrop here, are unstratified tuffs, with many sills and dikes of porphyrites, and as such cannot be considered as producers of the asfalt. This has probably come from limestones, intercalated in the Tuff Series lower down, whilst the only means of escape was through fissures along the contact between the more or less impermeable rocks from the Serpentines and from the Tuff Series. In general the rocks of the latter formation ; being well stratified and folded, will be reasonably permeable. In this particular case however, with the local abundance and diversity of porphyrites, there might not be a great difference, as to permeability, between the Tuff Series and the Serpentines.

Chapter VIII : **PREVIOUS LITERATURE.**

The existing literature on the geology and paleontology of Cuba is rather large and scattered, but mostly of a very summary character. It will not be reviewed here in full.

There are several general reports on Cuban geology (HAYES, SPENCER & VAUGHAN, bibl. 5 ; DE GOLYER, bibl. 2, and WHITNEY LEWIS, bibl. 6), containing descriptions of the stratigraphy and tectonics of the island. Their more detailed descriptions, however, mostly are of other provinces, mainly Habana, Matanzas, Pinar del Rio and Oriente, whereas for Santa Clara only general statements are made. Moreover their stratigraphic divisions are largely based on local sections, with stress laid on local petrographic characters, without stating definitely the paleontologic evidence for the divisions made. For these reasons it would have been doubtful if, by applying old names to the divisions I made in Santa Clara, the statigraphic elements named would be the same as with the older authors. For these reasons, I have not taken into account these older geologic descriptions, and have given an account of the geology of the district only, as it appeared from our own observations.

PALMER (bibl. 9.) recently gave a detailed description of the geology in the vicinity of Habana City. Although the geographic distance between Habana City and Santa Clara is rather large, it was clear from the detailed description of the formations, coupled with the fauna PALMER mentions, that his formational divisions are parallel to those I made in Northern Santa Clara. For these reasons I have used the names of Habana Formation for the transgressive sediments of Maastrichtian age, and of Guines Limestone for the Oligo-Miocene, horizontal, cavernous limestones, found South of Quemado ; as PALMER's description of these formations are taken from localities where they are of typical habit and common occurrence.

The other formational names used by PALMER I intentionally omitted, as the outcrops of these formations, found in the vicinity of Habana are of local extent, whilst it is not certain that their habit is representative of Cuban deposits. Until more is known of Cuban geology, I preferred to use stratigraphical names instead of formational names.

SCHÜRMANN (Bibl. 12), very recently published descriptions and analyses of Cuban rocks, with some general statements on Cuban geology. His views differ in several respects from mine, but he does not give geologic evidence for his statements, whilst his find-spot-map is on too small a scale for accurate use. Serpentines are given as syn-orogenetic, and in Habana Province he assumes a second younger sequence of Serpentines. But in the petrographic descriptions a serpentine from the Tuff Series is described also. Stress is laid on two points, which I wish to contend. The Diorites are given as mainly post-orogenetic, in contrast with the syn-orogenetic Serpentines. From the description of the Diorites in this paper it may be seen that these rocks mostly show signs of a cataclastic structure, which in many rocks is very apparent and sometimes becomes predominant. Good, unsheared, dioritic rocks are rare in the district, so we may place them with the syn-tectonic Serpentines.

SCHÜRMANN parallelizes the intrusion of the Serpentines and the later Diorites with the strongest orogenetical phase, before the sedimentation of the Upper Cretaceous. From our observations, it is clear, that this phase was not very strong, compared with the post-Cretaceous phases, which for a large part were responsible for the forming of the imbricate structure of the island.

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ERRATUM:

On the geologic map a small area of Turonian-Emscherian Limestones, South of the Carretera Central between Placetas and Falcon is indicated with a green instead of a blue colour.

Explanation of plate I.

In the figures of the microscopic thin-sections, arrows indicate the position of various minerals. If a crystal lies close to the boundary of the figure, one arrow is used, otherwise it can be found at the point of intersection of two arrows with the same letter. Figures 1, 2, 3, 7, 8 and 9 are made with nicols crossed, figures 4—6 were taken in ordinary polarized light.

fig. 1. Spilite from the Tuff Series, with small phenocrysts of cloudy, acid plagioclase felspar. × 15. Locality L. 411, South from Camajuani.

fig. 2. Schistose Serpentine, built up by antigorite and small patches of bastite, for instance at *a*. × 9. Locality H. 425, Southwest from Santa Fé, at the contact of Serpentines with Aptychi Limestones.

fig. 3. Schistose Eclogite, a foreign inclusion from the Serpentines. Schistose groundmass of omphacite, with idiomorphic crystals of garnet and prisms of green amphibole, for instance at *a*—*d*. × 15. Locality H. 531, Southwest from Santa Fé.

fig. 4. Albite-chlorite-epidote-muscovite-schist, a foreign inclusion from the Serpentines, with clear, poikilitic albite, epidote in small grains (dark), aggregates of greenish chlorite (*a*), prisms of zoisite (*c*), and tables of muscovite (*b*). × 13. Locality H. 115, foreign inclusion from the Serpentines, found as boulder in the Upper Eocene basal conglomerate near Conyedo.

fig. 5. Epidote-Amphibolite, a foreign inclusion from the Serpentines, being built up by green amphibole and epidote in irregular crystals, with some titanite (at *a*) and a small amount of clear albite. × 16. Locality H. 502, South from Encrucijada.

fig. 6. Zoisite-Amphibolite, a foreign inclusion from the Serpentines, with green amphibole (*a*) and prisms of zoisite (*b*) and a rather large amount of poikilitic, quartz-clear albite, with rare leaves of muscovite (*c*). × 15. Locality H. 412, East from Santa Clara.

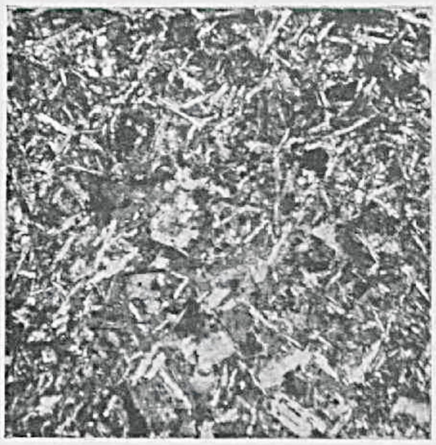
fig. 7. Gabbro, a dike in the Serpentines, with coarsely granular structure, built up by basic plagioclase felspars and rhombic pyroxenes, for instance at *a* and *b*. × 15. Locality V. 164a, East of Santa Clara, on the road to Remedios.

fig. 8. Olivine-Gabbro, a dike in the Serpentines, differing from the Gabbros by the presence of olivine (*b* and *c*). Rhombic pyroxene at *a*. The felspars show lamellar twinning. × 15. Locality L. 355, on the Carretera Central, West of Santa Clara.

fig. 9. Sheared Quartz-Diorite, with cloudy, acid plagioclase felspars at *a* and *b*, amphibole at *c*, quartz at *d* and a shearing-zone indicated at *e*. × 15. Locality M. 465, near San Andres.

fig. 10. Colony of *Diplochaetetes longitubus* WEISSERMEL. Polished surface at the left side of the coral. *a.*: Point of attachment. Locality H. 121, near Conyedo. × 1,4.

fig. 11. *Monticulastrea regularis* KÜHN. Polished surface showing at the right side of the photo. Locality H. 121, near Conyedo. × 2.



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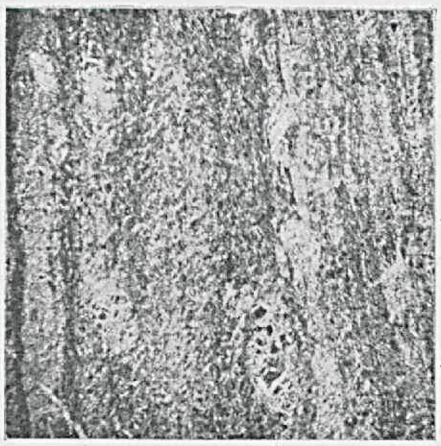

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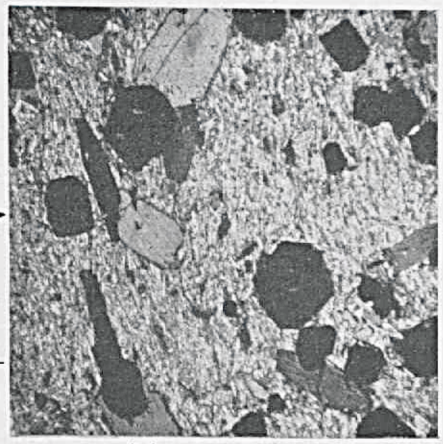

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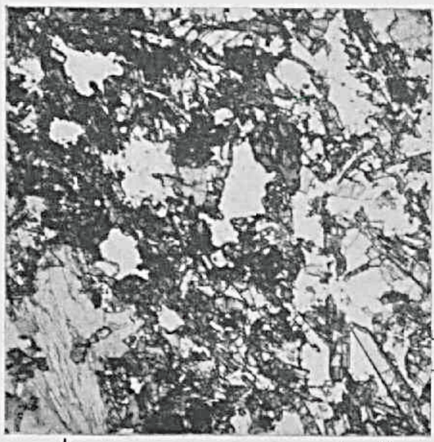

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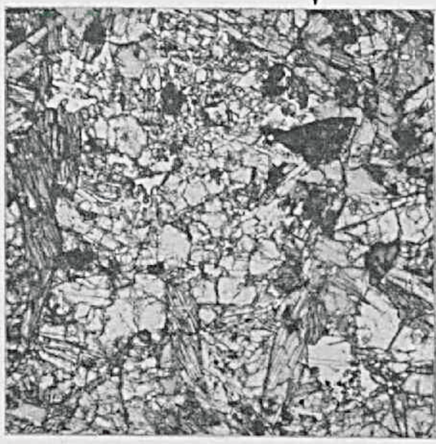

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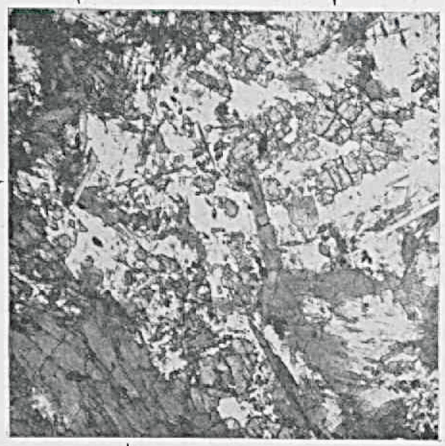

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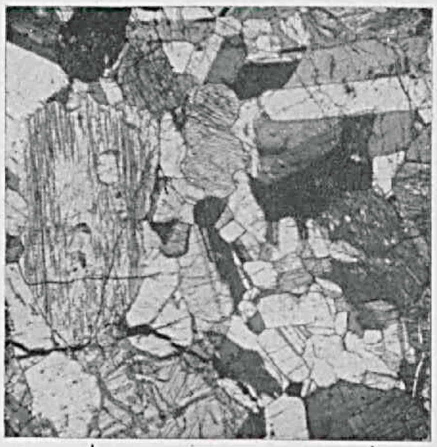

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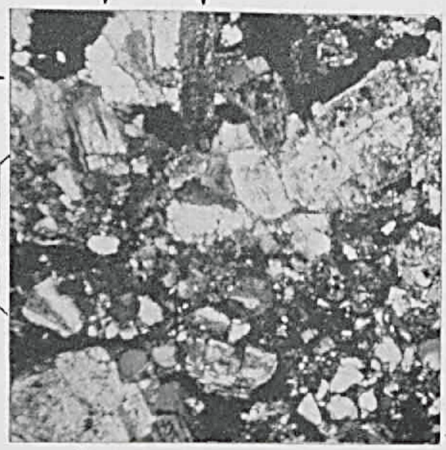


9

10

11

STELLINGEN

I.

Radiolarieten zijn geen bewijs voor diepzeesedimentatie.

D. K. PALMER: The occurrence of fossil *Radiolaria* in Cuba. Mem. Soc. Cubana de Hist. Nat. VIII, 1934.

II.

THALMANN's voorbeelden van een invoering der trinaire nomenklatuur bij fossiele Foraminiferen zijn onvolledig en ten deele onjuist.

THALMANN: Über geographische Rassenkreise bei fossilen Foraminiferen. Paleont. Z. 16, 1934.

III.

De opstelling van het genus *Orbitoina* VAN DE GEYN en VAN DER VLERK geschiedde op onjuiste en onvolledige gronden.

VAN DE GEYN en VAN DER VLERK: A monograph of the *Orbitoididae*, occurring in the Tertiary of America. Leidsche Geol. Med. VII, 1935.

IV.

De meeste diabazen van Bonaire kunnen beter tot de spilieten gerekend worden.

P. PIJPERS: Geology and Paleontology of Bonaire (D.W.I.). Utrecht 1932.

V.

BEREK's bezwaren tegen toepassing der methode van FEDOROW bij mineralen met hooge dubbelbreking zijn ongegrond.

BEREK: Universaldrehtischmethoden.

STELLINGEN

I

Radiokoolstof [illegible]

[illegible]

II

[illegible]

[illegible]

III

De opvatting van het eerste [illegible] gevonden.

[illegible]

IV

De [illegible] worden.

[illegible]

V

[illegible]

[illegible]

VI.

Het bestaan van een ‚Normalzugrichtung' (Geyr von Schweppenburg) wordt door het verloop van de vogeltrek over Nederland niet aangetoond.

VII.

Symmetrische rangschikking der mineralen in metamorphe gesteenten is geen bewijs voor het ontstaan dezer regeling door inwendig glijden van het gesteente (Durchbewegung).

B. Sander: Gefügekunde der Gesteine.

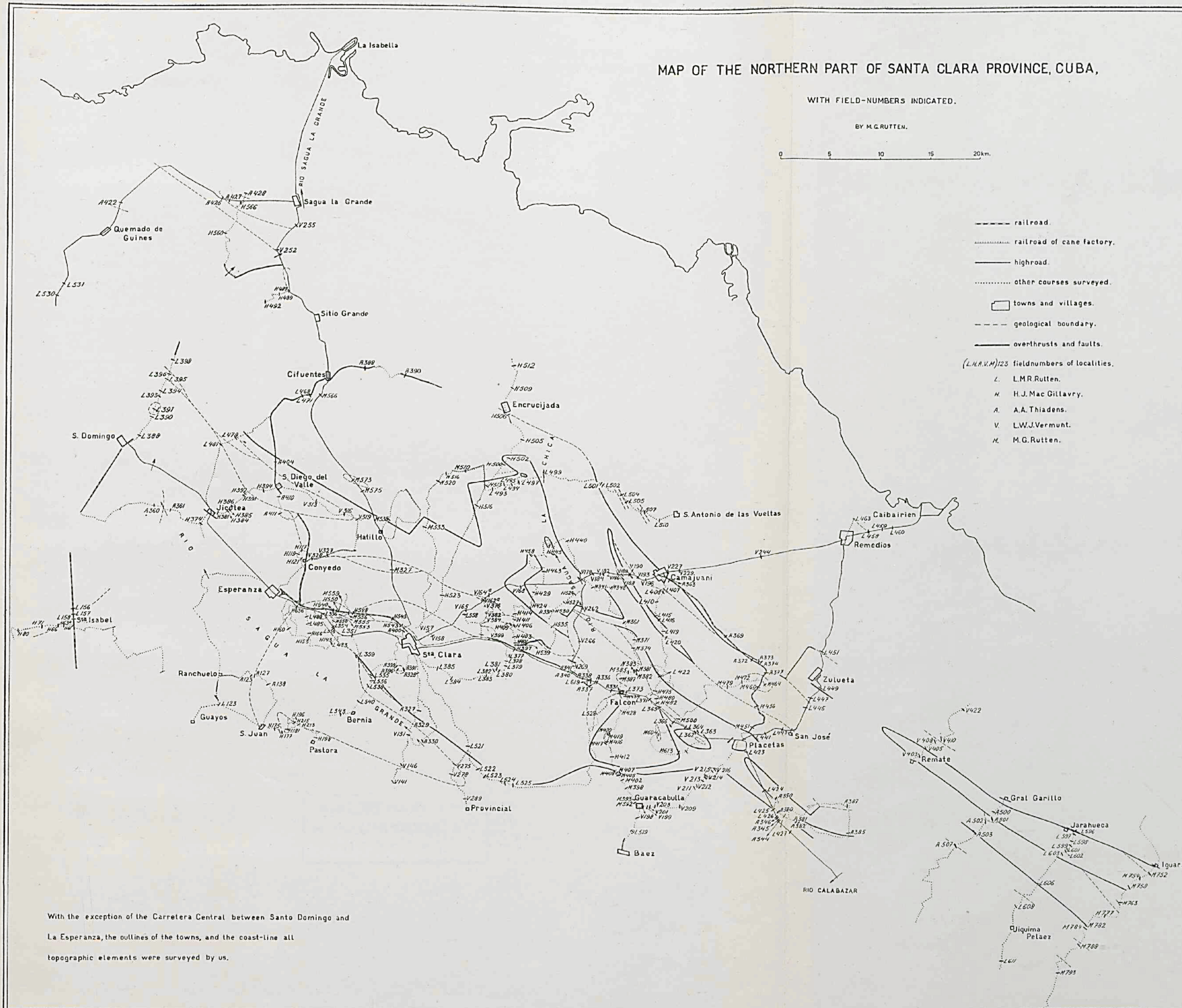
VIII.

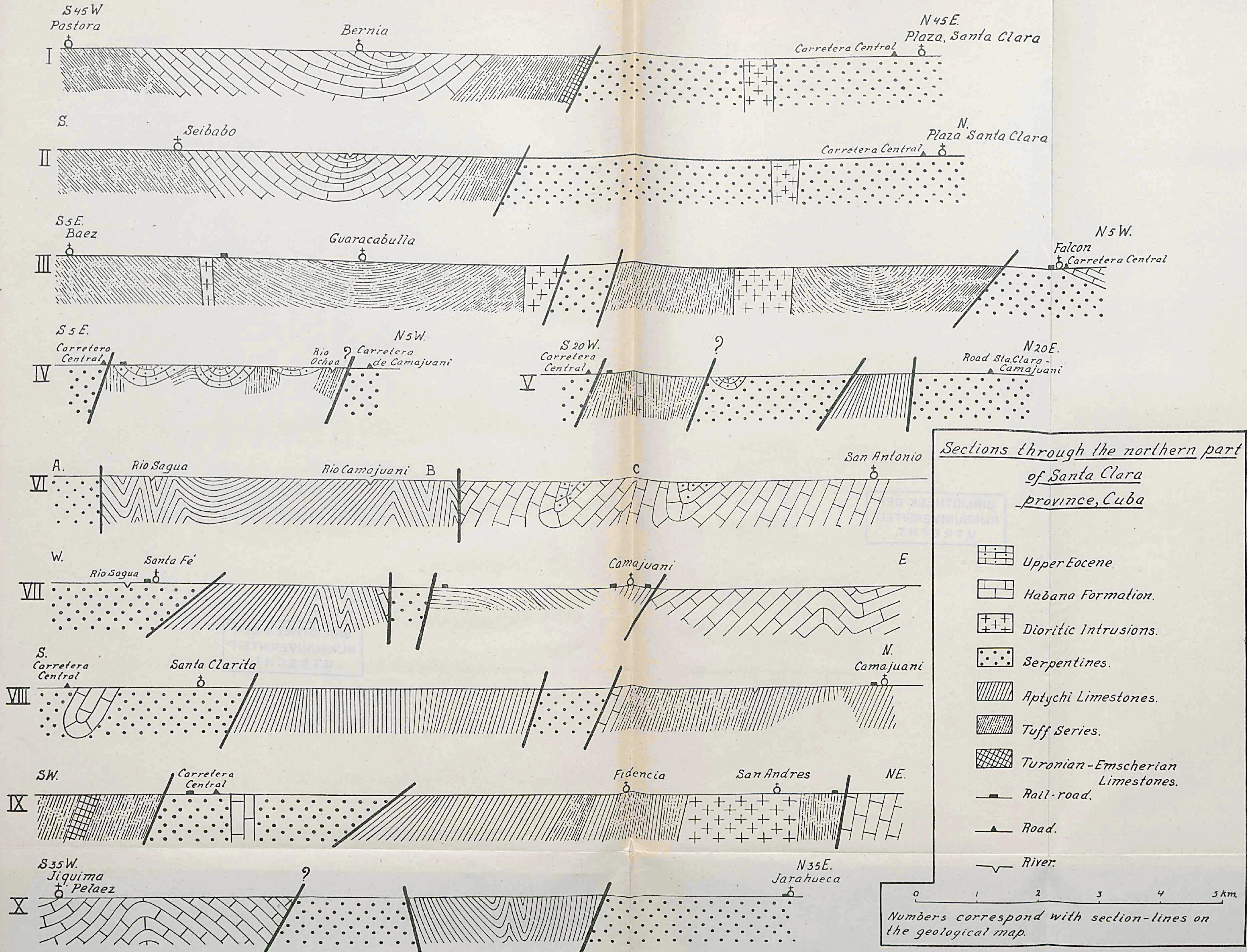
Met behulp van de vloeidruk verklaart men op de aannemelijkste wijze de mogelijkheid van het schaatsenrijden.

IX.

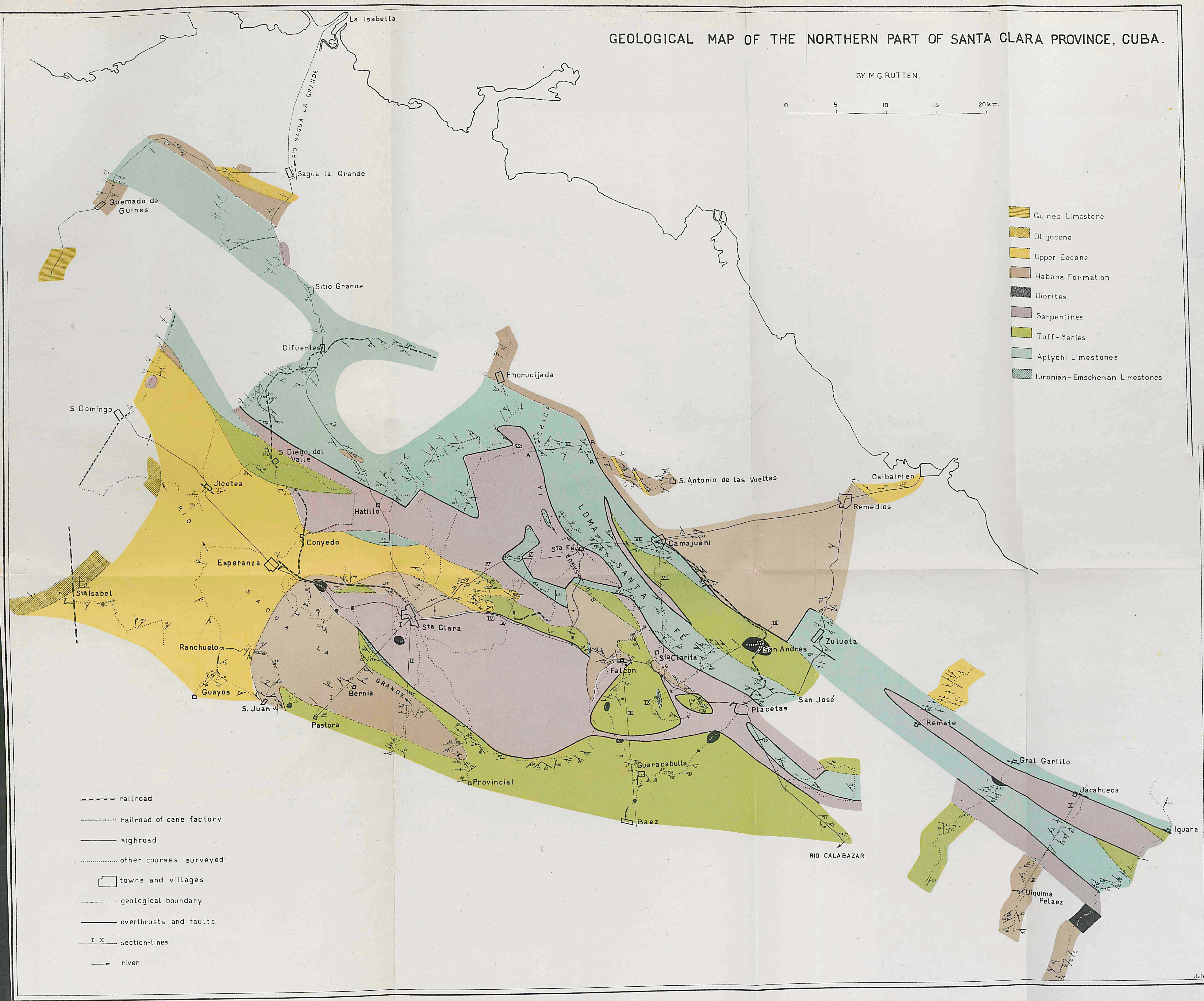
Het zwaartekrachtsveld in de Maleische Archipel wordt door van Bemmelen op aannemelijker wijze verklaard dan door Vening Meinesz.

R. W. van Bemmelen: Über die Deutung der Schwerkrafts-anomalien in Niederländisch-Indien. Geol. Rundschau, XXVI, 1935.


MAP OF THE NORTHERN PART OF SANTA CLARA PROVINCE, CUBA,
WITH FIELD-NUMBERS INDICATED.
BY M.G.RUTTEN.
0 5 10 15 20km.
railroad.
railroad of cane factory.
highroad.
other courses surveyed.
towns and villages.
geological boundary.
overthrusts and faults.
(L.H.A.V.M)123 fieldnumbers of localities.
L. L.M.R.Rutten.
H. H.J.Mac Gillavry.
A. A.A.Thiadens.
V. L.W.J.Vermunt.
M. M.G.Rutten.
La Isabella
RIO SAGUA LA GRANDE
Sagua la Grande
Quemado de Guines
Sitio Grande
Cifuentes
Encrucijada
S. Domingo
S. Diego del Valle
Jicotea
Hatillo
S. Antonio de las Vueltas
Caibarien
Remedios
Conyedo
Camajuani
Esperanza
Sta Isabel
Sta. Clara
Ranchuelo
Guayos
S. Juan
Bernia
Pastora
Provincial
Falcon
Zulueta
Placetas
San José
Guaracabulla
Baez
Remate
Gral Garillo
Jarahueca
Iguara
Jiquima Pelaez
RIO CALABAZAR
RIO SAGUA LA GRANDE
LA CHICA
With the exception of the Carretera Central between Santo Domingo and La Esperanza, the outlines of the towns, and the coast-line all topographic elements were surveyed by us.



These ideal sections are schematic and only serve to give an idea of the larger structures.


GEOLOGICAL MAP OF THE NORTHERN PART OF SANTA CLARA PROVINCE, CUBA.
BY M.G.RUTTEN.
0 5 10 15 20 km.
Guines Limestone
Oligocene
Upper Eocene
Habana Formation
Diorites
Serpentines
Tuff-Series
Aptychi Limestones
Turonian-Emscherian Limestones
railroad
railroad of cane factory
highroad
other courses surveyed
towns and villages
geological boundary
overthrusts and faults
I-X section-lines
river
La Isabella
RIO SAGUA LA GRANDE
Sagua la Grande
Quemado de Guines
Sitio Grande
Cifuentes
Encrucijada
S. Domingo
S. Diego del Valle
S. Antonio de las Vueltas
Caibarien
Remedios
Jicotea
Hatillo
Conyedo
Esperanza
Sta Fé
Camajuani
LA CHICA
LOMA SANTA FÉ
Sta Isabel
Sta Clara
San Andres
Zulueta
Sta Clarita
Falcon
Ranchuelo
RIO SAGUA LA GRANDE
Bernia
Guayos
S. Juan
Pastora
Placetas
San José
Remate
Gral Garillo
Jarahueca
Iguara
Guaracabulla
Provincial
Baez
RIO CALABAZAR
Uiquima Pelaez
J.D.