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

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OF THE SOUTHERN PART OF
THE PROVINCE
SANTA CLARA, CUBA

A. A. THIADENS

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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. W. E. RINGER, HOOGLEERAAR IN DE FACULTEIT DER GENEESKUNDE, VOLGENS BESLUIT VAN DEN SENAAT DER UNIVERSITEIT TEGEN DE BEDENKINGEN VAN DE FACULTEIT DER WIS- EN NATUURKUNDE TE VERDEDIGEN OP MAANDAG 22 FEBRUARI 1937, DES NAMIDDAGS TE 4 UUR

DOOR

AREND ALBERT THIADENS
GEBOREN TE UTRECHT

DEZE DISSERTATIE VERSCHIJNT TEVENS ALS No. 12 VAN DE PHYSIOGRAPHISCH-GEOLOGISCHE REEKS DER GEOGRAPHISCHE EN GEOLOGISCHE MEDEDEELINGEN

AAN MIJNE OUDERS

Aan het einde van mijn studie aan de Utrechtsche Universiteit is het voor mij de vervulling van een lang gekoesterde wensch, dank te brengen aan allen, die het mogelijk gemaakt hebben, dat mijn studietijd een zoo goede is geweest.

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CONTENTS.

INTRODUCTION.

In this paper the geology of the Southern part of Santa Clara Province in the middle of Cuba is treated. The district here described is bounded on the North by a line drawn over Central Caracas, Guayos, San Juan de los Yeros, Central Pastora, Provincial, Baez and the crossing of the Rio Calabazas with the Carretera Central. The Northern part of Santa Clara Province has been described by M. G. RUTTEN (41).

The material which forms the base of this description, has been collected during a geological survey by students from the University of Utrecht, Holland under the leadership of Prof. L. M. R. RUTTEN, with Mrs. C. J. RUTTEN-PEKELHARING, Miss A. RÖNTGEN, my fellow-students L. W. J. VERMUNT, H. J. MAC GILLAVRY, M. G. RUTTEN, and the author of this paper.

The fieldwork in Santa Clara Province has been done during the second part of February, the whole of March and the first half of April of the year 1933 during which time both the Northern part described by M. G. RUTTEN and the Southern part described in this paper have been surveyed. The results of our researches and the notes and samples bearing on the Southern part of Santa Clara Province have been committed to my care to compile a geologic description.

In the field we had at our disposal the military maps of Cuba on the scale of one inch to a mile. Already the first day these maps appeared to be unfit for geological fieldwork and a fortiori for a base of a geological map. Instead of using these unreliable maps we surveyed our own courses by taking the direction with a geological hand-compass and measuring the distance by counting our paces or by noting the speedometer of the motor car. In Holland we had also at our disposal the nautical charts of the American Navy and special blueprint maps of the "Carretera Central", the central highroad along the axis of the island. The construction of the topographical map, which forms the base of our geological map has been carried out as follows : the nautical chart gave us the location of Cienfuegos, Casilda, the Obispo and La Isabella (on the North coast, near Sagua la Grande). In consequence we plotted out the courses between La Isabella and Cienfuegos, using for the Northern part of the Santa Clara Province the map of RUTTEN Jr. and for the Carretera Central the blueprints. According to our survey the distance La Isabella-Cienfuegos was 4 km. shorter than on the nautical chart. To eliminate this difference it would have been best to divide the difference over the whole distance La Isabella-Cienfuegos. This was impossible, as the map of M. G. RUTTEN of the Northern part of the province had already been published. Now there were two things I could do. 1.— I could make the correction of 4 km. in my district only. In that case the distance from coast to coast would agree with the nautical map, but there would be striking mistakes in the map of my district, as for instance the highroad Cienfuegos-Hormiguero, which is 16 km. long, would be on my map 18 km. 2.— I could remove the position of Cienfuegos, Casilda and the Obispo and with them the whole Southern coast 2 km. to the North, and divide the other 2 km. in the traces in my district. In this case our map would not agree with the nautical maps concerning the distance Cienfuegos-La Isabella, but our map would become a better representation of the surveyed roads.

I chose the last construction. Next, the courses Cienfuegos-Cumanayagua-Manicaragua-Santa Clara-Carretera Central-Sancti Spiritus-Obispo and Santa Clara-Placetas-Fomento-Manacal-Trinidad-Casilda were plotted, and after some slight corrections, our map agreed with the nautical chart. As can be seen from the map I had at my disposal several polygons, with the help of which I could make further corrections. The sketch map obtained in this way is more useful than the Cuban military maps. Two maps have been prepared : one to show the geology, and another with the "localities", where determinable rocks or fossils have been sampled. All the courses surveyed by us, and these only are on the maps. As the map shows, the surveyed area is by no means covered by a dense network of observations, our survey having been only a preliminary one. Nevertheless, mostly I filled in the geological map as, according to our conception, the structure and geological history of our area is rather simple. Observations about the landscape and the topography helped us, moreover, to make a geological map covering large areas of the surveyed district. There are, however, in the East part several "white patches" on the map, as on these places more than one interpretation of the data at hand was possible. Moreover, with both maps one can differentiate immediately the "direct observations" and the "interpretations". I intended to put into the map all tectonical observations. Only on places where many observations were made close together, some had to be omitted for the sake of clearness and readableness. This could easily be done as the strikes and dips in these exposures only differ slightly from one another; so there cannot be question of alteration of the tectonical features by subjective selection of strikes and dips on some places.

At T. 1384 and T. 1387A Dr. TSCHOPP, of the BATAAFSCHE PETROLEUM MAATSCHAPPIJ, found Rudists, which he gave to us and which have been described already (47).

The numbers with D "in parentheses" indicate the number in the thin section collection of the Mineralogical-Geological Institute of the State University in Utrecht.

Previous literature is treated in the last chapter. This has been done since our survey has been the first more or less detailed one of this part of the island. The literature is of more general character, and has not influenced our survey to a large extent.

This paper is written in English in order to make it accessible to the many American geologists who are studying the West Indies.

To all those who have given me help and advice I am greatly indebted and I wish to express my sincerest thanks for it.

I tender my thanks in the first place to the "MOLENGRAAFF-FONDS" and the "BATAAFSCHE PETROLEUM MAATSCHAPPIJ" for their financial support to our field work. To the "BATAAFSCHE PETROLEUM MAATSCHAPPIJ" moreover I am beholden for several fine fossils from Southern Santa Clara Province.

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Mr. J. van Dijk prepared for publication the maps and photographs of this paper with careful application. Mr. J. Grootveld and Mr. J. Vermeer made the many thin sections.

Mr. Vickers read and revised the english text of the paper.

Chapter I: **GEOLOGICAL HISTORY.**

The core of Southern Santa Clara Province here described consists of Cretaceous and, very probably, Upper Jurassic rocks, bordered and partly covered by younger Tertiary rocks belonging to the Eastern part of the Colon basin and the Western part of the Moron basin.

Geologic history begins with the genesis of those rocks, which furnished by metamorphism the schists and marbles of the Schist Formation. The age of these rocks cannot be stated with certainty, as fossils, if formerly present, entirely disappeared in consequence of the metamorphosis. By comparison of these rocks with others, found elsewhere on Cuba and on surrounding islands, it may be deduced that the age is very probably Lower Cretaceous and Upper Jurassic. This age, however, has not been proved and the rocks may be very well older. They are at least of pre-Middle Cretaceous age. The Schist Formation comprises many paraschists and probably some orthoschists, all belonging to the "meso-zone". They mainly consist of quartz-bearing marbles and mica-schists.

The facies of the original rocks (calcareous and argillaceous) is not known, because of to the high grade of metamorphosis. The thickness of the complex, being about 11000 m., proves that the sedimentation of these rocks took place in a region of strong submergence. The Schist Formation outcrops in the Southern part of the district in two large cupola-like anticlines, forming the three Sierras of the Trinidad Mountains. The serpentine schists of the Schist Formation easily may be distinguished from the Upper Cretaceous serpentines of the large serpentine massive in the Northern part of the Province.

The next following formation is the Middle Cretaceous Tuff Formation, consisting of volcanics (porphyrites, diabases, spilites, glass-tuffs, crystal-tuffs and tuff-porphyrite-breccias) and sedimentary rocks among which the Provincial limestone with Caprinids and many other fossils. These rocks are very probably of Cenomanian-Turonian age, and have been formed in a sea with varying depth during a long general subsidence. The Tuff Formation is very thick. In one section we found a thickness of 8000 m.

Following the volcanic and sedimentary deposition of the rocks of the Tuff Formation and Provincial limestones, enormous masses of dioritic magma intruded. Serpentine, occurring only in one small exposure, is of minor importance. The first consolidation products of the dioritic magma are hooibergitic rocks, which are mostly found altered by dynamo-metamorphism and contact-metamorphism, the latter caused by the somewhat later consolidated quartz-dioritic rocks and the aplitic dikes. The large bulk of the intrusive mass, which probably is a batholith, is built of quartz-diorite with aplitic and lamprophyric dikes and some quartz-diabases.

On the Northern side of the intrusive mass quartz-diorite-prophyrites are common and the rocks of the Tuff Formation are affected by contact metamorphism on many places. At the end of the intrusion, after the consolidation of the igneous rocks and before the sedimentation of the rocks of the Upper Cretaceous Habana Formation, orogenic forces caused rather strong folding and faulting. Probably the schists came to the surface during this orogenesis. The schists and diorites are separated from each other very probably by a long straight fault. In the dioritic rocks many inclusions of amphibolitic rocks are found, which are altered gabbros, altered hooibergites, magmatically stooped porphyrites of the Tuff Formation and rocks of unknown origin.

After the intrusive and orogenetic activity followed a period of denudation, and then the sedimentation of the transgressive rocks of the Habana Formation of Uppermost Cretaceous age. The rocks of this formation contain a rich fauna of *Foraminifera* and Rudistids and other fossils. Because of the occurrence of species of the genus *Lepidorbitoides* we may parallellize this formation with the Maastrichtian in Europe. At the side of Orbitoidal and Rudist limestones and marls, in this formation vitric tuffs, crystal tuffs and many tuffaceous limestones are found, witnessing a slight volcanic activity during its sedimentation. Porphyrites, although very probably observed N. of Guayos (Carretera Central) have not been sampled in the district. The rocks of the Habana Formation have been deposited in a shallow sea. A minimum thickness found in our district is about 700 m.

After the sedimentation of the rocks of the Habana Formation a second orogenesis begins and a large stratigraphical gap is found between the Maastrichtian and Upper Eocene.

The character of this second orogenesis has been stronger in the NE. part of the district than in the SW.part.

Following the second orogenesis and a second period of denudation, limestones and marls of Upper Eocene and Oligocene age have been formed, lying in conformable beds. The age of these rocks is determined by many Larger *Foraminifera* amongst which species of the genera *Dictyoconus*, *Camerina*, *Lepidocyclina*, *Helicolepidina* and *Discocyclina* (Upper Eocene), and the subgenus *Eulepidina* (Oligocene). These rocks are slightly folded, indicating the existence of a third orogenesis. The age of this orogenesis is pre-Upper Oligo-Miocene as Upper Oligo-Miocene rocks with *Miogypsina* and *Amphisorus* are found almost or quite horizontal.

After this third orogenesis Upper Oligo-Miocene marls and conglomeratic limestones were formed, carrying species of the genera *Archaias*, *Amphisorus* and *Miogypsina*.

West of Jatibonico these rocks are found dipping very gently over a large distance, proving that a fourth, post Upper Oligocene-Lower Miocene orogenesis occurred. The complex of Tertiary strata is very thick. N. of Trinidad e.g. about 3000 m. South from Manacal the transgressive Tertiary beds form a 5000 m. thick complex.

Chapter II: **STRATIGRAPHY AND PETROGRAPHY.**

Schist Formation.

We find the Schist Formation in the Southern part of the Province where it forms the Sierra de San Juan, Sierra de Trinidad and, very probably, the Sierra de Sancti Spiritus. These Sierras are strongly accidentated mountains, reaching an elevation of 981.5 m. in the Pico de Potrerillo.

The Schist Formation comprises the following rocks : quartz-marbles, crystalline limestones, calcite-quartz-schists, mica-schists, quartz-mica-schists, gneisses, quartz-chlorite-muscovite-plagioclase-schists, chlorite-schists, calcite-chlorite-schists, calcite-quartz-chlorite-schists, serpentine-schists, amphibolites, amphibole-albite-epidote-schists, actinolite-schists, and calcite-actinolite-schists. The large bulk of the Schist Formation is formed by the mica-schists and marbles. This two types of rocks are rather evenly distributed and alternate continually with one another.

In the Sierra de San Juan and the Sierra de Trinidad the rocks of this formation form a large cupola-like anticline, as can be seen from the dips on the map. At some localities on the uttermost North border of this cupola we find the schists vertical and even overturned with a steep southward inclination. In the Sierra de Sancti Spiritus the formation, very probably, forms another dome-like anticline. We are, however, not absolutely sure about this last mentioned cupola, as the survey in this part of the district has been unsufficient.

As can be seen from the sections, the Schist Formation is a very thick complex. On the North side we find a thickness of about 11700 m. and on the South side of 7100 m.

All the rocks of this formation show more or less traces of cataclasis. On some places this cataclasis has been rather strong.

The Schist Formation is bounded on the South by transgressive Tertiary, on the East, North and partly on the West by rocks of the Dioritic Intrusion, and on the North-West by rocks, belonging to the Tuff Formation. No evident traces of contact metamorphism have been found, and, as the schists are the oldest rocks of the district this probably might be an indication for the supposed fault on the boundary between the Schist Formation and the dioritic rocks. This will be discussed in the chapter on Tectonics.

AGE: In the geologic history we placed the Schist Formation at the beginning. In consequence of the rather strong metamorphism, fossils, if formerly present, have entirely disappeared. So it is impossible to state the age with certainty. There are, however, geological evidences for our assumed age.

The Schist Formation is pre-Tertiary as it is covered by transgressive Tertiary beds, which contain detritical schist material.

The schists are pre-Upper Cretaceous, since we find detritical schist material in the Maastrichtian beds.

The Schists Formation is pre-dioritic, as, in Isla de Pinos (36) a malchite intrudes clearly a formation of schists, which are in every respect comparable with those of Santa Clara. In the Santa Clara region itself it is difficult to find arguments, which prove the above-stated age-relation. The occurrence of small patches of diorite within the schists area on the railroad Fomento-Trinidad (M. 667, D. 16773, D. 16774; and M. 715, D. 16782); and the occurrence of compact pyritic ores at the Mina Carlotta (M. 254, D. 16715) SE. of Cumanayagua within the schists seem to prove the same age-relation. On the other hand it is striking, that no true contact-metamorphosis has been observed in the schists near the contact of the diorites.

The schists are very probably older than the peridotites-serpentines of Northern Santa Clara. M. G. Rutten describes inclusions in these serpentines of meso-zonatic metamorphic rocks, comprising: amphibolites and actinolite schists and moreover glaucophane- and muscovite schists. Of these rocks the albite-amphibolites and the actinolite schists are highly alike those found in the Schist Formation and described below. This makes it very probable, as Rutten already noticed, that those inclusions "have originated from a formation in the deeper underground of the province, which is the equivalent of the Schist Formation". (41 p. 17). If this last supposition holds true the Schist Formation is older than these serpentines. It must be observed, however, that in the Sch. Form. no glaucophane-and muscovite schists have been found, and only at some localities amphibolites, while the marbles and mica schists and gneisses, which form the great bulk of the Trinidad Mountains, do not occur as inclusions in the Serpentines in Northern Santa Clara. Perhaps, here we are dealing with different facies of the same formation.

The schists are older than the rocks of the Tuff Formation for the following reason: the tuffs dip away from the schists, as can be seen from the map. If the Schists are autochtonous, which is highly probable, they must be the oldest rocks of the region, forming, a large, highly metamorphosed, crystalline complex.

The most important argument for our assumed age we find in the comparison with the lower part of the San Andres Formation in mountain ridges of Pinar del Rio. Here L. W. J. Vermunt (58) found quartzites, marbles, crystalline limestones, phyllites etc. all of which show a great analogy with the Trinidad schists, although they are less metamorphosed. In the San Andres Formation Upper Jurassic Ammonites and Lower Cretaceous Aptychi (54) have been found in concordant intercalations. Comparing the Trinidad schists with the lower part of the San Andres formation we presume an, at least, Upper-Jurassic age for the Schist Formation in Southern Santa Clara.

Petrographic description.

Marbles and Crystalline limestones. Dark grayish-blue rocks, cut by many white calcite veins, thin-bedded or in very thick layers. Coarse- to medium-grained, clearly crystalline, and mostly clearly foliated. The quartz-bearing marbles are of lighter colour than the crystalline limestones. The former are compact crystalline with dark and light patches. Microscopically they show a coarse granoblastic structure. Large calcite crystals, often polysynthetically twinned, contain poikilitic quartz "drops" and, in distinct portions, a dusty, dark powder of a black mineral which, very probably, is graphite. In one almost black rock the graphite occurs in such a large amount, that it could be separated and tested (M. 240, D. 16707). Sometimes a few muscovite flakes are present. The crystalline limestones show microscopically a medium-grained, granoblastic structure with the following components: inequigranular calcite, almost always with polysynthetic twinning and also very often with compound twinning; often interlocking grains; a varying amount of homoeoblastic quartz grains; always a constant amount of small muscovite flakes, situated parallelly to the schistosity. Accessory components are albite and orthoclase, pyrite in varying amount, magnetite, apatite, zircon and graphite. The pyrite occurs in cubes, which often are altered into hematite. Magnetite occurs in small and large crystalls, often changed into limonite. Albite and orthoclase are clear.

It is difficult to state whether we have to deal with epi-meso- or kata-marbles. The unequigranular, coarse to medium granoblastic structure and the mineral composition probably point to the meso-zone.

Between the quartz-bearing crystalline limestones and the gneisses and mica-schists we found transitional rocks. L. 27 (D. 17107) and V. 97 (D. 16845, D. 16846) are fine schistose rocks with dark-blue and grayish layers sometimes micro-folded. These rocks are granoblastic, built up by quartz and calcite in varying amount. There are layers with predominant calcite and other ones with predominant quartz, while some layers are built up entirely by quartz, which is fine grained and shows strong schistose structure. Sometimes a small amount of dark pleochroitic biotite flakes mark the microfolds. Accessorily there is always a varying amount of oxidic ore. At M. 241 (D. 16710) a very lose foliated, gray-green coloured calcitic-mica-schist occurs, which is composed of alternating layers of mica-schist, and quartz-marble, and of transitional patches with medium-to coarse-grained calcite, quartz, mica and oxidic ore with accessory titanite.

The mica-schists are white-lightgreen-gray crystalline rocks, more or less strongly foliated. The components are quartz and colourless or green mica and oxidic ore. The quartz shows a certain tendency to elongation in the common direction, while the slender flakes of the mica show a clearly parallel arrangement, and sometimes forms streaks through the rock. The quartz is coarse-to medium-grained, only somewhat interlocking. The mica is muscovite or biotite, the latter p.p. altered into chlorite. The oxidic ore is magnetite with hematite. Accessory there may be some colourless garnet and apatite.

The gneiss is whitish to grayish and rather coarse-grained. The components are quartz, forming the large bulk, orthoclase, albite, oligoclase, muscovite, calcite as constituents in medium amount and accessorily apatite and oxidic ore. The structure is granoblastic, slightly interlocking. Orthoclase contains poikilitically small fragments of the other minerals. Albite and oligoclase are clear, the latter typically showing the plagioclase cleavage. Quartz forms interlocking, inaequigranular grains, muscovite broken plates.

At M. 254 we found a quartz-chlorite-muscovite-plagioclase-schist (D. 16719). Predominent component is quartz in medium to coarse, interlocking grains. Albite and orthoclase, light green fibreous and spheroidal chlorite, muscovite, zoisite, apatite, pyrite, hematite and limonite are the other components. This rock is a transition between gneiss and quarzite.

Chlorite-schists A. 247, (D. 17020); L. 259, (D. 16453, D. 16454); L. 563, (D. 16599); V. 61, (D. 16821) are light-green to green, greasy, more or less foliated rocks, weathering with a red-brown colour. Microscopically we see a dense, scaly aggregate of chlorite with zoisite and magnetite, and accessory calcite. The chlorite is clinochlor with refractive index of 1,59. Zoisite forms rather large idiomorphic grains. Magnetite is granular.

At A. 297, (D. 17018, D. 17019); M. 154, (D. 16668) and M. 669 in Manacal (D. 16775) serpentine-schists are found. The rocks are light to dark green, compact and, in one case, foliated. Under the microscope we see bordering against one another some patches of serpentine with "Maschenstruktur" and many others with fibres arranged in beautiful "Gitterstruktur". In one thin section we found a "Gitterstruktur" with the serpentine flakes arranged in the direction of amphibole cleavages as can be seen on the photograph. (Plate, fig. 1). This serpentine has a refractive index of 1,56 and a positive optical character. These rocks probably originated from an amphibole-peridotite. They are clearly different from the serpentine from L. 117 (D. 16408) described below and the serpentines from the Northern half of Santa Clara described and figured by M. G. Rutten.

Amphibolites (L. 628, D. 16630) are light green, foliated rocks, showing macroscopically amphibole and plagioclase grains. Microscopically the rocks appear to be holocrystalline poikiloblastic. Components are coarse grained plagioclase which is very clear and contains inclusions of the other constituent minerals, amphibole: light green, not pleochroitic, in large porphyroblastic and smaller grains, calcite, chlorite, epidote, muscovite and titanite. The amount of epidote can become equivalent or even larger than the amount of amphibole. Then we have epidote-amphibolites.

The actinolite-schists (L. 628, D. 16628, D. 16629) are of highly schistose structure. The rocks are built up entirely by actinolite and epidote, both of which form large elongated crystals. Finer grained actinolite schists with a porphyroblastic structure occur also. Here actinolite forms the porphyroblasts, laying in a nematoblastic groundmass existing of actinolite, chlorite, magnetite and hematite.

Calcite-actinolite-schists (V. 103, D. 16847; M. 258, D. 16721) of the Trinidad mountains are green slightly foliated rocks. Microscopically they show a highly foliated texture, porphyroblastic with a fibroblastic groundmass. The porphyroblasts are poikiloblastic. The components are calcite in elongated crystals, albite and oligoclase with parallelly arranged inclusions, long and short streaks of actinolite parallel to the common direction or not so, rounded zoisite grains, rounded and elongated epidote grains, pyrite and titanite.

At V. 92 (D. 16843) we found a green, grainy foliated plagioclase-epidote-actinolite-schist which microscopically shows a highly poikiloblastic structure. It is built up by clear albite and oligoclase grains containing many inclusions, epidote grains and needles, some quartz, and calcite, and much fibreous light green actinolite crystals together with muscovite and chlorite. Oxidic ore and titanite seem to be accessory.

Almost all rocks of the Schist Formation show more or less clearly traces of cataclasis. The calcite twins are bent or broken, the quartz shows undulatory extinction, and, when the cataclastic action has been stronger, we see a clear mortar structure, especially around the quartz and calcite crystals. The structure and composition of the rocks suggest that they belong to the mesozone, and that most of them are para-schists.

Tuff Formation.

This formation comprises both volcanic and sedimentary rocks.

The former are porphyrites, diabase-porphyrites, diabases, spilites, vitric tuffs, crystall tuffs and tuff-porphyrite breccias. The latter are cherts, limestones and marls. The volcanic rocks alternate with one another, and the limestones, which furtheron will be called the Provincial limestones, are found clearly intercalated in the tuffs and porphyrites. On the map these limestones got a separate colour at those places where we were certain of their existence. One should bear in mind, however, that there are more Provincial limestones in the district.

The rocks of the Tuff Formation are found mainly in a broad uninterrupted zone running WNW-ESE along the Northern side of our district.

Here they dip monoclinally to the North and, as in the Northern half of Santa Clara Province we find the adjacent rocks of the same formation dipping to the South, we roughly can speak of a large synclinal in the central part of the island. As we can see from the schematic sections annexed to this paper and from those of M. G. Rutten this formation may have a thickness of about 8000 m.

To the East the direction of the strike changes clearly, bending from ESE-WNW to ENE-WSW.

In the broad synclinal the Provincial limestones form a rather distinct zone near the Northern border of the map. They form steep mountains 100—200 m higher than the surrounding hilly plain. Near Provincial the Provincial limestones are found clearly intercalated in the tuffs, cherts and porphyrites, several times alternating with them.

The rocks of the Tuff Formation outcrop moreover South of the above mentioned synclinal zone, at places where the Upper Cretaceous and/or the Tertiary transgressions do not cover them as e.g. N., NE. and E. from Sancti Spiritus and E. and S. from Soledad. West of Cabaiguan the Tuff Formation outcrops in the core of an anticline of the Upper Cretaceous beds.

Age. The age of this formation is very probably Cenomanian-Turonian, as the fauna of Caprinids occurring in the conformably interbedded Provincial limestones can be parallellized with Cenomanian-Turonian faunas in Mexico, namely with the faunas at Soyatlan de Adentro (Jalisco) and of the Escamela Limestones (Orizaba) described by R. H. Palmer (30). I studied the Cuban fauna and published the results of this study separately (48). The age of the Mexican faunas is discussed in this study, and I concluded that we can be pretty sure that the Cenomanian-Turonian age, stated by R. H. Palmer and others is right. So we accept this age for the Provincial limestones too. This agrees rather well with the Turonian-Emscher age assumed by M. G. Rutten for the uppermost beds of his Tuff Series, on the base of Ammonites studied by Jaworski. In the Southern part of the Province the limestones with these Ammonites have not been found by us, probably, because the uppermost beds of the Tuff Formation are not exhibited in this area.

The contact phenomena in the Tuff Series near the contact with the diorites prove that the Tuff Formation is older than the diorites. These contact phenomena is treated at page 18—21.

Petrographic description.

The porphyrites are dark-green to dark-gray, fine-grained, hard, rather fresh rocks with clearly porphyritic texture, the phenocrysts being light green. Sometimes the rocks are amygdaloidal. On weathered surfaces they are yellow to brown. The porphyrites are often found as large blocks of several cubic metres. In the neighbourhood of bedded tuffs or cherts they occur in concordant beds.

Microscopically we see a well established porphyritic texture. In some rocks the amount of the groundmass is larger than that of the phenocrysts; in other rocks they are about equivalent. The phenocrysts are plagioclase and monoclinal pyroxene, the former prevailing above the latter. The plagioclase is mostly found in groups of several phenocrysts; they are drifted together and grown together. The average composition of the unaltered plagioclase ranges from andesine-labradorite to bytownite. The phenocrysts are tabular and show lamellar and intersecting twins. Often albitisation is found, beginning along fissures. The monoclinal pyroxene is a colourless diopsidic augite. It occurs in large, idiomorphic phenocrysts, which are sometimes twinned, and sometimes in smaller grains too, gradually diminishing in diameter, and passing into the augite microlites of the groundmass. In one slide yellowish-green amphibole has been found in large phenocrysts (V. 40, D. 16812, D. 16813). Large magnetite grains always are present. Apatite in large crystals has been found as an accessory mineral. The groundmass is holocrystalline, built up by small plagioclase prisms, sometimes more or less fluidally arranged, tending to a trachytic texture; moreover of augite grains, magnetite and chlorite between the plagioclase laths. The composition of the plagioclase of the groundmass sometimes could be classified as andesine-labradorite. The amount of plagioclase and augite in the groundmass of fresh rocks is about equal. Chlorite is an alteration product of both, plagioclase and augite. The amount of magnetite varies strongly. In some cases it predominates above the other components and then the rock is almost black. In other cases it occurs in a small amount only and we have light coloured porphyrites. The felspars decompose by weathering into chlorite and calcite, zeolites or zoisite. Sometimes the decomposed felspars are surrounded by an ore rim. Augite is altered into uralite and epidote or calcite; in the groundmass into chlorite too. Silicification is found sometimes, resulting in the occurrence of secondary quartz throughout the groundmass. The amygdales are filled in with calcite, quartz, spheroidal prehnite or spheroidal chlorite.

The diabases are dark-green, medium-to coarse-grained, crystalline rocks. Mostly the rocks are fresh. On weathered surfaces they are brown. Pillow structure has been found once. Microscopically the texture is more or less porphyritic; transtional diabase-porphyrites between coarse-grained porphyrites and normal diabases are met with. In the diabase-porphyrites the amount of phenocrysts predominates largely above the groundmass. Ophitic or subophitic texture always is present. The main constituent minerals are pyroxene and plagioclase. The plagioclase is developed in large, tabular, twinned crystals, which mostly are clear or have zonally arranged inclusions of dust. Albitization, as in the porphyrites, often is met with. Pyroxene occurs in large and smaller crystals. It is colourless to light-green, diopsidic augite, showing beautiful cleavage and twins. Seldom the augite is found in idiomorphic crystals, mostly in allotriomorphic ones. In one sample olivine has been found in large crystals, which are decomposed by serpentinisation. The olivine is colourless to salmon coloured, pleochroitic. In this case we have an olivine diabase. Magnetite forms many large grains, apatite long needles. Occasionally quartz is found in a small amount. It seems to be primary and occurs interstitially. Mostly the plagioclases are idiomorphic with regard to the quartz, sometimes the borders show an irregular granophyric intergrowth (L. 189, D. 16434, a.o.).

By weathering, the plagioclases decompose into sericite and dust, chlorite, epidote and calcite. Occasionally they show zonal decomposing e.g. chlorite zones or cores are met with. Augite is altered into uralite, which in some cases is found as a rim around the augite crystalls, or into chlorite and calcite.

Spilites: Many more or less porphyritic rocks, composed of acid plagioclase, augite, and magnetite with their decomposition products, I reckon to the spilites for several reasons. 1. For their mineral composition. 2. For their texture. ROSENBUSCH (35, p. 449) describes the spilitesas follows: "Spilite (AL. BRONGNIART) sind Einsprenglingsfreie oder doch sehr Einsprenglingsarme, sehr feinkörnige bis dichte, grünliche bis graugrünliche Ergussgesteine, die zu den Effusivformen der Gabbromagmen gehören und sich durch grosse Neigung zur Mandelsteintextur, meist dünnplattige oder kuglige Absonderung und leichte Verwitterbarkeit auszeichnen". HOLMES (22, p. 215) gives the following definition: "Spilite: A basaltic rock, generally vesicular or amygdaloidal, whose felspars have been albitized. Pyroxene or amphibole, more or less altered, and sometimes serpentinized olivine may be present". I used the term spilite for diabasic or basaltic rocks with a fine intersertal structure, composed of acid plagioclases, especially albite, augite and their decomposition products, among which chlorite predominates. Often the rocks are weathered. Amygdales are met with.

In Santa Clara province rocks of this type occur together with porphyrite and diabase. The essential differences with these two mentioned rocks are the average composition of the plagioclases and the texture. Even in the porphyritic spilites the groundmass shows a more or less intersertal texture. However, texturally spoken, we find all transitions between true spilites, diabase-porphyrites, and porphyrites.

The spilites are darkgreen, compact, dense rocks, weathering with a yellow brown colour. Microscopical study reveals holocrystalline rocks with intersertal texture formed by divergent laths of felspar, with in the spaces between these augite with chlorite or with other secundary minerals, which probably originated partly from some glassy mesostasis, and magnetite. The amount of felspar is larger than the amount of augite. The felspars are cloudy, filled up with minute dusty inclusions. The composition ranges from albite to oligloclase and sometimes andesine. Often they are twinned. The augite forms small grains like magnetite. If the rock is porphyritic, there are phenocrysts of albite-oligoclase to andesine, and of augite. The felspars are tabular, twinned, dusty, and decomposing into chlorite, sericite, epidote or prehnite. The augite occurs in large, allotriomorphic grains, decomposing into amphibole. Both, augite and amphibole decompose into chlorite and epidote. If the augite grains are large and dissected by felspar laths we have ophitic texture.

The amygdales are filled with calcite or interlocking undulose quartz and epidote, or spheroidal quartz. Often the spilites are silicified. The clearly secondary quartz penetrates the intersertal spaces. The mafic components are chloritised and the chlorite also is replaced by quartz.

The genesis of the spilites is problematic. In the literature on the spilites the central problem is whether the origin of the albite in the spilitic rocks is magmatic or metasomatic (either autometamorphic or exomorphic). JAMES GILLULY (19, p. 225) gives an extensive discussion of the question and comes to the following results: "spilitic rocks are derivates of normal alkalicalcic magmas; spilites . . . . . have been metasomatically enriched in albite; the enrichment was probably entirely subsequent to their consolidation and brought about either by resurgent water from the wet sediments as suggested by DALY, or by albitic solutions derived by deeper seated differenciation along trondjemitic lines". With regard to these conclusions the following must be stated about the spilites of Santa Clara Province. As we find them associated with marine limestones and marls, we can be pretty sure about their submarine genesis. The associated diabases and porphyrites sometimes show the beginning of albitization and, on the other hand, in the spilites relics of calcic plagioclases occasionnally are met with. This makes it probable that all albite in our spilites is of metasomatic origin. The occurrence of the association of spilite with normal fine-grained diabases, and diabase-porphyrites can be more easily explained by metasomatic origin of the albite in the spilite than by magmatic genesis of the spilites. The albitization-process probably was limited to special places under special conditions, as the spilites are found only very locally on several places. Difficult to understand are the many twins in the albite crystals. Never albitic veinlets have been found, only a quartz vein. The conditions which caused the albitization of the spilites in our district are unknown to me. Concluding I can say, that for the Cuban spilites the metasomatic origin of the albite is probable. It cannot be stated whether it was autometamorphic or exomorphic.

The vitric tuffs are darkgreen rocks with a dense, sometimes dyscrystalline structure weathering with a brownish colour. Microscopically they consist of lightbrown glass, sometimes dusty and clouded by small patches of chlorite or slightly larger ones of limonite. The refractive index mostly is lower than 1,54. When the glass is dusty, it is difficult to measure its refractive index. Once we found a refractive index slightly higher than that of the canada balsam. In some cases the vitric tuffs contain no crystal fragments at all. Mostly, however, we find angular fragments of plagioclases, ranging from very few, diminutive fragments to a larger amount of coarser ones. Often *Radiolaria* are found, at H. 41 (D. 16899) a very rich fauna occurs of very small and larger forms, amongst which the largest ones are spherical, measuring up to 250 μ in diameter.

Crystal tuffs and tuff-porphyrite breccias. The tuffs range from very fine cryptocrystalline and microcrystalline tuffs to coarser crystal-tuffs, which in their turn gradually pass into very coarse tuff-porphyrite-breccias. The crypto-and microcrystalline tuffs and cherts are finally bedded; the coarser tuffs and the porphyrite-breccias are poorly bedded; the coarsest breccias are structureless. The fine-grained tuffs often show spheroidal parting. Bloctuffs with many diaclases are found many times. The fine-bedded tuffs alternate with the coarse tuffs. The colour mainly is green to grayish-green, while also blue, red, and sandy-yellow tuffs are met with. Very often the tuffs are strongly decomposed by weathering, becoming brownish.

Microscopically they show strong variation with regard to the structure and the composition. Both, number and dimensions of crystal fragments increase with the decrease of the amount of the groundmass. The coarse tuffs of pyroclastic genesis are built up almost entirely by crystal- and rock-fragments; the fragments being cemented by secondary minerals as quartz, limonite, sericite and chlorite. Moreover there are tuff-porphyrite-breccias cemented by calcite.

The dense cryptocrystalline tuffs appear to consist of a fine volcanic dust with very few diminutive crystalfragments of plagioclase.

The microscrystal-tuffs and the coarser crystal-tuffs show a very fine-grained "groundmass" of plagioclase, chlorite, limonite and leucoxene, which is in some cases more or less silicified, and the fine-grained rock becomes cherty. At the side of this "groundmass" occur larger crystal fragments, especially of andesine and other plagioclases, some secondary amphiboles, and chlorite and limonite as rests of former mafic constituents. In the tuffs we often found *Radiolaria*. Once we found opal.

The tuff-porphyrite-breccias are built up by many large fragments of crystals and rocks. We find, albite, andesine, labradorite and bytownite, the last two of which being clear, twinned, and with zonal structure; andesine rather dusty. Besides the plagioclase frequent augite, and rare olivine, light green pleochroitic amphibole and magnetite occur. The imbedded rock-fragments mainly can be recognized as debris of porphyrite, spilite, diabase and vitric tuff. Porphyrites with pilotaxitic or hyalopilitic groundmass occur.

The tuffs, and especially the coarser tuff-porphyrite-breccias are very strongly decomposed by weathering. Calcite, epidote, chlorite or sericite are developed from the felspars; while pyroxenes are altered into uralitic amphibole, chlorite, and calcite. The porphyrite-fragments are altered in many ways. The groundmass may be replaced entirely by light green chlorite and dark brown ore, or by calcite. The phenocrysts are altered in the same way as the crystalfragments. Apart of these strongly altered porphyrite fragments we found also almost entirely fresh ones. This rather strong differrence in the decomposition of the rock fragments in one sample is a remarkable fact.

The Provincial limestones are found at many localities in the Tuff-Formation, forming steep pronounced hills. In the Northern zone of exposures of these limestones many Caprinids have been found. At L. 328 Caprinids-bearing Provincial limestone was exposed imbedded between tuff layers. At A. 236 the limestones rich in Caprinids are found as isolated blocks in the field.

The Provincial limestones are light-yellow, dark-gray, grayishblue, fine-to medium-grained, mostly microconglomeratic rocks, cut by many small and larger, white calcite veins. They may be thickbedded (up to 1 m.), but mostly they are thinbedded. These conglomeratic limestones appear under the microscope to be built up by many small and larger rounded rockfragments which are wholly calcified. The texture of the original rock often can be recognized as a porphyritic one. Oolites of calcite occur also. These rounded calcified rockfragments and oolites are cemented by fine- to medium-grained calcite. Often the limestone contains unaltered fragments of porphyrite, or their plagioclase phenocrysts. The latter are of basic composition, clear, tabular, twinned, sometimes showing the beginning of calcification. Small and larger clear quartz-grains also have been found. In one sample in a quartz crystal a liquid inclusion was found. As the diorite intrusion undoubtedly is younger than the Tuff Formation, it is very probable that the quartz inclusions in the Provincial limestone derive from some yet unknown prae-Cenomanian volcanic rock, containing clear quartz, or partly possibly from the quartz-bearing rocks of the Schist Formation. The fact that in the tuff-porphyrite-breccias and the crystal tuffs never quartz has been found probably can be explained as follows: the tuffs and tuff-porphyrite-breccias are quickly sedimentated rocks while the sedimentation of the limestones took a much longer time; so the chance to find detritus of foreign rocks in the limestones is larger than in the tuffs and breccias. Apart from the conglomeratic limestones, compact, fine-grained, light yellow limestones have been found, and fine-bedded, dark, compact marls containing many Smaller *Foraminifera*, partly related to the *Globigerinidae*, and dense, light-yellow, finely bedded radiolarian limestones.

Fauna. The Provincial limestones contain a rather rich fauna. *Radiolaria*, Smaller *Foraminifera*, Corals and Bivalves (*Caprinidae*) and *Nerineidae* are found. Where *Radiolaria* occur, their silica is replaced totally by calcite.

They are more common than the *Globigerinidae*, which are only found in some places.

In the layers, where *Mollusca* have been found, they occur rather abundant. They always are found in solid rock, and on weathered surfaces in the conglomeratic limestones. They do not occur in the finer-bedded limestones. *Caprinuloidea perfecta* Palmer, and *Sabinia* sp. were found in dark-grayish-blue, compact, microconglomeratic limestones; *Coalcomana ramosa* (G. Boehm) and *Tepeyacia corrugata* Palmer in a light-yellow, coarser conglomeratic limestone. Together with the Caprinids many *Nerineidae* and Corals and Smaller *Foraminifera* have been found, which not yet have been studied. The occurrence of Caprinids and Corals in a conglomeratic limestone indicates a littoral facies. The fine grained limestone with *Globigerinidae* and *Radiolaria* inform us, however, that probably sometimes the sedimentation took place at a longer distance of the coast.

Contact Tuff Formation and Dioritic Intrusion.

As already mentioned the diorite is younger than the Tuff Formation. This is proved by several phenomena.

1. Dioritic dikes in the Tuff Formation near the contact.
2. Inclusions of altered rocks from the Tuff Formation in diorite.
3. Contact metamorphosis in the rocks of the Tuff Formation caused by the Dioritic Intrusion.
4. The existence of a "marginal facies" in the diorite at the contact with the Tuff Formation.

ad 1. On several places there occur dioritic dikes in the Tuff Formation as can be seen on the map. These, however, are not always convincing, as the exposures are often bad and the determination of the dioritic character of the rocks was only sure in a few cases. At L. 318 (D. 16512), S. of Provincial a real quartz-diorite-porphyrite was found, at L. 320 (D. 16516) a silicified porphyritic rock with rests of quartz-phenocrysts. At H. 255 (D. 16911), N. of Gavilan a porphyrite occurs which is rather weathered. The groundmass is granular, composed of plagioclase tablets, primary and secondary quartz, and chlorite. There are large and small, very dusty, tabular plagioclase phenocrysts of medium average composition in a large amount, and chlorite and epidote replacing the very few mafic phenocrysts. The form of the latter sometimes suggests decomposed amphiboles. Magnetite in large crystals occurs. This porphyrite differs from the common porphyrites of the Tuff Formation by *a*. the lack of ore in the groundmass, *b*. the structure of the groundmass never containing plagioclase laths with intersertal mafic minerals, *c*. the small amount of the latter or their decomposition products both in the groundmass and the phenocrysts, *d*. the lack of augite or traces of it ,and *e*. the composition of the plagioclase phenocrysts. The form of the decomposed mafic phenocrysts suggests a diorite-porphyritic origin of the rock, although the groundmass is aberrant from the common type of diorite-porphyrites.

ad 2. In the Diorite Intrusion North of Manicaragua and La Moza we found foreign inclusions of uralite porphyrites and uralite diabases A. 203 (D. 17024, D. 17025); A. 306 (D. 17029); L. 334 (D. 16537); L. 337 (D. 16540); L. 338 (D. 16541); L. 339 (D. 16543, D. 16544, D. 16545); M. 314 (D. 16739); M. 318 (D. 16745); M. 135 (D. 16666); L. 340 (D. 16546). The last two samples are uralite diabases.

These rocks are totally uralitized and often largely silicified. The rocks are green, fine-grained, rather hard. The porphyritic structure is visible in several cases. Under the microscope the rocks appear to be holocrystalline, hyp-idiomorphic porphyrites and diabases. According to the varying richness in pyroxene of the original rocks we find uralite-porphyrite and -diabase with a varying amount of uralite. Sometimes the rocks exist almost entirely of this mineral. The phenocrysts of augite are entirely amphibolized and mostly have disappeared or they recrystallized into innumeral fine, green, pleochroitic needles and fibres of uralite and small magnetite grains. Here and there the original pyroxene form is preserved, and we see traces of beginning uralitization. The felspar phenocrysts are more or less silicified. In the samples, where no silicification occurs, the plagioclases are dusty, often twinned, decomposing into chlorite or sericite. The average composition ranges from andesine to labradorite. The groundmass is composed by uralite, felspar, ore, epidote and chlorite and rather often secondary quartz. Light green, slightly pleochroitic uralite occurs in broom-like bundles, arranged in all directions, sometimes radiating, stretching beyond the original form and space of the augite, intruding the surrounding plagioclase laths. The felspar laths are dusty, partly of wholly replaced by quartz. The quartz penetrates the whole groundmass with small irregular grains. A rather large amount of magnetite grains is always found.

At M. 322 (D. 16751) near the Rio Arimao, North of Manicaragua we we found as foreign inclusion in the diorite an uralite-zeolites rock. The internal structure suggests very probably its diabase-porphyritic origin. The rock is medium-grained, porphyroblastic, built of uralite and zeolites and relics of very dusty plagioclase. The uralite mostly is pseudomorphic after augite, and occurs also in an irregular crowd of small, green pleochroitic needles. The zeolites are tabular, grainy, with two directions of perfect cleavage, irregularly twinned, with undulatory extinction, cloudy low polarisation colour, slightly higher than quartz, positive optical character, negative elongation, and a refraction index only slightly lower than the canada-balsam.

ad 3. Contact metamorphic rocks are very well exposed at M. 582 and M. 583 (D. 16752—D. 16760) on the Carretera Central, East of Sancti Spiritus and at A. 433 (D. 17052) North-East of Sancti Spiritus, at M. 119 (D. 16662) East of Soledad, and V. 90 (D. 16842) North of Cumanayagua. At M. 582 and M. 583 we found the finest example of contact metamorphism.

The tuffs of the Tuff-Formation are uralitized, epidotized and silicified. The impure limestones are strongly altered. The most common product of metamorphism in them is "common garnet", which is colourless or slightly yellow. It is present in abundance in some samples, forming compact garnet rocks. Large crystals are found which mostly are amazingly pure. Their section is hexagonal and octogonal. The refractive index is higher than 1,77. They show distinct zones of growth, are isotropic or often birefringent, this property varying in successive zones. The core of the larger crystals is anomalously birefringent, and does not show a special growth pattern. The large crystals are broken, and secondary clear quartz penetrated between the garnet and in the fissures through the broken crystals. In one case the garnet was associated with large magnetite crystals, which decomposed into hematite. In garnet-rocks, almost entirely consisting of fine dusty calcite and very little garnet it is difficult to state whether the calcite is primary or secondary. In one sample a garnet rock with many calcite veins and veinlets has been found. Here the secondary character of the calcite is evident. One very pure limestone has been altered into coarse-grained marble, consisting almost entirely of large, very clear, twinned calcite crystals, cut by some small veins carrying quartz and garnet, and other ones, carrying zoisite and chlorite or quartz and epidote.

At M. 119 (D. 16662) a garnet-wollastonite rock has been found. This rock is very homogeneous, fine-to medium-grained, light coloured. The garnet is regularly crowded, consisting of medium sized colourless grains. The garnet is isotropic or birefringent. Allotriomorphic, fine grains of wollastonite fill in the space between the garnet. The rock is cut by small calcite veinlets. No rests of original carbonates have been found. This rock probably has originated from a homogeneous, rather pure lime-marl as found in the Provincial limestones.

At V. 90 (D. 16842) we found a contact metamorphic rock of quite another type, for here a large amount of the original carbonate has been left. The irregular distribution of the components of the rock suggests its conglomeratic origin. The rock is coarse-grained with poikilitic texture. It is built up by calcite, which is recristallized in large twinned crystals, including many small and larger grains of garnet, epidote, and chlorite. Other patches of the rock are built up entirely by garnet and again others by epidote and quartz. The quartz is very clear, allotriomorphic, anomalous, showing a slightly biaxial interference figure. Probably it has come into the rock in a later, cooler stade of the metamorphism. The garnet is isotropic or birefringent. Many very small and larger, colourless, idiomorphic crystals are irregularly distributed in the rock. Slightly pleochroitic epidote forms well-established grains. The chlorite is allotriomorphic in nests and veinlets. Many larger and smaller garnet crystals are broken. It is possible that in the second phase, when the quartz intruded, the garnet has been broken.

At A. 433 coarse grained marble, partly altered by contact metamorphism, has been found. The large calcite crystals are strongly corroded at the border by quartz, epidote and zoisite. Locally the calcite carries also a crowd of inclusions of these minerals. Some garnet grains occur too.

At the side of all these more or less strongly contact metamorphic rocks there are found on several other places near the diorite intrusion in the Tuff Formation rocks with slight metamorphism or only with traces of its beginning. The first effect always found is the uralitization of the pyroxene in the groundmass and the phenocrysts of the porphyrites. In the tuffs uralite and also quartz, and in the amygdaloidal spaces clear quartz including fine uralite needles can be considered as traces of slight contact metamorphism.

The silicification of the rocks of the Tuff Formation probably also is connected with the metamorphic action of the Diorite Intrusion. On some courses, which cross the contact of the Tuff Formation and the diorites, no traces of contact have been found. This, however, is not astonishing as often the rocks of both formations are strongly weathered, and the contact is not exposed. In these cases we often were able to draw the boundary between the two formations as the weathered diorite is easily recognizable, by its typical yellowish sandy decomposition.

ad. 4. Near the contact of the diorites with the Tuff Formation we find many quartz-diorite-porphyrites.

Serpentines.

In our district we found two distinct types of serpentine. In the Schist Formation we found serpentine schists, which have been already described in the petrography of the Schists on page 10.

At L. 117 (D. 16408) serpentine is found which is not foliated, and does not show a schistose texture under the microscope. This serpentine is very alike those which outcrop in a large area in the Northern half of Santa Clara Province and which have been extensively described by M. G. Rutten. The rock is light green, compact, with large discernable grains which appear to be bastite. The rock is full of small calcite veinlets, and broader ore-bearing calcite veins. Microscopically the rock appears to consist of colourless or light green, leaf-like antigorite, irregularly arranged, and of large bastite crystals, sometimes showing the pyroxene cleavage; small and large chlorite aggregates, which are colourless and under crossed nicols show an anomalous dark blue polarisation colour. Many large irregularly arranged calcite veins with or without magnetite in medium or fine grains and hematite are present. The original rock, which yielded this serpentine, probably was built up mainly by rhombic pyroxene and olivine.

Quartz-Diorites and other rocks belonging to the Quartz-Diorite Intrusion.

Large masses of rocks of the quartz-dioritic and dioritic clans outcrop North, East and West of the Schist Formation. As can be taken from the map the diorite outcrop North and East of the Schist Formation has an enormous extent. The elongation is, generally, parallel to the tectonic axes of the mountain range. Many of the rocks belonging to the Dioritic Intrusion are more or less strongly cataclastic, a fact which proves that after consolidation the rocks were subdued to strong stresses, probably caused by orogenic action. The time of intrusion partly coincided with a period of mountain building. The form of the boundary between the Dioritic Intrusion and the Tuff Formation proves a cross-cutting relation between them. Nothing is known of the floor and the walls of the intrusive body. The several inclusions found in the dioritic rocks probably are rests of the roof of country rocks, which has been replaced by the intrusion. The present author is inclined, for the above mentioned facts, especially the large extent and the lack of knowledge about the floor, to call the large intrusive dioritic mass a batholith. As will be seen later-on we then are dealing with a differentiated batholith, mainly existing of rocks of the quartz-dioritic clan. On the West border of the Schist Formation smaller intrusive masses are found, which probably must be called stocks.

The way in which the Dioritic Intrusion surrounds the Schist Formation is very peculiar. The rocks of the Schist Formation form a autochthonous complex or are part of an overthrust mass. These two cases will be discussed in the chapter on Tectonics. As will be pointed out there, the first possibility is the most probable one. As the Schist Formation is older than the Dioritic Intrusion (see below) traces of contact metamorphism in the schists caused by the diorites probably could be expected, as e.g. replacement of the foliation by the hornfels class of structure and replacement of the stressminerals as chlorite, muscovite and actinolite by antistress-minerals. This we never found. This fact, together with the vertical and overturned position of the schists on the North side of the complex, and the strong cataclastic structure found in the dioritic rocks and sometimes in the schists too, were the reasons why we drew the boundary between the two formations as a fault.

The age of the intrusion is Upper Cretaceous. The diorites are younger than the Cenomanian-Turonian rocks of the Tuff Formation, since the latter are contact metamorphically altered by the former. On the other hand the diorites are older than the Maastrichtian as in the rocks of the Habana Formation detritical material of dioritic rocks is found.

The Dioritic Intrusion is differentiated. The following rocks have been found: quartz-diorite, quartz-free-hooibergite and pyroxene-hooibergite, metahooibergite, gabbro-diorite, pyroxenite, hornblendite, amphibolites, quartz-diorite-porphyrite, vintlite, aplites, lamprophyres, and quartz-epidote-rocks. A rather regular distribution of the rocks is found. The quartz-diorites and sandy decomposed diorites are found almost in the whole area. In the centre these are the only occurring rocks. The hooibergitic rocks, the gabbros, hornblendite, pyroxenite and the amphibolites outcrop only on the Southern side of the batholith. When we approach the schists, the amount of these basic igneous rocks increases.

They are strongly cut by aplitic dikes. With the exception of two samples all the aplites found by us in the district are associated with the above mentioned amphibole-rich rocks. On the other hand the quartz-diorite-porphyrites are found only near the Northern border of the intrusion. On some places they are found as dikes in the Tuff Formation. The hooibergitic rocks are probably early consolidation products in the roof and the uppermost margins of the batholithic chamber. Together with the hooibergitic rocks amphibolites, which are probably magmatically stooped country-rocks, are found. These facts suggest that we are dealing in the area where the hooibergitic and amphibolitic rocks are found with exposures very close to the roof of the intrusion. The many quartz-diorite-porphyrites on the Northern border of the intrusion, represent another marginal facies of the intrusion.

Many rocks of the dioritic intrusion are more or less strongly affected by cataclasis. Mylonitization is often found. On the other hand nearby the regions of cataclasis we find regions where no cataclastic action has taken place. Once undoubtedly traces of protoclasis have been found.

In the strongly cataclastic dioritic rocks and the amphibolites often "strike and dip" could be measured and accordingly have been drawn in the map. The main trend of these schistose rocks indicate that the direction of the cataclastic forces had been SSW. to NNE.

Quartz-Diorites. The quartz-diorites are medium-to coarse-grained rocks with evenly spread white and dark minerals. The white minerale are felspar and quartz, the dark ones amphiboles, forming large columnar crystals, measuring up to 7 mm. Nearly always the rocks are decomposed into a yellowish, loose diorite-sand, causing a very typical landscape, as erosion and denudation act very quickly on it, forming deep gullies. On about only 20 localities dioritic rocks, which are slightly or not at all decomposed by weathering, have been sampled.

The texture is holocrystalline and hypidiomorphic-granulose, sometimes porphyritic, gradually passing into diorite-porphyrite and vintlite. Depending on the presence or absence of biotite we are dealing with quartz-biotite-amphibole-diorite or quartz-amphibole-diorite. The main constituent minerals are plagioclase, amphibole, quartz and biotite. In general the plagioclases are the most important minerals. In some rocks, however, the amphiboles are prevailing. When biotite is present, it is almost equivalent with the amphibole or the amount of biotite is slightly smaller.

The plagioclases are idiomorphic or hypidiomorphic, large tabular or smaller, lath-shaped in section. The composition varies from oligoclase to labradorite. Mostly a medium composition of andesine-labradorite is found. Simple and polysynthetic twinning is always present, while zonal crystals often are found. The peripheric zones are more acid than the core. In one sample vermicular quartz was found in plagioclase, probably as a result of corrosion of the liquid containing residual quartz. Granophyric intergrowth in a few cases is found. Albite is always present in large crystals, filling together with quartz the room between the other minerals. Often a very peculiar texture is formed then: large allotriomorphic very clear albite encloses smaller tabular dusty andesine crystals and small typically idiomorphic, well-cleaved amphibole crystals. This texture, which seems to be rather uncommon in the diorites, has been found several times in Southern Santa Clara. Besides, we find albite as zonal rim around a centre of more basic plagioclases. Mostly the plagioclases are clear. Sometimes they are more or less strongly weathered. Once a sample has been found with clear plagioclases containing a crowd of small and large slender plates of sericite and grains of calcite. Usually, if weathering, the plagioclase becomes dusty, containing fine epidote, sericite or chlorite. Orthoclase is of little importance, clear, allotriomorphic, younger than the plagioclase.

Amphibole of both the quartz-amphibole-diorite and quartz-amphibole-biotite-diorite is alike. The crystals are evenly distributed in the rock or they occur in groups together. The form is varying, idiomorphic or hypidiomorphic. Sometimes the border between amphibole and plagioclase is irregular. Mostly the amphiboles are idiomorphic with regard to the plagioclase, but contain on the other side idiomorphic plagioclase inclusions. The amphiboles form short or long prismatic crystals, often twinned, showing a well developed cleavage. The colour, pleochroism and extinction point to the common green amphibole. We find at the side of the large amphiboles small, idiomorphic ones. The amphiboles are generally clear and fresh; only sometimes they have been partly replaced by epidote or chlorite. Rarely in some amphibole crystals small rounded, and irregularly shaped quartz inclusions have been found in a rather large quantity, e.g. in L. 261, (D. 16460). This poikilitic amphibole is found in the diorite, which is very poor in quartz. It is probably that this phenomenon can be explained by corrosion of the amphibole by a residual liquid.

Biotite, when found, forms large broad tabular prisms and smaller flakes. It is green to dark green or brown to black pleochroitic. Very often it is more or less altered into light-green to green pleochroitic chlorite, which has a typical brownish polarisation colour. In some rocks all the biotite is replaced, and only the chlorite, pseudomorphic after biotite, is present. Together with chlorite, epidote sometimes also replaces biotite. Often the biotite is found in the neighbourhood of amphibole, the latter being idiomorphic with regard to the former. Sometimes small plagioclases are enclosed in the biotite.

Quartz is found in varying amount, allotriomorphic, filling the space between the other minerals. It is clear and sometimes occurs in large crystals. Typical for the quartz are the very fine inclusions which are found in straight lines in thin sections.

Accessory minerals: apatite in small and large prisms and needles is enclosed in quartz and other minerals. Titanite in very large idiomorphic crystals or in angular grains is very conspicuous. It is always present in a rather large amount. Magnetite is often found together with apatite needles in medium grains. Pyrite sometimes is met with. These accessory minerals are the eldest components of the rock. Leucoxene and hematite occur as alteration products of titanomagnetite and magnetite.

South of Provincial near the border with the Tuff-Formation several aberrant diorites have been found. V. 119 (D. 16815), V. 120 (D. 16853), and V. 121 (D. 16854) are strongly weathered rocks, very rich in quartz. They are medium- to coarse-grained, greenish-browny coloured. Microscopically very large clear quartz crystals with many lines with liquid and gaseous inclusions are conspicuous. The quartz is primary and forms about one third to one fifth of the rock. The other components are plagioclase and amphibole or their decomposition products. The plagioclases are slender and broader prisms, and of medium length, or broad tabular ones; strongly altered into very dusty patches with sericite, or epidote and chlorite. The average composition is andesine while much albite occurs too. The amphiboles are partly replaced by epidote, chlorite and calcite. The plagioclase prisms and the amphibole sometimes form a rather coarse intersertal texture with wide spaces filled in with quartz.

Cataclastic Phenomena. On several places the rocks of the Dioritic Intrusion are affected by more or less strong cataclasis in consequence of which the rocks become more or less parallel-textured. In the beginning of the cataclasis, we see the quartz with undulatory extinction and with a slight desintegration of the crystals. The plagioclases are bent and show undulatory extinction too. In a more advanced stage of cataclasis mortar structure is produced. Large quartz and plagioclase grains lie as lenticular relics in a squeezed, crushed, finer matrix. The biotite becomes flaky and forms streaks in the rock, the hornblende desintegrates into many small grains and prisms, the magnetite is ground almost to a powder, the apatite and titanite are crushed. All the minerals and fragments of minerals show a parallel trend. Sometimes the stress has affected the diorites to such an extent that fine grained eyed-gneisses are formed. In these rocks a light yellow garnet occasionally is found. The lenticular relics are orientated in the common direction. In one sample the processes have been carried almost to the extreme. A laminated structure results, closely resembling "flow-structure", emphasized by trains of thin streaks of colour, representing the breaking down of some particular mineral of the original rock. The lenticular relics are almost entirely ground away. We are dealing with mylonites.

SiO_2-solutions have been present in the rock during the cataclasis, as can be seen from the quartz veins and the plagioclases corroded by quartz in the less strongly cataclastic rocks. Sometimes it is impossible to say, whether the rock at hand was originally a common diorite, or a gneiss.

Some diorites must be mentioned for their slightly aberrant texture. While in the common diorite a distinct crystallization sequence is present, in the rocks from M. 667 (D. 16773, D. 16774), this sequence is rather indistinct. The light minerals are about equigranular. The plagioclases, which are well twinned and zoning, form short, broad tabular polygonal crystals or crystals with undulating irregular rim. The quartz forms equally polygonal grains. The amphiboles which mostly are hypidiomorphic too, form larger crystals than the light minerals. The different minerals impede each other mutually. By their arrangement the amphiboles cause a slightly parallel texture which in the sample is still more conspicuous. The composition of this rock agrees mineralogically with quartz-amphibole-diorite. Probably we are dealing with a gneissic facies of the diorite.

In the Southern part of the intrusion at L. 304 (D. 16497, D. 16498) we found white-green, banded rocks, which are very interesting differentiation products of the quartz-diorite-magma. Macroscopically they show a clear parallel texture, marked by dark-green, and white bands, patches and lenses. The dark bands and patches do not contain white minerals, while in the light bands many dark green amphibole crystals are visible. Microscopically the rock appears to be a banded hornblende gneiss with a strongly foliated texture. No crystallization sequence can be observed, as most minerals are allotriomorphic. The plagioclases (about andesine) are all arranged in the common direction and have an undulatory extinction. Quartz in rounded grains is present. Amphibole occurs in a large amount. Some hypidiomorphic crystals with elongated habit, are found between the plagioclases and quartz. More important is the occurrence of amphibole in compact bands and lenses. The colour, pleochroism, and extinction points to common green amphibole. Cleavage is often well exhibited. In the bands the crystals are all elongated, parallelly arranged, allotriomorphic. Titanite, apatite, magnetite and zircon are accessory minerals. The light bands can be compared mineralogically with acid quartz-amphibole-diorite. These rocks have been affected by strong cataclasis, in consequence of which they have a mortar-structure in the white bands. The plagioclase and quartz have an undulatory extinction. The former is often bent, the latter crushed at the periphery of the grains. The quartz intrudes sometimes corrosively into the plagioclases. Hence a SiO_2 solution must have been active during the cataclasis.

The hornblende in the dark bands shows, in consequence of the cataclasis, a rather strong undulatory extinction and also slightly crushed rims. The undulose extinction of the hornblende proves the primary character of this mineral. The rocks are primary banded by magmatic differentiation and have been affected by cataclasis after the consolidation.

Diabasic quartz-diorite: green-brownish weathering, medium- to fine-grained, holocrystalline rocks. L. 622 (D. 16617, D. 16618) is the best sample. The rock is grayish green, medium-grained. Microscopically we see a holocrystalline, hypidiomorphic rock, with a diabase-structure. The constituant minerals are plagioclase, hornblende, biotite, quartz, with titanite, apatite, magnetite, chlorite and calcite. The plagioclases are idiomorphic, twinned prisms. They are clear, sometimes replaced by sericite and epidote. The average composition is andesine, with a rim of albite at the periphery of the crystals. Often at the borders of the plagioclases a rim of myrmekite is formed by the corrosive action of quartz. The quartz fills the space between the other minerals. Hornblende occurs in many hypidiomorphic grains. With regard to the plagioclase it is allotriomorphic, with regard to the quartz idiomorphic. It is green-pleochroitic, the same hornblende as we find in the amphibole-quartz-diorite. Biotite is green-dark or brown pleochroitic; it is streaky. It takes up less room than the amphibole. Titanite is found in large crystals, apatite in many needles, magnetite in small grains. Chlorite is the decomposition product of amphibole and biotite. Epidote is found in the plagioclases. H. 316 (D. 16938) is another fine sample. This is a medium-grained rock. Microscopically we see a holocrystalline rock with ophitic texture. The main constituant minerals are plagioclase, pyroxene, quartz, with their decomposition products, especially chlorite, and accessory apatite and magnetite. The ophitic texture is formed by the tabular plagioclase prisms with intersertal quartz and chlorite and sometimes pyroxene. However, the pyroxene can also be idiomorphic with regard to the plagioclase. The average composition of the plagioclase corresponds with andesine. Broad twins are present. Micrographophyric intergrowth with the quartz often is found. The andesine is dusty and replaced by sericite and chlorite. The pyroxene is a colourless diopsidic augite. Mostly it is replaced by chlorite. In the intersertal spaces also chlorite, which is the product of replacement of an original, yet unknown mesostasis, occurs. Quartz is clear and allotriomorphic. Biotite, for a large part altered into green pleochroitic chlorite, is found in a small amount. Apatite is developed in very long fine needles. A rather large amount of magnetite is present.

At V. 118 (D. 16850), V. 124 (D. 16859) and V. 125 (D. 16860) finer grained, slightly porphyritic quartz diabases occur. The components are alike of the above described rock. The only difference is the porphyritic texture caused by a few larger crystals of plagioclase and mafics in a predominant groundmass, showing a more or less clearly developed ophitic texture. These rocks too are strongly weathered.

Hooibergitic Rocks. As already quoted, these rocks are found only in the Southern part of the intrusive area. Here they occur in a rather large amount, sometimes in exposures of 1 km. and more. They form steep, elevated hills in the plany diorite landscape as a result of selective erosion. Near L. 310 and L. 311 they are very well exposed. Mostly the hooibergites have been, like so many other rocks in the Dioritic Intrusion, affected by cataclasis and altered into "meta-hooibergite". A very conspicuous phenomenon is the occurrence of many small and larger dikes of dioritic and aplitic rocks in the dark hooibergites.

Often fragments of the latter are found in these dikes (Plate, fig. 12). Here we see very well proved that the more acid dioritic and aplitic rocks are younger than the basic hooibergites.

As will be seen in the petrographic description the hooibergites are characterized by their texture and composition. Qualitative-mineralogically the hooibergites are alike the diorites, but the quantitative distribution of the components is quite different. Texturally the very large amphibole and pyroxene crystals are typical. The Cuban hooibergites differ from the types of these rocks as described and figured by WESTERMANN (59) 1. by the lack of quartz, 2. the quantitative distribution of the components, the hornblende being always strongly predominant in the Cuban rocks. Moreover the state of preservation is different, as the Cuban rocks are much more decomposed by weathering than the Aruban ones.

The fresh hooibergites are dark green, coarse-grained rocks, mainly consisting of large, idiomorphic, dark green, lustreous hornblende crystals, and very few smaller ones (amphibole prisms occur, measuring 21 × 13 mm., mostly they are about 9 × 3 mm., while small ones measuring 1 mm. are very rare). Between these amphiboles a white "groundmass" occurs. Apart from the dark, green, lustreous hornblendes sometimes dusty, green, smaller pyroxene crystals occur. We are dealing with pyroxene-hooibergite then. With the intergration-stage in the sample of L. 302 we found 62.65 % amphibole, 28.22 % pyroxene, 9.07 % plagioclase.

Microscopic description of hooibergite. The constituant minerals are amphibole, plagioclase, epidote, zoisite, magnetite, apatite and zeolite. The amount of amphibole is predominant. It is the only idiomorphic mineral. It is found in large isometric, long prismatic crystals, and in smaller ones. Both are of the same generation, as the smaller ones work in with the bigger ones. The smaller are idiomorphic with regard to the light minerals too. The hornblendes are green, light-green pleochroitic, scarcely twinned. Very conspicuous are the large amphibole crystals often with very few or without any inclusion or any weathering, while the plagioclases are strongly altered. However, some patches of coarse epidote and magnetite grains are found in the amphibole crystals. The altered plagioclases are allotriomorphic, dusty, sometimes polysynthetically twinned. The composition ranges from albite to andesine. Once dusty orthoclase has been found. The plagioclases are very strongly decomposed by weathering. They are dark dusty, sometimes entirely sericitized, sometimes with large grains of zoisite and epidote. Once titanite has been found. Apatite occurs in small prisms and needles in the plagioclase. Spheroidal zeolites are present as hydrothermal minerals. Quartz is entirely lacking.

Microscopic description of the pyroxene-hooibergites. The most important minerals are hornblende, pyroxene and plagioclase. The large, homogeneous, sometimes twinned hornblendes are similar to those of the hooibergites, light-green to green, sligthly pleochroitic, beautifully cleaved. Also the idiomorphism of the smaller and large crystals with regard to the plagioclase is the same. Very few inclusions of magnetite and epidote and weathered plagioclase occur. Often amphibole is intimately intergrown with pyroxene. In the prismatic zones the two minerals border at each other with straight faces. In section about perpendicular to the prismatic zone both minerals become under crossed nicols extinguished at the same time. The pyroxene is colourless diopsidic augite. It occurs as large tabular crystals. Rarely the crystals are built up entirely by pyroxene only, mostly they are intergrown with amphibole, both showing the typical cleavage of the respective minerals. They are both very clear and it is obvious that they crystallized simultaneously side by side. With regard to the plagioclase the pyroxene is idiomorphic. The plagioclase occurs in a rather small amount. The average composition is albite-andesine. Once a clear polysynthetically twinned bytownite has been found. The plagioclases are sericitized or saussuritized, and very dusty. Large idiomorphic zoisite is found in the "groundmass". Accessory minerals are apatite, titanite and magnetite. Quartz is lacking entirely. The fact that bytownite is found, is remarkable, for now we cannot be sure about the original composition of the plagioclases.

About the distribution of quartz-free hooibergites and pyroxene hooibergites nothing can be said. Fresh samples of both types were found together. In the metamorphosed hooibergite, which form the bulk of these rocks, it is difficult to state whether they are altered hooibergites or altered pyroxene-hooibergites. WESTERMANN says on page 50 "so all the hooibergites might be metamorphosed pyroxene-hooibergites" as he finds that near the contact with dioritic and aplitic dikes the augites are altered into amphiboles. The same phenomena are found in Santa Clara (see below). However, the occurrence in one rock of large clear primary hornblende together with pyroxene, and the way in which they are intergrown induces me to assume really primary hornblende-hooibergite and to deny the above mentioned possibility.

The hooibergites are plutonic rocks, older than the diorites. They were already in an advanced state of consolidation when the dioritic magma intruded, as can be seen from the contactmetamorphic phenomena, described below and from the inclusions described above. The mineralogical composition points to their belonging to the dioritic magma. As WESTERMANN (59) already mentions, probably the hooibergites were the first differentiates of the intrusion in the sense as described by DALY (14, p. 347). In this conception the hooibergites are the first chilled parts of the magma in the roof of the batholith. The fact that we find magmatically stooped inclusions of the country rocks (e.g. meta-porphyrites as described below) near the hooibergites on several localities supports this supposition. The hooibergites show resemblance with gabbros, having, qualitatively corresponding mineral composition. However, again the texture and quantitative mineral composition are obviously distinct.

Gabbro-diorites. We did not find real fresh unaltered gabbros in Southern Santa Clara. However, there are more or less contact-metamorphic rocks, which are obviously altered gabbro-diorites. They occur like the hooibergites in the southern part of the intrusive area, and are also strongly cut by acid dioritic and aplitic veins. Hence they are older than the diorite intrusion. L. 278 (D. 16465) is the best sample, which is a dark green, coarse-grained plutonic rock with long amphibole prisms (measuring up to 1 cm). Microscopically we see a coarse-grained hypidiomorphic gabbroic texture. The main constituent minerals are plagioclase, pyroxene, amphibole, magnetite and titanite. No quartz is present.

The rock is slightly affected by contact metamorphism. A small amount of the pyroxene is replaced by uralitic hornblende, and the original contours of the minerals are more or less disturbed by corrosion. The plagioclase forms large tabular crystals with polysynthetical twinning, which often wedges out. The average composition ranges from andesine to labradorite. The plagioclases are slightly dusty, especially in the centre of the crystals. Sometimes they have an undulatory extinction. Locally the plagioclases are strongly altered by saussuritization. The pyroxene is colourless diopsidic augite. It forms hypidiomorphic broad tabular prismatic crystals. Often it is intergrown with amphibole and sometimes it is repladed by amphibole. Hornblende is light green pleochroitic, idiomorphic with regard to plagioclase, having sometimes inclusions of idiomorphic plagioclase crystals. Hornblende and augite are of the same age, as they are intergrown with one another. Some large amphibole crystals show a dense, very regular crowd of black ore inclusions, parallelly arranged, perpendicular to the prismatic zone.

It is difficult to differentiate this intergrown amphibole from the secondary amphibole. When the intergrown amphibole is primary, we see in the primatic zones both minerals bordering on one another with straight faces. Both minerals are very regularly distributed in the composed crystals. Uralitic amphibole is irregularly shaped, mostly found at the periphery of the augites. Moreover in the last case the two minerals are not so clearly distinguished from one another as they are slighlty dusty and the amphibole is light coloured. Epidote is sometimes found in a small amount, probably as a by-product of the uralitization of augite. A few large polyangular crystals of titanite and many smaller of magnetite occur. Apatite is present in a small amount.

At L. 279 (D. 16469) a contact metamorphic rock in a rather advanced stage of metamorphism, with a relic-porphyritic texture and a decidedly gabbroidic mineral composition has been found. As rests of phenocrysts we find pyroxenes, amphiboles, and plagioclases. The pyroxenes are of different composition. A lot of very large colourless diopsidic augite crystals with a hooibergitic habit occurs. This augite is partly or wholly replaced by light green, pleochroitic, uralitic amphibole, while often a slight concentration of magnetite is found in the phenocrysts. Moreover, light coloured pink-grayish to green pleochroitic hypersthene is found. It is idiomorphic, clear, unweathered and without inclusions. Some large plagioclase crystals occur, ranging in average composition from andesine to labradorite with many inclusions of amphibole and pyroxene grains forming a poikiloblastic texture. The groundmass is a totally recrystallized medium-grained, granoblastic mosaic of plagioclase, amphibole and diopsidic augite crystals. Small and larger grains of magnetite and some pyrite are present.

A third type of plutonic rock of the same nature as the hooibergites and gabbros occurs, namely an olivine-pyroxenite (D. 16467). This is a dark green to black coarse-grained rock. Microscopically it appears to have a hypidiomorphic texture. The large crystals impede each other and there is no distinct sequence of crystallization. The main consituent minerals are pyroxene and olivine. The pyroxene is partly a colourless, rhombic one, with a low polarisation colour. It has been partly replaced by almost colourless to light green dusty amphibole. Much more space is taken by monoclinic pyroxene, which is diopsidic augite and diallage. These too sometimes are replaced by amphibole. Olivine occurs in large crystals in and between the other minerals. It takes more space than the rhombic pyroxene and less than the monoclinic pyroxene. It is partly serpentinized. Accessory magnetite is present. This rock is also very probably a basic differentiation of the dioritic magma.

In the diorite intrusion E of Gavilan on some places hornblendite is found. The green, coarse-grained rocks are built up almost entirely of hornblende, wich is dark-green, pleochroitic and shows a typical cleavage. The crystals are large, hypidiomorphic, broad prisms. Epidote and chlorite are present in small amounts. Accessory magnetite and titano-magnetite is found.

Meta-hooibergites. The large bulk of these basic plutonic rocks, which consolidated before the main dioritic intrusion has been affected by contact metamorphism caused by the intruding magma and by dynamometamorphism caused by orogenic activity during and after the intrusion. The augite is replaced then by amphibole and epidote, the amphiboles pass into innumerous small needles of uralite, and many new small idiomorphic crystals are formed. The plagioclases are cleared up and, in a further stage, recrystallized into polyangular allotriomorphic grains and crystals. If the dynamometamorphosis is strong a definite foliation is found, emphasized by the amphiboles.

At L. 302 (D. 16493, D. 16494) we sampled a dioritic dike enclosing fragments of hooibergite and isolated hornblende crystals. The latter are easily distinguished from the amphiboles of the diorite being of a much larger shape. As can be seen from the photograph (Plate, fig. 12) both rocks are sharply bordered. Microscopically we see normal quartzfree hooibergite enclosed in slightly linear textured, cataclastic quartz-hornblende-diorite. The hooibergite does not contain any pyroxene, although in samples from the same locality pyroxene-hooibergites are found. The amphibole of the enclosed hooibergite is partly primary and partly secondary, replacing the pyroxene. The amphiboles are slighthly resorbed at their margin and somewhat dark by ore-inclusions, but on the whole their appearence is the same as in the hooibergites. The dioritic dike-rock is normal quartz-amphibole-diorite, with andesine, quartz, granophyric intergrowth between these minerals, amphibole, epidote, titanite, some biotite and magnetite. It is cataclastic, showing undulatory extinction and mortar structure of the minerals. Probably the irregular contour of the enclosed fragments may be caused by the cataclasis. The only effect of contact-metamorphosis here, is the amphibolitization of the pyroxene. It was complicated by the later cataclasis.

In a more advanced stage of metamorphism the hooibergites become dark-green, showing a pseudo-porphyroblastic texture, caused by the occurrences of many large amphibole crystals which have been saved from desintegretion by metamorphism, lying in a green, fine-grained "groundmass". The latter may show foliation. Mostly, however, no special texture can be seen. Microscopically these rocks are immediately recognized as altered hooibergites by the remnants of the large amphibole crystals. We find namely the large, prismatic crystals as in the hooibergites. At the ends of the prisms and, in a smaller amount, on their prismatic faces, the amphibole crystals are resorbed and desintegrated into many small amphibole needles and prisms and into uralitic needles, which together with the recrystallized clear albite and epidote form a granular medium-grained "groundmass". The albite forms polyangular to rounded isodiametrical grains, which are sometimes twinned. The amount of plagioclase depends on the original composition of the hooibergite. In some cases the amount of leukocratic minerals decreases and it is even found that no leucocratic minerals at all are present. Very probably the "groundmass" is squeezed out then. In these cases we find between the large amphibole crystals a fine-grained, "fluidal" mass of amphibole grains, and small prisms. The large amphibole crystals often show internal recrystallization, new small slender prismatic amphiboles being formed in them. Sometimes this recrystallization is excessive and we find a dense crowd of amphibole needles and prisms in the original large crystals. In the amphiboles are found poikilitic inclusions of epidote, calcite and albite. The epidote of the "groundmass" forms crowds of isodiometrical, medium-grained crystals. In the pyroxene-hooibergite the augite is mostly totally replaced by amphibole and epidote. A rough calculation shows that after uralitization of the diopsidic augite we can expect as much uralite as epidote or slightly more. This agrees well with our samples. In some cases, when the metamorphosis was not very strong we see large crystals of colourless augite with a rim of amphibole.

If the dynamometamorphosis was predominant over the contact metamorphosis the recrystallized amphiboles became slender prisms, the "groundmass", arranged parallelly to a common direction together with slightly elongated albite and epidote, producing a "fluidal" texture. Some large plagioclase crystals contain small inclusions of amphibole and epidote. Sometimes the epidote of the groundmass is affected by strong myrmekite-like corrosion by albite.

Amphibolitic rocks. In the Dioritic Intrusions on the South-side many amphibolitic rocks of various types have been found. They could be separated from the metahooibergites, as the last ones always are easily recognized by the relic hornblende crystals of the hooibergite. The origin of the different types cannot be stated with certainty. The ortho-nature is almost sure. There are amphibolites very probably originating from gabbros or hooibergites or hornblendite, recognizable by the mineral components, the chemical constitution and the relic textures. On the other hand amphibolites, very probably originating from magmatically stooped country rocks (porphyrite) are found. Finally of some amphibolites the origin is obscure. Several amphibolites are described in the following.

At M. 255 (D. 16720) a medium-grained, green, holocrystalline amphibolite, consisting of amphibole, pyroxene and plagioclase is found. Microscopically the rock shows a granoblastic texture. There are some large hornblende crystals carrying plagioclase inclusions. They are probably relics of the original rock. The great bulk of the rock is formed by smaller-grained, granoblastic, light green amphibole. The crystals are prismatic or isodiametrical quadrangular, and hexagonal, carrying often plagioclase inclusions. A small amount of diopsidic augite is found, almost always enclosed in or surrounded by amphibole granoblasts. These augites, which are smaller in size than the hornblende, are probably also relics of the original rock. Plagioclase is the second mineral of the rock and occurs in isodiametrical, often twinned, clear crystals. The average composition ranges from andesine to labradorite. Often poikilitic amphibole inclusions are found. For the chemical composition of this rock see analyse no. 3 on page 51. This suggests an ortho-rock of basic composition between the gabbro-norite and pyroxene-hornblendite.

The structure of the samples from V. 356 (D. 16878), L. 437 and L. 438 (D. 16569—D. 16579) is very similar to that of the sample of M 255. The amount of amphibole is larger; epidote is present and pyroxene is lacking. In this rock also allotriomorphic chlorite and magnetite occur, which, in consequence of dynamometamorphosis form streaks in the rock. In these cases the amphibole and plagioclase are arranged in a common direction and the rock is foliated. These rocks are cut by albite veins and some of the plagioclases are albitized. The origin of these rocks is not clear.

At A. 495 (D. 17103) and A. 497 (D. 17105) another amphibolite occurs. The rock is light-green, pseudo-porphyroblastic, foliated. Microscopically we see large, broad hornblende prisms mostly not parallel to the common direction. They are often poikilitically sieved by many plagioclase inclusions, especially at the periphery of the crystals. These amphiboles are not porphyroblasts, but relics of the original rock. They are situated in a "groundmass" which is for the smaller part granoblastic and for the larger part nematoblastic to lepidoblastic. It is built up by small and large amphibole prisms and elongated clear plagioclase grains. The amphibole is light-green and pleochroitic. The average composition of the plagioclase is andesine to labradorite, while albite and oligoclase also are present. The rocks are cut by aplitic veinlets. The large primary amphiboles suggest a gabbroic or hooibergitic origin for these rocks.

In other rocks the texture is strongly lepidoblastic and no more large lenticular relics of primary amphiboles are present. H. 297 (D. 16923, D. 16924, D. 16926), H. 299 (D. 16927) and H. 302 (D. 16933) are rocks of this type. These rocks are finely foliated. Microscopically they appear to be totally recrystallized rocks with a very fine linear texture, caused by the very regularly distributed, equigranular crystals of amphibole and andesine. These crystals are elongated, rather small, and very clear; they carry poikilitic inclusions of each other. Magnetite occurs in smaller grains, between or enclosed in the other minerals. Epidote occurs in these rocks in a certain amount. Sometimes it is found together with calcite and ore and sericite in patches, which originally have been plagioclase crystals.

Finally amphibole-schists have been found, existing almost entirely of green pleochroitic hornblende. This mineral is present in fine needles, and prisms or in tabular elongated prisms. Chlorite is often found. Porphyroblastic texture, marked by large hornblende and chlorite (pennin) crystals occurs. In many amphibolites a larger or smaller amount of secondary epidote is found. If the amount of epidote and hornblende is about equivalent, we are dealing with epidote-amphibolite. At L. 287 (D. 16975—D. 16977) e.g. a fine-grained highly foliated, microgranoblastic epidote-amphibolite is found.

Quite different from the above mentioned amphibolites are the pyroxene-amphibolites from V. 115 (D. 16848), L. 438 (D. 16577), L. 570 (D. 16608), and M. 277 (D. 16725). These rocks show macroscopically alternating lenses and bands of a dark- and lighter-green colour giving a schistose impression. Microscopically it appears that these colours are caused by green hornblende, and almost colourless pyroxene. The texture is a "Hornfels Structur". The minerals form isodiametrical or slightly elongated grains. The main constituant minerals are amphibole, pyroxene and plagioclase. The different bands appear to be built of plagioclase with predominant amphibole or in other bands with predominant pyroxene. Plagioclase is clear, never twinned, in composition ranging from albite to andesine, with the latter prevailing. In the bands rich in augite the plagioclase occurs in a larger amount than in the amphibole-bands. The amphibole is green, pleochroitic. This mineral shows most of all an elongated habit of the crystals. It is largely prevailing over the plagioclase and pyroxene together, at least in the amphibole bands. The pyroxene is colourless diopsidic-augite. Accessory magnetite grains and apatite needles are present. Epidote is sometimes found replacing the augite. On the whole these rocks are very fresh. About the origin of them nothing can be said. Very probably these rocks, which are found as inclusions in the dioritic intrusion represent metamorphic rocks in a rather advanced stage of metamorphism.

Quartz-diorite-porphyrite. Many rocks of this type were sampled in the Northern part of the intrusion, especially near the contact with the Tuff Formation. Three dikes of this rock-type were found in the Tuff Formation near the contact. These originated very probably from the main intrusion, which lies close below the surface and below the rocks of the Tuff-Formation there. The other quartz-diorite-porphyrites occur as dikes in the quartz-diorites. Macroscopically the rocks are grayish-white, mostly greenish or brownish weathering. Quartz and plagioclase phenocrysts are visible in a finegrained to aphanitic groundmass. Microscopically we see rather acid porphyrites, with a more or less strongly predominant groundmass. The phenocrysts are quartz and plagioclase; often rests of mafic phenocrysts are found as aggegrates of chlorite, calcite, and sometimes epidote or brown oxidic ore. Unaltered hornblende or biotite phenocrysts never are found. Quartz phenocrysts occur sometimes in a larger, mostly equal or in a smaller amount than the plagioclases and in a larger amount than the altered mafic phenocrysts. Apatite, titanite and magnetite are accessory minerals.

The plagioclase phenosrysts are short or long, simply twinned prisms, which often are found in groups. In the fresh, unaltered ones they border sharply with the groundmass. The average composition ranges from albite over albite-oligoclase to andesine. Often they are very dusty and the crystals are rounded off, this caused by the groundmass which works in with the plagioclase phenocrysts. The plagioclase is altered in many different ways by weathering. We see albitization, chloritization, sericitization and epidotization in varying amounts. The quartz forms beautifully clear, mostly unaltered, idiomorphic phenocrysts, carrying lines of inclusions. Often they are rounded off, and partly resorbed by the groundmass, sometimes showing a broad resorption rim. In some thin-sections the quartz phenocrysts are broken and the fragments lie close to each other, with between them groundmass. Hence, during the intrusion the phenocrysts are broken and afterwards the groundmass consolidated between the fragments. Here, locally we have protoclastic structure. The partly consolidated magma must have been affected by stresses and this may be considered as an indication for the coincidence of an orogenesis and the intrusion.

The aggregates of alteration products of the mafic minerals sometimes show the form of amphibole prisms. They are mainly composed by calcite and/ or chlorite. The calcite may be microcrystalline or medium-grained. Chlorite forms dark-green, not pleochroitic, irregularly shaped grains. In other places this mineral is obviously a light green pleochroitic alteration product of biotite. The groundmass is holocrystalline, fine- to small-grained. The texture is panallotriomorphic-granulose, or hypidiomorphic-microgranitic. The components are quartz and plagioclase and often chlorite, calcite, oxidic ore and sometimes small, green, pleochroitic biotite flakes. In the last mentioned micrograniti groundmass the plagioclases form small laths, and sometimes micrograniphyric intergrowth with the quartz is found. Chlorite may be found then in very streaky leaflets between the other minerals. The groundmass is often altered; silicification is found and in other cases it is replaced by a fine calcite and sericite powder. In L. 318 (D. 16512) the altered groundmass is a fluidally arranged isotropic chlorite, calcite and sericite mass.

Many of the quartz-diorite-porphyrites are totally silicified and form quartz dikes with a relic-porphyritic texture.

Hornblende-diorite-porphyrites. We found two different types of these rocks. At A. 492 a hornblende-diorite-porphyrite with a crypto- to micro-crystalline groundmass occurs, while on A. 497 (D. 17106) and H. 630 (D. 16971) rocks of this type with a holocrystalline, rather coarse groundmass are found.

The hornblende-diorite-porphyrite of A. 492 (D. 17101) is a light coloured rock with dark phenocrysts in a white groundmass. Microscopically we see large and smaller phenocrysts of amphibole and plagioclase in a crypto- to micro-crystalline groundmass consisting of a fine panallotriomorphic aggregate of a colourless minerals (probably plagioclase and quartz) with epidote and slightly larger amphibole and magnetite microlites. The amount of the groundmass and the phenocrysts is about equal. The plagioclases are clear, and sometimes strongly weathered, idiomorphic, isodiametrical or prismatic phenocrysts. They show twinning and zoning. If decomposed, they are weathered into epidote, calcite and sericite. The average composition of the plagioclase is andesine. The amphibole phenocrysts are dark green, pleochroitic, idiomorphic and often twinned. Sometimes they carry several inclusions of ore or epidote. By weathering they are replaced by chlorite or epidote with ore. Magnetite is an accessory mineral in medium-grained crystals.

H. 630 is a light, porphyritic, grayish rock with plainly visible plagioclase, quartz, amphibole and biotite phenocrysts. Microscopically we see that the amount of phenocrysts is about equivalent with the groundmass. The phenocrysts are p.p. broken into angular fragments. The plagioclases are clear, isodiametrical, and prismatic crystals, often with twins or zonal arrangement. The average composition ranges from andesine to labradorite. Some smaller, clear quartz phenocrysts are found. Amphibole forms large and smaller idiomorphic grains of green pleochroitic hornblende in a small amount. Biotite occurs is a larger amount than amphibole and a smaller than the plagioclase. It occurs in large and smaller, brown, pleochroitic crystals. The groundmass is a dusty, light aggegrate of quartz grains, plagioclase laths, biotite flakes, hornblende scales, apatite needles, and ore grains.

A. 497 is a amphibole-diorite-porphyrite only differing from the common diorite by its porphyritic texture. The mineralogical composition is the same as in the diorite.

Leucocratic dike rocks. To this group several light coloured dike rocks belong. They are partly of magmatic origin (diorite-aplite, grano-diorite-aplite, plagiaplite), partly of postmagmatic origin (quartz-epidote rocks, quartz-rocks, and epidote-rocks). They form clearly dikes in the hooibergites, gabbros, amphibolites and quartz-diorites. Mostly these dikes are narrow, sometimes broad. At M. 252 a very large dike measuring 15 m in diameter is found.

The aplitic rocks are grano-diorite-aplite, plagiaplite and diorite-aplite. They are holocrystalline, panallotriomorphic, medium- to coarse-grained, white, yellowish and pink rocks. They consist mainly of felspars and quartz. The dark minerals are biotite and ore, occurring in small numbers and small crystals. Quartz is white and felspar sometimes pink. Microscopically the granodiorite-aplites show the following components: orthoclase, microcline, albite, oligoclase-andesine, quartz, granophyric intergrowth of albite and quartz, microcline-perthite, myrmekite, biotite, garnet, aptatite and magnetite. Secondary epidote, chlorite and limonite are found. The quartz occurs in a smaller amount than the plagioclase and in a larger amount than the kalifelspars. Myrmekite is found on the border of quartz and microcline or plagioclase. The granophyric intergrowth of quartz and albite sometimes is rather coarse, almost graphic. Biotite occurring in small flakes, mostly is weathered into lightgreen, pleochroitic chlorite.

In the plagiaplites no kalifelspars occur. Biotite and muscovite are present at the side of spheroidal light-green chlorite. Epidote is found in a somewhat larger amount than in the granodiorite-aplites.

One plagiaplite must be mentioned separately for its special texture. At L. 314 (D. 16507) we found a white dike-rock, which microscopically shows a typical texture. Idiomorphic albite and oligoclase prisms lie in and around allotriomorphic quartz grains and then form an almost intersertal-like texture. The quartz is clear, the plagioclase is dusty and sericitized. Magnetite and hematite are present in this rock.

The aplites are affected by cataclasis on several places, and the same structures, as described in the other dioritic rocks are found. The extinction becomes undulatory, the crystals are broken at the margin and mortar structure comes into being, the desintegration continues and lenticular relics of the original crystals lie in a mylonitic matrix of crushed grains. SiO_2 solution was mobile, and secondary quartz is found with new grains and corrosive in the primary crystals. The brittle nature of the aplitic rocks was very capable for mylonitization. The aplites yielded the most striking examples of gneissification and mylonitization. On the Plate the figures 10 and 11 show strongly cataclastic aplitic rocks.

The post-magmatic dike rocks are light-green to green, on weathered surfaces with a brownish colour. Once white quartz amygdales in the green rock have been found. These rocks are built of varying amounts of quartz and epidote. They are small-, medium-, and coarse-grained. Almost entirely epidote is found in H. 248. The epidote crystals are coarse and show polyangular contours. This mineral occurs together with green, pleochroitic chlorite and titanite. In H. 251 (D. 16910) and M. 185 (D. 16675) epidote is predominant over quartz. H. 251 has amygdales, filled in with clear quartz and at the periphery with clear polyangular, epidote, sometimes radially arranged, in prisms. These amygdales lie in a "matrix", which consists of very irregular medium-grained, dusty epidote and some quartz. A. 489 (D. 17097) is a medium to fine-grained quartzitic rock with chlorite and epidote veinlets. In A. 292 (D. 17013) and M. 192 (D. 16684) the small-grained quartz and epidote are equivalent. M. 188 (D. 16678) is an epidote-chlorite-quartz-rock, with epidote predominant. Chlorite occurs together with titanite and probably is altered biotite from the country rock. Magnetite is present as an accessory.

Lamprophyric dike rocks. Several malchites, some spessartites and one odinite have been found. We did not find a special distribution of occurrence of the lamprophyres. They are found as dark dikes in the quartz-diorites.

The malchites are small- to fine-grained, green rocks. Microscopically the rock mainly consists of plagioclase, hornblende and quartz. The amount of dark and light minerals is almost equal. The texture is holocrystalline, hypidiomorphic, fine- to medium-grained, granular, while some large crystals of amphibole and plagioclase occur. The plagioclase is andesine-labradorite and albite. The albite always is allotriomorphic. Sometimes it forms large crystals, enclosing rare idiomorphic amphibole and plagioclase prisms. This is the same peculiar texture as we also found in the quartz-diorite in several samples. The common texture is determined by hypidiomorphic equigranular prisms of amphibole and plagioclase. The amphibole often is idiomorphic too. The plagioclase forms small laths and short twinned prisms, which are mostly idiomorphic with regard to the quartz, while sometimes quartz and plagioclase work in with each other. Quartz is clear; plagioclase slightly dusty, sericitized or replaced by epidote and chlorite. The amphibole is light green, pleochroitic. It is always idiomorphic with regard to the quartz. Titanite grains, small magnetite grains and small apatite needles are found accessorily.

The spessartite from A. 493 (D. 17102) and L. 288 (D. 16478, D. 16479), is texturally, and structurally very much alike the malchites. It differs from them by the occurrence of orthoclase in allotriomorphic grains.

The odinite from H. 306 (D. 16935) is a fine-grained, brownish green rock. Microscopically it consists of hypidiomorphic plagioclase laths and fine brownish idiomorphic amphibole needles and chlorite grains which are probably altered pyroxene. The texture is hypidiomorphic.

Foreign inclusions in the dioritic intrusion. Amphibolites, differing in texture and composition from all the above described ones are found as inclusions in the diorites at L. 277. Dark green porphyritic rocks with a dense groundmass show microscopically augite phenocrysts replaced by amphibole at their periphery, in a panallotriomorphic, medium-to fine-grained groundmass, built of amphibole and felspar. The amphibole is dark to light green, pleochroitic, irregularly shaped, often replaced by epidote or chlorite. In spite of their irregular shape sometimes they suggest by their arrangement, a slightly linear texture. The felspars form isodiametrical fine-to medium-grained crystals which are more or less clear. Orthoclase, microcline, albite and oligoclase are found. Apatite and titanite are accessory minerals. The phenocrysts are primary diopsidic-augite, more or less replaced by amphibole, with many poikilitic intrusions of felspar and amphibole. Many amphibole phenocrysts show an augite shape. The augites are like those found in the porphyrites of the Tuff-Formation. The groundmass is quite different from those in the other amphibolites, by its more evenly distributed, fine-grained, equigranular granoblastic texture. These features suggest an original porphyritic rock from the Tuff-Formation, altered by contact metamorphism. These rocks too are cut by leucocratic dikes.

At H. 296 a quartz-sillimanite-mica-schist is found, together with strongly, finely foliated amphibolites. The rock is feltlike, light-brown. Microscopically it appears to consist of quartz, brown mica, sillimanite, and accessory magnetite. The quartz occurs in clear, allotriomorphic, large grains, the sillimanite in long needles, the mica in light-brown, pleochroitic crystals. The foliated structure is caused by the sillimanite and mica. Oxydic ore is, in large and small grains, irregularly spread in the rock. This a rather strongly contact-metamorphic rock, the origin of which is unknown.

At L. 291 (D. 16486) an amphibole-biotite-plagioclase-schist is found with many biotites. The rock is foliated, dark green. Microscopically it shows a foliated texture, caused by the streaks of biotite and the elongated green amphiboles. Biotite is light brown, pleochroitic. Occasionnaly it is found within the amphibole crystals. The amphibole is common green hornblende. The amount of both are equivalent, and together they take up more space than the andesine, which is the only light mineral. Some crystals of rhombic-pyroxene are present. Magnetite and hematite are accessory minerals. Chlorite and many coarse grains of epidote are decomposition products of the mafics. The origin of this rock is unknown.

At M. 237 (D. 16704) a calc-silicate-hornfels occurs as inclusion in the diorite. The origin of this rock is not known. It has a foliated porphyroblastic structure with a medium grained granoblastic groundmass, while the phenocrysts are highly poikiloblastic. The porphyroblasts are amphiboles or replacing calcite and epidote, the latter allotriomorphic or pseudomorphic after amphibole. The amphibole is secondary, tabular, its character, however, is not uralitic. Probably this is a result of a higher grade of metamorphism than in the uralite-porphyrites. The groundmass is composed of clear microcline, albite, and andesine as allotriomorphic rounded polygonal grains; and idiomorphic yellow garnet surrounded by calcite. Magnetite, pyrite and zircone are found, too. Calcite fills the spaces between the other minerals.

Habana Formation.

The name "Habana Formation" was given by PALMER (32) for Upper Cretaceous beds near Habana. M. G. RUTTEN applied the same name for all the Upper Cretaceous beds on the island, which may vary rather strongly in lithological and petrographical character, but which contain the same fauna and are of the same age.

In Southern Santa Clara this formation outcrops on many places in rather small exposures. The extension has been much larger than is found now, as can be seen from the relics of the Habana Formation lying on the Tuff Formation on several places in the centre of the tuff area. Probably it has covered very large parts of island and it has been thoroughly affected by denudation during the Lower and Middle Eocene.

The rocks of the Habana formation are chiefly found on the rims of the Tertiary basins, where the transgressive Tertiary rocks do not cover them by overlapping.

The age of the Habana Formation is determined by the occurrence of the foraminiferal genera *Lepidorbitoides* and *Orbitoides* which in Europe are index-fossils for the Maastrichtian beds. Moreover a large fauna is found of *Globigerinidae*, *Vaughanina*, *Camerina*, Rudists, Corals, Echinids and a small amount of *Radiolaria*. In the palaeontological list the species will be enumerated with their finding-places.

The rocks of the Habana Formation are transgressive over the diorites (A. 486) and over the Tuff Formation on many places. Detritical material of these two formations is found in the conglomerates of the Habana Formation, e.g. fragments of porphyrites and spilites of the Tuff Formation and of quartz-diorites and aplites of the diorites. Very often these fragments are found together with several typical Upper Cretaceous fossils.

The structural unconformity between the Habana Formation and the Tuff Formation can be seen clearly on the map in the surroundings of Soledad, SE. of Palmira, N. of Jutia and around Fomento. In this last mentioned region the Habana Formation forms a synclinal.

In the Western part of Southern Santa Clara it is difficult tot state whether the Habana Formation and the Upper Eocene are structurally conformable or unconformable. Stratigraphically there is a large gap between both formations. In the Eastern part of the Provnice a structural unconformity occurs, as can be seen from the map NW. of Cabaiguan. Here the strikes of the Tertiary and Upper Cretaceous strata are divergent.

The structures of the Habana Formation in the Western part of the Province are simple. In the Eastern part near Fomento and Guayos, and

North of Zaza del Medio, the folding is much stronger and we see steep synclines and anticlines. On the Carretera Central e.g. South of Guayos, this is well exposed. South and East of Fomento at V. 332 and L. 573 and also at V. 307 South-East of Guayos the rocks of the Habana Formation are even overturned.

The Habana Formation North of Jutia is to the North bordered by a fault, which in the landscape is emphasized by a steep slope of the hill consisting of rocks of the Habana Formation.

The Habana Formation comprises limestones, microconglomeratic and tuffaceous limestones, marls, crystal-tuffs, vitric tuffs, and probably porphyrites too. The vitric tuffs are found only at two localities. All the other types of rocks, except the porphyrites, are found in the whole district, irregularly alternating with each other. The volcanic tuffs and the tuffaceous limestones prove a volcanic activity during Upper Cretaceous times. M. G. Rutten describes intrusions of porphyrites in the Habana Formation and concludes that: "We may consider the volcanic activity, during the sedimentation of the Habana Formation, as the waning of the igneous activity that formed the earlier dioritic intrusions." In the Southern part of the Province no porphyritic rocks have been sampled in the Habana Formation, although it must be mentioned that, on the course from Guyaos (Carretera Central) to the NE. and in a smaller amount on the course from Zaza del Medio to the NE. many large rounded porphyrite blocks are irregularly distributed in the region of the white marls and limestones, which in consequence of their lithological and tectonical habit very probably belong to the Habana Formation. As these "orientation courses" were very long ones, no samples could be collected; so we are not sure about the age and the character of these porphyrites.

Vitric tuffs are found at V. 367 (D. 16882, D. 16883), and V. 369 (D. 16884). They are white-yellowish or light purplewhitish, in one sample cut by many very fine epidote veins. They are distinguished from the vitric tuffs of the Tuff Formation by their colour. Microscopically we see cloudy glasstuffs, p.p. calcified, p.p. chloritized and, in one case, cut by epidote veinlets. V. 367 carries large inclusions of epidotized and silicified rock fragments and separated crystals.

A. 442 (D. 17062) is a purple, dense clayish rock showing microscopically a glassy mass with many microcrystalline, small, light-coloured needles, with a low birefringence, forming, together with brown limonite, dusty green chlorite and dark ore, a very dusty rock mass. Some larger crystals of plagioclase, quartz, amphibole and epidote occur.

A. 443 (D. 17063) is a greenish fine-grained rock. Microscopically we see a micro-crystal tuff with a large amount of small, clear fragments of crystals, in amount prevailling over the crypto- to micro-crystalline basis. The crystal fragments are of andesine (twinned prisms), amphibole, more or less calcified or chloritized, biotite and ore.

Another sample from A. 443 (D. 17064) is a tuffite with a calcareous cement. Between rocks of this last mentioned type and limestones, carrying volcanic material, all transitional rocks are found. Tuffaceous and micro-conglomeratic limestones are micro- to fine-grained, grayish rocks. The amount of inclusions is strongly varying, and also the dimensions of the inclusions and conglomeratic material vary from small to rather coarse grains.

In the conglomeratic limestones occur the following inclusions: fragments of quartz-diorite, quartz-diorite-porphyrite, aplites, porphyrites Tuff Formation, spilites, tuffs, vitric tuffs, schist material, and grains of quartz, plagioclase, augite, amphibole and chlorite.

It is difficult to distinguish the tuffs of the Habana Formation and those of the Tuff Formation. M. G. RUTTEN enumerated several distinguishing features, which hold true for the Southern facies of the Habana Formation in Santa Clara Province. The most important one is the constant occurrence of fragments of clear quartz crystals in the Habana Formation. Other distinguishing features are 1, the occurrence of clear twinned plagioclase in the Habana Formation, 2, the occurrence of Upper Cretaceous fossils as e.g. Orbitoids, *Camerina dickersoni*, *Vaughanina cubensis*, and Rudist fragments, 3, the occurrence of detritical material of dioritic rocks. The second one is a very good feature, because in very many samples fossils are found, and the difference with other formations is evident.

The limestones of the Habana-Formation usually are yellow, sometimes greenish or reddish, compact rocks with many fossils. They are thinbedded to platy and sometimes occur in horizons of 15 meter width. Microscopically we see crypto- to micro-crystalline limestones with patches of medium-grained calcite and fossil material. Often they carry a few, small inclusions of fragments of quartz, plagioclase or calcite.

The marls are white (at one locality purple) and compact. Often they carry Smaller *Foraminifera* related to the *Globigerinidae*. The marls alternate repeatedly with the limestones and microconglomeratic limestones.

At V. 79 (D. 16835) an almost totally silicified Habana limestone is found. The rock is replaced by very small SiO_2 grains, and spheroidal quartz. Some of the *Foraminifera* have saved their calcite, most of them are silicified.

The rocks of the Habana Formation are formed on a submergent bottom of a shallow sea. With regard to the thickness of the Habana Formation it must be mentioned that possibly large quantities of rocks have been carried of by denudation, and the minimum thickness of 700 m found by us is not representative for the formation. R. H. PALMER found a thickness of 7000 feet for this formation in the province of Habana.

List of Fossils from the Habana formation.

? *Archaias rutteni* Palmer	L. 128, A. 454.
Camerina dickersoni Palmer	M. 20, M. 62, M. 76, H. 614, L. 67, L. 128, L. 129, L. 130, L. 136, L. 138, L. 139, L. 435, L. 547, L. 548, A. 62, A. 438, A. 441, A. 457, A. 461, A. 466, V. 38, V. 43, V. 71, V. 300, V 307.
Camerina sp. c.	L. 128.
Vaughanina cubensis Palmer	M. 20, M. 62, M. 64, M. 65, H. 601, L. 67, L. 136, L. 170, L. 214, L. 435, L. 547, A. 436, A. 437, A. 441, A. 457, A. 461, V. 36, V. 37, V. 38, V. 43.
Orbitoides browni (Ellis)	M. 29, M. 62, M. 64, M. 76, M. 101, L. 129, L. 136, L. 140, L. 205, L. 225, L. 547, L. 548, A. 62, A. 436, A. 437, A. 438, A. 466, V. 36, V. 43, V. 71, V. 300.
Orbitoides apiculata Schlumberger	M. 101, L. 136, L. 138, L. 225.
Orbitoides palmeri Gravell	M. 29, L. 128, L. 225.
Orbitoides sp.	M. 20, H. 601, L. 435.
Lepidorbitoides rutteni Thiadens	L. 128, L. 140.
Lepidorbitoides rutteni var. armata Thiadens	L. 128.
Lepidorbitoides macgillavryi Thiadens	L. 128, L. 140.
Lepidorbitoides palmeri Thiadens	L. 128.
Asterorbis sp.	M. 62, M. 101, L. 67, V. 36, V. 43, V. 71.
Pseudorbitoides israelski Vaughan and Cole	M. 62, M. 65, A. 457, A. 461, V. 36, V. 37, V. 43.
Pseudorbitoides trechmanni H. Douvillé	H. 614, A. 436, A. 437.
Rudist fragments	M. 20, H. 55, H. 271, H. 274, H. 614, H. 617, H. 621, L. 170, L. 205, A. 461, A. 466, V. 38, V. 71, V. 300, V. 301.
Mitrocaprina tschoppi (Palmer) [1])	H. 616.
? *Antillocaprina* sp.	H. 627.
Barrettia sparcilirata Whitf.	L. 128, H. 627.
Parastroma sanchezi H. Douvillé	L. 549, L. 550, L. 553, L. 554.
Radiolites macroplicatus Whitf.	T. 1384.

[1]) determinavit H. J. Mac Gillavry.

Bournonia planasi Thiadens	H. 241, H. 245, L. 225.
Bournonia n.sp.	H. 601.
Bournonia sp	H. 206
Biradiolites aquitanicus Toucas	H. 624, L. 549.
Tampsia rutteni Vermunt (in lit.)	H. 614.
Durania sp.	H. 260.
Titanosarcolites giganteus (Whitf.)	H. 245, H. 624, L. 128, L. 138, A. 450.
Hawkensia cubae (Hawkins) [1])	H. 233.
Lanieria lanièri Cotteau [1])	H. 233, T. 1312, T. 1316, T. 1317, L. 130, L. 220.
Brissoides sp. [1])	T. 1312.

Tertiary.

Upper-Eocene, Oligocene and Upper-Oligo-Miocene beds have been found. Lithologically and in the field they are very much alike and difficult to distinguish. In the laboratory they could be separated by fossils, especially by *Foraminifera*. For these reasons we have indicated on the map all the Tertiary rocks with one colour, whilst E, EO, O and M indicate those places, where we are sure of the special age of the rocks. There is a stricking difference between the faunas of the rocks which are found on localities, indicated with O and with M on the map, but it is not absolutely sure, that the rocks considered as "Miocene" are not "Upper-Oligo-Miocene". On the places indicated with EO Upper Eocene *Formanifera* have been found together with Oligocene ones (see page 47), and we are dealing therefore with transitional beds. These faunas will be described in a separate study, which is in press with the Journal of Paleontology and will appear in the course of this year. The finding places of the different species are enumerated in lists on page 46—47.

The Upper-Eocene rocks contain *Discocyclina*, *Dictyoconus*, *Helicolepidina* and *Lepidocyclina* (*Isolepidina*), the Oligocene ones *Eulipidina* and *Nephrolepidina*; the Upper Oligo-Miocene deposits contain *Miogypsina*, *Amphisorus* and *Archaias*.

In Southern Santa Clara Province Tertiary rocks are found at many places. The largest exposures are around Cienfuegos and North of Caracas; moreover North-East of Trinidad and South and East of Sancti Spiritus. The two first mentioned regions are in connection with the large basin of Colon, the last two with the basin of Moron. Moreover, Tertiary strata are found North and South of Manacal in two small synclines on the schists.

Around Cabaiguan folded Tertiary beds are found unconformably over rocks of the Habana Formation. At L. 104 SE of Cruces, finally, a small Tertiary outcrop has been found. These last mentioned Tertiary rocks

[1]) determinavit J. van Soest.

may be synclinal or surrounded by faults. The Tertiary beds are transgressive over all the older Formations, as can be seen on the map. Stratigraphically a large disconformity between the Upper Cretaceous and Upper Eocene must exist, since Lower and Middle Eocene rocks never have been found. A structural unconformity is found also between the Habana beds and the Upper Eocene beds, although not on all places, where they border with each other. This structural unconformity is exposed around Cabaiguan, where the Upper Cretaceous strata are folded with a general East-West strike, and the Tertiary beds are folded in a more gentle way, striking NW—SE. Moreover North of San Juan a structural unconformity between both formations has been found as can be seen on the map of M. G. RUTTEN. In the large exposures of Tertiary and Upper Cretaceous rocks around the bay of Cienfuegos no structural unconformity could be observed, although we found the Tertiary overlapping the Habana Formation. As it was difficult to distinguish the rocks of both Formations in this region, only fossils were decisive.

The Tertiary is transgressive over the diorites South of Gavilan and Sancti Spiritus and North of Manacal; over the Tuff-Formation North of Cienfuegos, South-East of Cruces, East of Cruces and South of Sancti Spiritus; over the schists North of Trinidad and near Manacal. Pebbles of all these formations are found in Tertiary conglomeratic limestones.

On the whole in the Southern part of the Province the Tertiary is gently folded. Only North of Cabaiguan some steep dips up to 50° were found. No inter-tertiary unconformity has been observed. On other places on the island, e.g. in Pinar del Rio a distinct unconformity between Eocene and Oligocene on the one side and the Upper-Oligo-Miocene on the other side is found. PALMER (32) too, mentions this inter-tertiary structural unconformity. The Upper-Oligo-Miocene beds in our district are found on three places. At L. 232 opposite to Cienfuegos, right across the bay, the Upper-Oligo-Miocene beds are horizontal, while the Eo- and Oligocene beds 2 km North of Cienfuegos dip up to 30°. Here, probably, we find indications for a structural unconformity. At M. 591 and M. 595 on the Carretera Central near Jatibonico the Upper-Oligo-Miocene beds dip only very little (about 5°), while the Eo-Oligocene beds dip slightly more. Here, however, no indications for the structural unconformity are present.

The Tertiary beds are mainly composed of white marls and white-yellow, thin bedded limestones, moreover of conglomeratic and fine sandy limestones. At one locality a limy, sandy shale, rich in coal has been found. N. of Cabaiguan the Upper-Eocene rocks begin with a medium-grained basis conglomeratic L. 431 (D. 16551, D. 16552).

The marls are sterile or carry many smaller *Foraminifera*, which could not be isolated and in consequence could not be determined. They carry small grains of quartz, chlorite and plagioclase.

The limestones are white or yellow, mostly thin-bedded, sometimes thickbedded. They are sometimes sterile, but mostly carry many organisms.

Fine-grained to marly limestones with *Globigerinidae* and fine- to medium-grained Orbitoidal-limestones are common in the district. These rocks, too, enclose volcanic material, which mostly is detritical and sometimes tuffaceous.

The conglomeratic limestones carry many inclusions, measuring mainly ½—1 cm in diameter, sometimes more. The samples of L. 431 (D. 16551, D. 16552) e.g.: fragments of quartz-epidote-schist, porphyrites with chloritized groundmass or phenocrysts, quartz-diorites, quartz-grains, plagioclases (albite to labradorite, myrmekite), microcline, amphibole, biotite, garnet, chlorite a.s.o.

The amount of calcite cement and rock fragments is strongly varying, mostly the calcite is predominant. In some cases we found in the limestones well rounded porphyrite fragments (detritical material) at the side of polyangular crystal fragments of quartz or plagioclase. The latter probably are of tuffaceous origin and represent uncertain traces of Tertiary volcanic activity. As already mentioned, all these rocks are distinguished from those of the Habana-Formation by fossils only.

One Tertiary, limy, sandy shale, rich in coal is a remarkable rock. It has been found at L. 433 (D. 16554) lying almost horizontally over conformable white marls. The rock is dark, greasy, slate-like, with a black streak. Microscopically we see a finely bedded, dense aggregate of quartz and calcite grains, muscovite scales, and black coal powder.

In the Upper-Eocene the limestones and conglomeratic limestones are predominant, while in the Oligocene white marls prevail. The Oligo-Miocene beds which probably can be parallellized with the "Guines-limestones", are composed of conglomeratic to sandy marls.

Fossils from Upper Eocene beds:

Dictyoconus fontabellensis (Vaughan)	M. 33, M. 59, M. 664, M. 671, L. 216, L. 431, L. 556, A. 481, A. 483, V. 75, V. 306, V. 362, V. 371.
Camerina petri M. Rutten	V 17.
Camerina malberti M. Rutten	V. 18, M. 664.
Camerina sp. cf. *C. parvula* Cushman	M. 678.
Camerina sp. d. Thiadens	M. 678.
Camerina sp. (is *Amphistegina cubensis* Palmer, pars)	M. 33, L. 119, A. 481.
Operculina sp.	M. 664, H. 281.
Lepidocyclina mortoni Cushman	M. 678, M. 681, V. 17, V. 18.
Lepidocyclina pustulosa H. Douvillé	M. 681.
Lepidocyclina trinitatis H. Douvillé	V. 17.
Helicolepidina spiralis Tobler	M. 678, M. 681, V. 17.
Discocyclina blumenthali Gorter and v. d. Vlerk	M. 678.

Discocyclina cubensis Cushman	V. 18.
Discocyclina vermunti M. G. Rutten	M. 664, M. 678, M. 681, V. 17.
Discocyclina sp.	M. 33, M. 59, M. 664, M. 671, H. 281, H. 285, L. 104, L. 163, L. 216, L. 431, L. 556, A. 481, A. 482, A. 483, V. 16b, V. 18, V. 306, V. 362, V. 371.

Fossils of the transitional beds between Upper Eocene and Oligocene:

Lepidocyclina maracaibensis Hodson	L. 588.
Lepidocyclina mortoni Cushman	L. 588, L. 590.
Lepidocyclina supera (Conrad)	L. 588.
Lepidocyclina tschoppi Thiadens	L. 588.
Lepidocyclina weeksi Hodson	L. 588.
Lepidocyclina formosa Schlumberger	L. 588, L. 590.
Helicolepidina spiralis Tobler	L. 588.

Fossils of Oligocene beds:

Camerina sp. A.	L. 229.
Camerina sp. B.	L. 229, H. 4, H. 10.
Planularia sp.	L. 229.
Lepidocyclina formosa Schlumberger	L. 229, H. 25, M. 587, M. 596.
Lepidocyclina undosa Cushman	L. 229.
Lepidocyclina marginata (Michelotti)	L. 229.
Lepidocyclina petri Thiadens	M. 587.

Fossils of Oligo-Miocene beds:

Archaias adunca (Fichtel and Moll)	L. 232, M. 591, M. 595.
Amphisorus matley Vaughan	M. 591, M. 595.
Miogypsina hawkinsi Hodson	L. 232, M. 595.

Moreover, in the Tertiary beds many Smaller *Foraminifera*, *Radiolaria*, Corals, *Lamellibranchiata*, *Gastropoda* and Echinids are found. As in most of the cases it was possible to determine the age with the Larger *Foraminifera*, the determination of the other fossils would be of palaeontological interest only. This has not yet been done for two reasons: first because time was lacking and secondly becanse part of the material was rather bad.

Chapter III: **TECTONICS.**

When we consider the tectonical features of the Southern part of Santa Clara Province, first of all the tectonics of the Schist-Formation must be treated. There are two possible suppositions.

1. The Schist-Formation is an autochthonous complex.
2. The Schist-Formation as a whole is part of an overthrust mass.

First we will treat the second possibility. The distribution of the dioritic rocks W., N. and E. of the Schist-Formation especially induced us to consider this. In this case the schistcomplex would be an overthrust mass with no known root, coming from the South and lying on the diorite-batholith. During the overthrusting already the schist must have been crystalline. The orogenic movement was pre-Maestrichtian, as in the rocks of the Habana-Formation detritical material of schists is found. With this supposition the following observations probably might easily be explained. 1. the distribution of the diorite around the schist-complex. 2. the very large thickness of the Schist-Formation, which might be only apparent, in consequence of the existence of a folded pile of "nappes" above each other. 3. the lack of evident contact-metamorphic phenomena in the schists. 4. the existence of vertical and overturned schists on the Northern boundery. 5. the cataclasis in the diorites, especially on the Southern side near the boundery with the schists. 6. the lack of detritical schist material in the Tuff Formation. 7. the straight boundary between the schists and the diorites on the Northern side of the schists.

The cupola-like form of the schist-complex need not be an objection against this supposition, as it might have been caused by pitching of the axis of the overthrust masses to the W. and the E.

There are, however, some decisive objections against the above treated supposition. We see that the front of the supposed "nappe" lies upon the diorites on the North side and that the flank of the "nappe" dips below the same diorite at the W. side. This is tectonically impossible.

A second objection is the occurence of dioritic rocks within the schists, (probably these are dikes in the schists, although one might consider them as "inlier") together with the hydrothermal rocks at the Mina Carlotta at M. 254, which almost surely came into being by the hydrothermal action of the Dioritic Intrusion (no volcanic activity capable for hydrothermal action on so large a scale being known after the Dioritic Intrusion).

A third objection is the consideration that it is almost impossible that during the enormous orogenic activity, wanted for the movement of the supposed overthrust masses, the rocks of the Tuff-Formation, which at that time already existed, only should have been affected by an orogenic activity of medium intensity.

The other possibility is that the schists are autochthonous. All the objections against the "nappe" are, on the other hand, arguments in support of this last supposition. In this conception the schist emerged during the Upper-Cretaceous orogenesis and are separated to the North side from the diorites by a large straight fault. The lack of contact-metamorphic phenomena and the steep and overturned position of the schists on the Northern side are probably explained by this fault.

The thickness of the Schist Formation, being almost 12000 m. is not a decisive objection against this supposition. The orogenetic activity which after the consolidation of the diorites caused the cataclastic phenomena, very probably also formed the fault. Decisive objections against the second supposition cannot be indicated, and we are inclined to adopt this conception as the most probable one, being at the same time the most simple one. The distribution of the diorites around the schists remains a remarkable fact. Maybe the large schist dome impeded the dioritic magma to form a regular batholith and the magma followed the discordance-plane between the schists and the tuffs.

There are four different phases of orogenesis known in Southern Santa Clara: the first one during the Upper Cretaceous, before the deposition of the Habana Formation; the second one in Lower- and Middle Eocene time, before the sedimentation of the Upper Eocene; the third one during the Oligocene, before the uppermost Oligo-Miocene time; and the fourth one after Oligo-Miocene time.

The Upper-Cretaceous orogenesis must have been rather strong. Probably the schists have emerged during this orogenesis because almost no fragments of schists have been found in the Tuff-Formation. The strong cataclasis of the already consolidated dioritic rocks came into being during this orogenetic phase, as the younger movements were rather unimportant. Moreover the fault between the diorites and the schists very probably was formed equally during this orogenesis. The structural unconformity between the Habana-Formation and the Tuff-Formation is rather great as can be seen on the map all around Cienfuegos and Fomento. Moreover it is proved by the occurrence of detritical material of the older formations in the conglomeratic limestones of the Habana-Formation.

The Upper Cretaceous movement in this part of the island appears to have come from the South, because of the vertical and overturned position of the schist in the Northern side of the complex, and the trend in the cataclastic dioritic rocks.

The second phase of orogenetic activity had a varying intensity at different localities. The rocks of the Habana-Formation in the SW. part of the Province are gently folded and almost conformable with the Tertiary. No evident structural unconformity between the Habana-Formation and the Tertiary is observed here. The Tertiary overlaps in this part of the Province the Habana-Formation. In the North-Eastern part of our district the Lower and Middle Eocene orogenesis has been much stronger, as can be seen from the structural unconformity between Habana-Formation and Tertiary in the region around Cabaiguan, and also by the rather steep dips of the Habana Formation. The direction of the Lower or Middle Eocene movement probably is equally from S to N according to the overturned Habana beds near Fomento and near Guayos (Carretera Central).

The Oligocene orogenesis in the district had a gentle character, as can be seen from the low dips of the Tertiary rocks in the district throughout. Only in the neighbourhood of Cabaiguan, again, some steeper dips are found, witnessing that to the Northern and Eastern side of the district also this orogenesis became stronger.

The fourth orogenesis is proved by the very gently dipping Oligo-Miocene beds exposed on the Carretera Central W. of Jatibonico over a rather large distance. This orogenesis must have been very gentle, as the same Oligo-Miocene beds have horizontal position at L. 232 SW. from Cienfuegos. As these beds are the youngest ones, surveyed by us, we are not sure about the uppermost limit of the age of this orogenesis. The direction of the movement of the two youngest orogeneses is not known in our district as the folds are only very gentle and by no means indicate a special direction of the dynamic forces.

Chapter IV: **PETROLOGICAL NOTES.**

Chemical analyses were made of five rocks from Southern Santa Clara Province, by Mr. W. van Tongeren. The results of these analyses are given here in two lists, together with the Niggli values and the number of the section in the Niggli tetraeder.

1. Diorite aplite, M. 210, 2 km. S. from Manicaragua.
2. Quartz-hornblende-biotite-diorite. M. 322, Rio Arimao, 1 km. NNW from Manicaragua.
3. Amphibolite from the Diorite Intrusion. M. 255, 8 km. S. from Manicaragua.
4. Porphyrite Tuff Formation, L. 45, 2 km. N. from Hormiguero.
5. Quartzfree-pyroxene-hooibergite. L. 302, 4½ km. S. from La Moza.

Table I (Weight percent.)

	1	2	3	4	5
SiO_2	78.58	59.46	48.03	46.95	42.61
Al_2O_3	11.80	15.69	11.70	19.49	12.47
Fe_2O_3	.38	3.71	3.37	4.29	5.49
FeO	.17	4.17	7.65	7.89	8.43
MnO	sp.	.09	.15	.26	.13
MgO	.11	2.72	10.51	3.15	13.04
CaO	1.06	6.93	12.50	9.48	12.44
Na_2O	4.53	4.33	2.57	3.28	2.31
K_2O	2.36	1.15	1.08	.87	.31
H_2O +	.42	.68	1.02	2.09	.89
H_2O —	.24	.07	.21	.65	.24
TiO_2	.07	.60	.75	1.34	1.54
CO_2	.00	.00	.00	.02	sp.
P_2O_5	.04	.25	.31	.14	.09
BaO	.03	.02	sp.		sp.
Cr_2O_3	.00	sp.	.06		.02
ZrO_2	sp.				
S_2	.02	.03	.02		.03
Sum	99.81	99.90	99.93	99.90	100.04

Table II. (Niggli values.)

Number	1	2	3	4	5
al	47.5	28.8	14.3	26.5	13.6
fm	4.3	32.5	51.3	42	57.1
c	7.8	23.2	27.8	23	24.8
alk	40.4	15.5	6.6	8.5	4.5
si	538	186	100	114	78.4
qz	276	24	—26.5	—20	—40
k	0.25	0.15	0.22	0.15	0.08
mg	0.26	0.38	0.64	0.32	0.63
c/fm	1.82	0.712	0.542	0.547	0.434
Section	VII	V	IV	IV	IV

I computed the Niggli values of these rocks together with those of the analyses published by H. M. E. Schürmann (45) and M. G. Rutten (41) in a Niggli diagram. This diagram is the same as that of M. G. Rutten (41) as the 5 new analyses of Southern Santa Clara fit well into the latter. So it seemed unnecessary to reprint this diagram. The quartz-hornblende-biotite-diorite is representative for the large intrusion. With the integration stage this rock appeared to consist of 64.1 % felspar, 16.3 % hornblende, 11.2 % quartz, 5.3 % biotite, and 3.1 % ore. The composition of this rock agrees with the normal dioritic magma of Niggli. It has a slightly more basic character than the quartz-diorites of Schürmann, which belong to the grano-dioritic magma. The diorite of M. G. Rutten is much more acid. This is not astonishing, as it is found in smaller intrusions in the serpentines and may be a younger acid differentiation of the quartz-dioritic magma.

Also analyses were made of extreme acid and basic differentiations of the batholith, a diorite aplite and a quartz-free pyroxene-hooibergite. The large MgO content of the latter is remarkable.

Of one amphibolite an analysis was made in order to state its origin. From the results of the analysis it may be deducted that this amphibolite is an orthorock. The chemical composition shows some resemblance with that of analysis 5 of Schürmann of a gabbroidic rock out of the serpentine in Santa Clara. The content of alkalies, however is different.

Finally a porphyrite from the Tuff Formation was analysed. The basic character of this rock is remarkable.

As we have seen in the petrographic descriptions in this paper, various thick beds of Meso-Cretaceous volcanic rocks are found, while in Upper-Cretaceous time in North Santa Clara a large serpentine massive and in South Santa Clara a large quartz-dioritic intrusion have been formed. The quartz-diorite is younger than the serpentines as dikes of the former are found in the latter (41 p. 18). The difference in age, however, is only small, both being post-Turonian-Emscher and pre-Maastrichtian. So we have Middle Cretaceous tuffs, porphyrites, diabases and spilites and Upper-Cretaceous serpentines and diorites close together. Although the geological and chemical data of these rocks are still unsufficient it seems well to make some suggestions about the possible relations. The serpentines and quartz-diorites are very likely differentiation products of some primary magma.

There are several possible relations.

1. The rocks belong to three different magmas.

2. There are two more or less independant magmas, a Middle-Cretaceous one and a Upper-Cretaceous one.

3. Only one magma produced by differentiation all the different rocks.

ad. 1. If the rocks belong to different magmas, nothing can be said about petrological relations inter se. This, however, seems rather improbable, as the rocks are found close to each other and even together, as the age of at least the serpentines and diorites differs only slightly, and as in chemical and partly in mineralogical features they show likeness, as can be seen from the analyses and the Niggli-diagram.

Moreover, if the serpentines and quartz-diorites belong to different magmas, then the other differentiates of the two presumed cycles must be somewhere and it would be astonishing that no traces of them are found.

ad. 2. The second possibility is that of two magmas. In this case nothing can be said about the Middle-Cretaceous one, as only extrusive rocks are known. If the serpentines and diorites are differentiation products of one primary magma, which is not improbable, according to their distribution and age, then this differentiation must have been a gravitative one. The peridotite, from which the serpentine originates, came into being below a dioritic rest-magma. However, the serpentines are found at the surface in the Northern part of the Province and are cut by dioritic veins. This probably can be explained by deep-seated tectonical activity during or shortly after the consolidation of the peridotite, and before the Dioritic Intrusion. Schürmann already drew attention to the possibility of tectonical influences on the surface distribution of serpentines and diorites in Cuba. Moreover the complicated tectonical features, described by M. G. Rutten for the serpentines, support this possibility.

The question arises whether it is possible to find the chemical composition of the primary magma. Some general considerations prove that it is not yet possible to solve this question. Primary we do not know anything about the quantities of serpentines, diorites and gabbros formed during the differentiation. Moreover in the rocks sampled and described by us, no one occurs which represents in chemical composition the original primary magma ad. 3. The third possibility is that of one magma. The mineralogical likeness of the rocks of the Tuff-Formation and the Dioritic Intrusion together with the Niggli-diagram seems to support this supposition. On the other hand the extrusive rocks are the eldest ones, while one should expect the extrusive period of a cycle to be the youngest one.

Chapter V: **SURVEYED COURSES.**

In this chapter only some surveyed courses are chosen for a detailed description. I choose those courses which are characteristic for some important geological phenomena.

I. Rio Calabazas-Cabaiguan-Guayos-Sancti Spiritus-Jatibonico. The Rio Calabazas crosses the Carretera Central at km. 354,4. Here we find structureless tuffs of the Tuff-Formation, which continue about 2 km. At km. 358,1 occurs an altered silicified porphyrite (L. 430, D. 16549), while from km. 358,7 to km. 361 well bedded tuffs dip to the East about 50°, striking N 190 E. At km. 363 again structureless tuffs are found and at km. 364 the last tuff outcrop occurs. Then we pass into rocks of Tertiary age and at km. 364,7 we find limestones, conglomeratic limestones and marls. The boundary between the two formations is about near km. 364,4. The Tertiary rocks are folded dipping up to 40°. At one locality a dip of 50° was found. The mean dip, however, is 35—40° S.; the strike is NW—SE. The Upper-Eocene beds begin with a medium-grained basis conglomerate (L. 431, D. 16551, D. 16552) with fragments of *Dictyoconus fontabellensis* (Vaughan), *Discocyclina* sp., *Camerina* sp., many Smaller *Foraminifera* which we could not isolate nor determine, and with many rounded fragments of foreign rocks as e.g. of quartz-biotite-diorite, quartz-diorite-porphyrite, porphyrite from the Tuff-Formation, quartz-epidote-chlorite-schists, and fragments of quartz and plagioclase and other crystals. The average diameter of the pebbles is $\frac{1}{2}$—1 cm. Upon this conglomeratical limestone lie conformably light coloured limestomes, and white to greyish marls. In Cabaiguan the same marls are found and at km. 369, direct S. of Cabaiguan black, coaly shales are found, together with greyish green sandstones, concordant upon these marls. Here the rocks dip slightly to SW. or lie almost horizontally; we are in the core of the Tertiary synclinal. The coaly shales are a finely bedded, dense aggregate of quartz and calcite grains, muscovite scales and a fine coaly powder. The sandstones are built mainly of schist material, undulose quartz, muscovite and some plagioclases, derived probably from the diorites. Moreover, some Smaller *Foraminifera*, probably *Globigerinidae*, are found in them.

West of the Carretara Central at L. 546 we find the same Tertiary rocks as at L. 431. Between L. 546 and L. 547 no good rock-exposures are found, while at L. 547 *Orbitoides*-limestones of the Habana Formation, carrying *Orbitoides browni*, *Vaughanina cubensis* and *Camerina dickersoni* are found. More to the West from this road we find many large, well rounded blocks of rocks of the Tuff-Formation, indicating that we are approaching the boundary between the Tuff Formation and the Habana Formation. At L. 549 and the following localities many large specimens of *Parastroma* *sanchezi* have been found. The rudist limestones alternate with marls and coarse red limy conglomerates. The rocks of the Habana Formation are gently folded, dipping 20—25° SSE. Direct North of the road we find rocks of the Tuff-Formation. From L. 551 going Southward we first meet loose rudists in the field, then sometimes white marls and conglomeratical limestones (N80E 25 S.). Without any change in the landscape we pass the boundary with the Tertiary rocks and at L. 556 we find a light yellow limestone with *Dictyoconus fontabellensis* and *Discocyclina* sp. striking NW—SE with a dip of about 5°. Until Cabaiguan marls and limestones are rather badly exposed. In Guayos (Car. Centr.) we pass into the Habana Formation. At km. 374, 2 the marls and limy sandstones dip 20° N striking N 100 E. So, here we see a difference in tectonic arrangement of the Tertiary and Upper-Cretaceous rocks. This difference is emphasized by the exposures 2 km. S. of Guayos. Here we find a E—W running chain of hills, consisting of conglomeratic limestones and white and greyish marls, which are strongly folded. Going from N to S we find on a distance of 1500 m. the following dips: 70° N, 90°, 60° S, 50° S, 25° N, 70° N, and 70° N.

At L. 435 we find strongly folded *Orbitoides*-limestones with *Orbitoides* sp., *Vaughanina cubensis*, and *Camerina dickersoni*. East of the Carretera Central the same rocks and rudist limestones occur. At V. 306 a conglomeratic limestone with *Dictyoconus fontabellensis* and *Discocyclina* sp. is found in a syncline on the Habana beds. At V. 307 the rocks of the Habana Formation with *Camerina dickersoni* are slightly overturned, dipping strongly to the S. At km. 377,2, 200 meter South of L. 435 on the Carretera Central the steep North dipping Habana Formation-rocks overlie porphyrites and red and green tuffs of the Tuff-Formation, striking probably N 40 E, dipping 50 W. These rocks show amphibolitization of the augites, being slightly affected by contact metamorphosis, caused by the Dioritic Intrusion.

Near the Rio Tuinucu we pass into dioritic rocks. First we find about 4 km. decomposed sandy diorites. Then at L. 437 dark schistose rocks with dark and light veins are found. The light veins are the youngest. The dark schistose rocks are amphibolites of unknown origin, built mainly of green pleochroitic hornblende, clear albite and oligoclase grains, and green biotite streaks. The light dikes are plagiaplites with microgranophyric intergrowth-structures. At L. 438 the same rocks occur together with pyroxene-amphibolites and amphibolites with a relic porphyritic texture. Some hundred meters S. of L. 438 again the normal diorites, more or less decomposed into sandy diorites, are found, continuing as far as km. 388, 1 km. E. of Sancti Spiritus. At M. 582 we find tuff, which by contact metamorphosis has been uralitized and epidotized (D. 16753). M. 582bI (D. 16755) is a metamorphic tuffbreccia or porphyrite, as we find altered rock fragments and phenocrysts of augite imbedded in a medium grained aggregate of epidote, zoisite and augite crystals. This last aggregate probably is altered tuff material or porphyrite groundmass. Together with this rock calcite-quartz-garnet-rocks, garnet-rocks and a marble are found. At M. 583 coarser grained garnet-rocks occur (plate, figure 3) in a small hillock 50—100 meter North of the Carretera Central at km. 389. At km. 389,4 white marls and micro-conglomerates of the transgressive Habana Formation are found, thoroughly folded, dipping 45° to the NE. Imperceptibly they grade into Tertiary rocks: white cavernous marls without clear bedding. Upper-Eocene fossils are not found here. At M. 587 (km. 392,7) in a large quarry many fossils are found, *Lepidocyclina formosa*, *Lepidocyclina petri*, and many other *Foraminifera*, corals, *Lamellibranchiata*, *Gastropoda* etc. From M. 587 to Jatibonico white marls are found carrying *Lepidocyclinae*, Oysters, *Pectinidae* a.s.o., often covered by alluvial detritus, containing much schist material. At M. 591 and M. 595 *Archaias adunca*, *Amphisorus matleyi* and *Miogypsina hawkensi* occur in gentle dipping layers. Here the Upper-Oligo-Miocene beds proof the existence of a small post-Upper-Oligo-Miocene orogenesis.

N. of Jatibonico we find the Upper Eocene and Oligocene beds and transitional beds between these two indicated by the occurrence of *Helicolepidina spiralis* and *Lepidocyclina mortoni* together with *Lepidocyclina* (*Eulepidina*) *formosa*. Still more to the North the rocks of the Habana Formation are found.

II. Baez-Fomento-Manacal-Trinidad (see also section I).

From Baez to L. 515 we pass through the Tuff Formation. Green bedded tuffs, structureless tuffs and porphyrites, the latter forming small hills, are found. The main strike is N90E, dipping 60—90° N. 5 km. S. from Baez a hill formed by Provincial limestone lies 1 km. W. from the road. Near L. 517 the high way passes a zone of Provincial limestones with Caprinids (*Coalcomana ramosa* and a Monopleurid). Several banks of limestones alternate with tuff-breccias. At L. 515 a *Radiolaria* tuffite occurs. At L. 514 we find a basis-conglomerate of the Habana Formation, containing small and large pebbles (up to 10 cm.) of tuffs, porphyrites, Provincial limestones with many smaller *Foraminifera*.

From L. 514, through Fomento untill 2 km. S. of Fomento rocks of the Habana Formation are found; limestones, marls, conglomeratical limestones etc. 1 km. NE. from Fomento at H. 601 (the same place as H. 627) a very rich fauna is found in the limestones. *Archaias rutteni* (Palmer), *Camerina dickersoni* Palmer, *Camerina* sp. c. Thiadens, *Orbitoides palmeri* Gravell, *Lepidorbitoides rutteni* Thiadens and some other species of *Lepidorbitoides*, *Barrettia sparcilirata* Whitf., *Bournonia* n. sp. Thiadens, *Bournonia* sp. and ?*Antillocaprina* moreover many Corals, Oysters and Echinids. Around Fomento the Habana Formation lies in a synclinal upon the Tuff Formation. The synclinal is overturned toward the N. and NE. side, the Southern wing dipping 40° toward the Tuff Formation. The latter begins with a coarse spilite-porphyrite-breccia, at L. 572 (D. 16609). From Fomento to Trinidad the railroad has been followed. The rocks of the Tuff Formation here are tuffs, porphyrites and intercalated thinbedded Provincial limestones. The outcrops of the latter are too small to be drawn on the map. Near km. 42

(2,6 km. S. of L. 572) the first dioritic rocks are found: strongly weathered porphyrites with aplitic dikes. 4 km. S. of L. 572 we find quartz-diorite in the general decomposed sandy habit. This keeps going on 3,7 km. Then again darker green amphibolitic rocks are found, alternating with normal diorites. At L. 570 a pyroxene-amphibolite and a amphibolite occur, while at L. 569 a cataclastic vintlite has been sampled.

200 m. S. of L. 569 and furtheron at L. 567 and L. 566 strongly weathered quartz-bearing marbles, calcite-quartz-muscovite-schists and crystalline limestones are found, striking N 40—60 E. dipping 60—90° S. No traces of contact metamorphism are observed. At our right hand we look down into the dioritic landscape. 750 m. East of L. 564 we are in the diorites again. Very curious are the strongly weathered porphyrites sampled at L. 564. The groundmass of this rock carries a considerable amount of magnetite and chlorite, and is very much alike the groundmass of the porphyrites of the Tuff Formation. If this rock really is a porphyrite of the Tuff Formation, it must be considered as an inclusion in the diorites, and it is curious that it is only so little altered.

From L. 563 to 200 m. N. of M. 664 rocks of the Schist Formation are found as e.g. crystalline limestones, and green chlorite schists; moreover: young schists breccias. The rocks of the Schist Formation here form a small anticline.

At M. 564 Tertiary rocks lie unconformably upon the schists. We find limestones and microconglomeratic limestones, containing much schist material and also pebbles of porphyrite. Many *Lepidocyclinae*, *Discocyclinae* and *Dictyoconus fontabellensis* indicate the Upper Eocene age. First they dip gently South, then they are found in horizontal beds and at M. 667 they dip 50° N. over diorites, which outcrop here on the border of the transgressive Upper Eocene and the schists. At km. 48, 400 m. N. of Manacal, the schists lie probably horizontally. In Manacal gently South dipping serpentine-schists occur. (D. 16775). 600 m. E. of Manacal light and dark marbles are found. At M. 671 again Upper Eocene conglomeratic limestones are found with *Dictyoconus fontabellensis* and *Discocyclina* sp. 400 m. S. of M. 671 schists and schists-breccias are found, lying horizontally or dipping slightly South. Passing the Rio Agabama we still find schist-breccias. At M. 678 we are definitely in the transgressive Tertiary beds. Limestones, marls and conglomeratic limestones are found carrying *Camerina* sp. cf. *C. parvula*, *Lepidocyclina mortoni*, *L. pustulosa*, *L.* sp. *Helicolepidina spiralis*, *Discocyclina blumenthali*, *D. vermunti*. From M. 678 to Trinidad Tertiary rocks keep going; we are are not certain, to which part of the Tertiary they belong as only few small samples were collected.

III. Course from L. 330 S. of Provincial via Manicaragua to M. 269 S. of Manicaragua (about section III).
From L. 330 to L. 327 covering a distance of 2150 m. we found the following section.

L. 330	0—300 m.	blue and beige, rather fine grained limestones with needles of *Spongia* (D. 16533), and *Radiolaria* (D. 16532), alternating with tuffs. At the end of the 300 m. tuff-porphyrite-breccias (D. 16531) dip 60° N.
L. 329	300—350 m.	Limestones.
	350—450 m.	alternating crystall-tuffs and vitric tuffs (D. 16530, D. 16529).
	450—550 m.	blue limestones E.—W. 50° N. in beds of 10 cm. thickness.
L. 328	550	Limestones N. 90 E., 30—50° N.
	550—750 m.	no exposures.
	750	Limestones with Caprinids.
	750—950 m.	no exposures.
	950—970 m.	Limestones and Caprinids.
	970—1100	No exposures.
	1100—1200	Limestones with Caprinids.
	1200—1400 m.	Depression.
	1400—1500 m.	Limestones with Caprinids.
L. 327	1500—1850 m.	Limestones with smaller *Foraminifera* (?*Globigerina*) *Radiolaria* (D. 16562) and marls. N70E, 30° N. Conglomeratic limestones (D. 16522) Gray and blue, rather crystalline limestones N95E, 55° N. and marls.
	1850—2150 m.	Tuff-breccias.

The Rudistids and Caprinids are ?*Tepeyacia corrugata* Palmer and *Caprinuloidea* sp. which, by comparison with Mexican forms, indicate a Cenomanian-Turonian age.

The limestones are fine-to medium-grained, microconglomeratic rocks, cut by many calcite veins.

Going Southward the road descends into a plain, formed by tuffs, porphyrites and tuff-porphyrite-breccias. The breccias are structureless. At L. 325 a ?dike of a silicified prehnite rock is found. This is a hydrothermal rock of unknown origin, probably it is the first trace of the approaching diorite contact. In the tuff landscape the coarse tuff-porphyrite-breccias form small ridges with tuff depressions between them. At L. 323 (D. 16518) and L. 322 (D. 16517) and 450 m. S. of L. 322 we still find rocks, typical for the Tuff Formation. At L. 320 (D. 16516) an altered porphyrite with rests of quartz phenocrysts is found, while the rocks of L. 319, originally probably belonging to the Tuff Formation (tuff breccias and porphyrites) are silicified and altered by the contact of the diorite rocks. A weathered quartz-diorite-porphyrite is found at L. 318 (D. 16512) at the side of a quartz-chlorite-epidote-rock (D. 16513), which probably is an altered porphyrite. At L. 317 a ?quartz-amphibole-diorite-porphyrite has been found, while at L. 316 a silicified chloritized spilite occurs. At L. 315 we found sandy soil, which is typical decomposed quartz-diorite. This continues until Manicaragua. Near the tuff boundary light-coloured dikes of quartz-diorite-porphyrite occur (L. 315, D. 16508, D. 16509; L. 313, D. 16505; V. 123, D. 16857, D. 16858; V. 122, D. 16855, D. 16856; V. 119, D. 16852), while at L. 314 (D. 16506), V. 124 (D. 16859), V. 125 (D. 16860) and V. 118 (D. 16850) quartz-diabases are found. The diorites found here are more or less decomposed, forming deep gullies in the landscape.

From Manicaragua going Southward first we remain in the same dioritic rocks. At M. 195 a silicified spilite is found as inclusion in the diorite (D. 16685). At M. 198 a cataclastic granodiorite aplite has been sampled. 200 m. Southward the colour of the soil becomes darker brown and we find in the field many blocks of schistose rocks. Very probably these rocks are gneissic dioritic rocks. No samples were taken. 350 m. N. of M. 203 again light coloured weathered diorite-soil occurs, while from M. 203 to M. 205 diorites are found. In the diorite of M. 203 the plagioclases are strongly replaced by sericite and calcite. They have been, like the rocks of M. 205, affected by cataclasis. At M. 206 we found green, strongly weathered schistose rocks, which are probably gneissic rocks of dioritic composition, carrying dark inclusions of calcite-chlorite schists of unknown origin (D. 16690), possibly derived from the Schist Formation. All the rocks are cut by light, strongly weathered dikes of mylonitized aplites (D. 16691).

From the point 120 meter S. of M. 206 to M. 214 again more or less weathered diorite is found, cut by light aplitic and lamprophyric dikes. A chemical analysis was made of the plagiaplite of M. 210 (analysis no. 1). From M. 214 to a point 300 m. South of M. 218 we find strongly weathered schistose rocks, and at M. 217 and M. 219 meta-hooibergites (D. 16695, D. 16696). Here, again, we consider the schistose rocks as mylonitized dioritic rocks, which are found together with altered hooibergite. More Southward again typical quartz-diorite-sand is found in a small valley. At M. 225 epidote-amphibolites of unknown origin (D. 16698) and gneissic diorites (D. 16699) are found, strongly cut by granodiorite-aplite-dikes which have been mylonitized. One broad dike, measuring 15 meter in diameter is found. From M. 225 to M. 229 the same dark schistose mylonitized rocks occur. At M. 230 and M. 233 gneissic diorites were sampled, while at M. 255 an amphibolite occurs (analysis no. 3). From M. 255 to M. 260 weathered and badly exposed schistose amphibolitic rocks are found; $\pm$ N100E, 60—90° S. 100 m. South from M. 260 the first mica-schists are found. They are strongly weathered. At M. 263 quartz-bearing marble occurs. From M. 265 to M. 269 we find in a narrow valley thinbedded blue limestones $\pm$ N120E dipping steeply South or standing vertically. Near M. 269 the first North dip is found.

Chapter VI: **PREVIOUS LITERATURE.**

A rather large amount of literature concerning Cuban geology exists. Notwithstanding, the geologic knowledge of the island in general and also of the Southern Santa Clara Province is very poor.

With the aid of Prof. RUTTEN, who kindly put at my disposition his bibliographic notes on papers concerning Cuban geology, I was able to compile a rather large list of papers and books concerning Southern Santa Clara Province. Not all numbers could be consulted "in originale" as many of them are not to be found in any library in Holland. Most papers are treating ore deposits or palaeontological subjects. Only two geological maps of the island exist, that of CASTRO and SALTERAIN which is reprinted with slight alterations in the report of HAYES c.s. (20), and in the book of HILL (21), and that of LEWIS (23) which is reprinted in SCHUCHERTS book (44). See also f.i. VAUGHAN (Geological mapping in the Western part of the United States, Central America and the West Indies. Proc. First Pan Pacific Scientific Conference Honolulu 1921 Bd. III p. 695—705).

The oldest geological quotation of the Southern Santa Clara Province we find in the book of I. A. WRIGHT 1916 (61) on the early history of Cuba. On page 58 we read that in about 1513 in the surroundings of Xagua, especially in the Rio Arimao gold was found. This was the reason why Trinidad was founded.

In 1838 BERTHIER (6) published some notes on different minerals of Cuba. From Villa Clara (this is Santa Clara) North of Trinidad he mentions an "arkose" with Cu carbonate and Cu_2O with a Copper content of 10.42 %; moreover iron ore with mica, pyrite, copper-pyrite and "sous sulfate de cuivre", pure copper, gold-silver ore, etc.

In 1857 D. T. ANSTED (3) gave a publication on the San Fernando Copper Lodes, near Cienfuegos. The San Fernando Lode which has been subject of some more papers (see below) lies North of La Moza, near the boundary of the Dioritic Intrusion and the Tuff Formation. ANSTED mentions the occurrence of granite, syenite, and also of porphyritic rocks in Central Cuba. The San Fernando Lode is found North of these rocks in an area with porphyrites and conglomerates, while N. and W. it is surrounded by limestones, striking E—W, dipping N. The ore body comprises carbonates and oxydes. We did not visit the locality, but from the description of ANSTED it is clear that it is to be found in the Tuff Formation near the Dioritic Intrusion.

In 1864 MANUEL FERNANDEZ DE CASTRO (9) states the finding of crocodiles and *Megalonyx* near Ciego Montero.

In 1876 the same author (10) published a "Catalogo de los Fosiles de la Isla de Cuba".

In 1884 the first geological map of Cuba by DE CASTRO and SALTERAIN Y LEGARA appeared. On this map the Sierra de San Juan and the Sierra de Trinidad are indicated as "(Palaeozoico) Silurico Carbonifero", while the Sierra de Sancti Spiritus as "Terciarios". North of the Schist mountains they indicated "Hipogenicos igneos: Granito, Serpentino, Basalto". All Mesozoic rocks they indicated with one colour. It is useless to compare this map with our map of Southern Santa Clara Province as the scales largely differ. DE CASTRO (11) mentions in the centre of Cuba schists of probably Palaeozoic age, possibly, however, they may be older or younger; Tertiary in the Sierra de San Juan, and a granitic syenitic meseta near Cumanayagua. Moreover unimportant mountains of diorite, andesite, serpentine and diabase "que parecen haber trastornado las capas del periodo Cretáceo" (p. 150). Obviously DE CASTRO was already of the opinion that the diorites and serpentines are Cretaceous or Post-Cretaceous. The Tertiary lies flat although "profundamente denudada". To the W. of Cienfuegos on the banks of the Rio Damuji, Cretaceous fossils are found (*Holectypus*, *Discoidea*, *Cassidulides*, *Codiopsis* and others) together with Tertiary ones (*Asterostoma*, *Aetobatis poeyi*, *Encope ciae*), which occur in horizontal beds. Near Ciego Montero *Crocodilus pristinus*, *Testudo cubensis*, *Megalonyx rodens* and *Miomorphus cubensis* are found in Quaternary rocks with several young marine deposits.

In 1881 COTTEAU (13) gave a description of 20 fossil Echinid species from Cuba without finding places.

In 1892 CARLOS DE LA TORRE (50) mentions an Ammonite found in Los Baños de Bija (cerca de Cruces). The exact locality is not known to me.

In 1914 the same author together with W. D. MATTHEW (53) states the finding of four genera of Mammals in the Plistocene. A complete skeleton of *Megalocnus* was fitted.

In 1915 DE LA TORRE begins a "Revision de la Fauna cubana" (51).

In 1916 the same author presents to the Sociedad Cubana de Historia Natural "Felipe Poey" an account on the above mentioned fitted *Megalocnus* skeleton (52).

In 1895 ADAN DE YARZA (1) describes granites and granulites from the Rio Arimao near Cienfuegos.

In 1896 J. W. SPENCER (46) published a paper on the Geographical evolution of Cuba. He describes the Trinidad mountains, in which tilted valleys and deep young cañons. In the "Metamorphic Formation" he found limestones and calcite-mica rocks, in the igneous Formation diorites, "strata of serpentine" and some granites. He considers these rocks to be older than the Cretaceous sediments on Cuba. From the east flank of the Trinidad mountains and from the underground of the Trinidad valley he describes limestones and sandstones. According to SPENCER, MATHEW has described from the W. flank and from the neighbourhood of Cienfuegos the same rocks with Cretaceous fossils as *Exogyra*, *Ostrea*, *Inoceramus* and *Hippurites*, *Caprinula* and *Caprotina*. I am very sorry that it was impossible to consult MATHEWS paper in Holland. In the neighbourhood of Trinidad in the coast chain, and near Sancti Spiritus SPENCER found Tertiary rocks with rounded quartz material.

In 1899 HILL published a book on Cuba and Porto Rico (21) with a small geological map of the island adapted from the map of DE CASTRO and SALTERAIN. The geology is treated only in a footnote.

In 1901 a report on a geological survey of Cuba by C. W. HAYES, T. W. VAUGHAN and A. C. SPENCER appeared (20). In the same year VAUGHAN (56) published a paper on the Copper Mines of the district. These papers are important. The map of CASTRO—SALTERAIN has been added to the paper of HAYES c.s. The authors regard the schists together with the serpentines and granites as basement rocks. The crystalline limestones and schists of the Trinidad mountains are considered to be of Palaeozoic age. They found Mesozoic limestones with *Barrettia*, *Monopleura* and *Requienia* etc., lying on an arkose existing of fragments of serpentine and granite. As is evident from our survey, the serpentine and diorite do not belong to the basement, but are of Upper Cretaceous age, younger than the Schist Formation and the Tuff Formation. The three authors doubt the existence of Eocene in Santa Clara. They mention Upper Oligocene, although they did not find fossils in it. They suppose that in Miocene time the whole island was emerged above the sea. Diorite-porphyrites, diabases and gabbros are mentioned from Southern Santa Clara. HAYES c.s. presume that Santa Clara consists of an anticlinorium built of many regular folds or domelike elevations with the axes E.—W. Moreover the several Copper Mines N.W. of Manicaragua are treated by VAUGHAN who refers especially to the observations of ANSTED, SPILSBURY and LA SAGRA, as VAUGHAN himself could not enter the abandoned and partly inundated mines.

In 1913 BARNUM BROWN (7) describes exhumations of fossils near Ciego Montero and Jatibonico.

In 1915 JUAN P. ROS (34) described granites from Arimao near Cumanayagua. He says on page 422 "He visto el granito, tambien perturbando notablemente las formaciones sedimentarias, calizas del Rio San Juan de Letran en Trinidad en su nacimiento". Moreover he saw gneiss in the rivers near Cumanayagua, Manicaragua and Barajagua "procedentes de la alteración del granito" (p. 425).

G. DE USERA (55) 1917 gives some informations on the three Copper Mines near Manicaragua: San Fernando, Santa Rosa and Santa Helena, which, according to him lie in the diorite area.

A thesis of DOMINGO F. RAMOS in 1915 (33) treates the history of the mineralogical and geological studies on Cuba.

The paper of DE GOLYER (15) on the geology of the cuban petroleum deposits is of no special value for our district.

In 1919 W. D. MATHEW (26) gives an extensive description of vertebrates from Ciego Montero (*Megalocnus*, *Crocodilus*). In 1931 (27) the same author describes genera and new species of ground sloths from the Plistocene of Cuba.

LUIS GARCIA LORENZANO 1925 (24) describes the occurrence of an asbestos variety, amiante, in the finca Ojo de Agua, 20 km. from Trinidad in serpentine (locality unknown to me). He added a small sketch map of the region.

ANTONIO CALVACHE resumed in 1926 (8) the mining history of Cuba. He stated that in the sixteenth century gold was found in the sands of the Rio Arimao, Rio Agabama and Rio Caonao. South of Cumanayagua a large pyrite deposit was found. Probably the Mina Carlotta is meant here.

In 1928 ROQUE ALLENDE (2) treated the Mina Carlotta (M. 254). The ore body is indicated as a conformable intercalation in gneisses and limestones, while the occurrence of acid and basic rocks is mentioned.

In the catalogue of the "Instituto Nacional de Investigaciones Cientificos y Museo de Historia Natural" in Habana by SANCHEZ Y ROIG, gold from Sancti Spiritus, pyrolusite from Santa Clara, grano-diorite from Sancti Spiritus, pegmatite, tremolite-limestone and mica-schist from Santa Clara are mentioned (43).

ALEXANDER WETMORE 1928 (60) describes bad material of bones of birds from Ciego Montero.

In 1932 J. WHITNEY LEWIS (23) published a paper on the geology of Cuba. In this paper a geologic map of the island was added. In consequence of the small scale of this map it is impossible to compare it in detail with our map of Southern Santa Clara Province. Nevertheless there are enormous differences with our observations as any reader of both publications can see. LEWIS has treated the geology of Southern Santa Clara only in a general way. Therefore it is of no use to compare in detail his results with ours.

R. H. PALMER (31) described several new Rudists from Cuba amongst which *Orbygnia guitarti* Palmer, *Orbignya sanchezi* Douvillé, *Praebarrettia sparcilirata* var. *cubensis* Palmer n. var., *Praebarrettia porosa* Palmer and *Chiapasella bermudezi* Palmer from Sancti Spiritus. The determinations of the first four species very probably are wrong (see 47).

In 1934 the same author published a paper on the geology of the surroundings of Habana city. From this study we took the names for the Upper Cretaceous Habana Formation and the Oligo-Miocene Guines limestones, as these formations seem to outcrop over large distances on the island, carrying the same Upper Cretaceous, respectively Oligo-Miocene faunas.

DOROTHY K. PALMER (28) and T. W. VAUGHAN (57) in 1934 stated the age of *Gallowayina browni*, which is a synonym of *Orbitoides browni*, to be Upper Cretaceous. DOROTHY K. PALMER moreover worked on interesting Larger *Foraminifera* (29).

In 1935 H. M. E. SCHÜRMANN (45) published a paper on the "Massengesteine aus Cuba". Seven analyses from Cuban igneous rocks are given, amongst which a granodiorite from Cumanayagua. On the whole our observations agree well with the general statement on the geology of the island given by the author. According to SCHÜRMANN the serpentines are synorogenetic and the granodiorites postorogenetic. Since we found protoclastic phenomena in the quartz-diorites, they must have been synorogenetic too. The strong cataclasis, which sometimes produced mylonitization, prove that the diorites have been affected by strong orogenetic stresses. As we did not find in the Upper Cretaceous Habana Formation so strongly altered cataclastic rocks, the orogenesis must have occurred during and after the dioritic intrusion.

In 1935 a large compiling study from SCHUCHERT (44) concerning the Antillean Caribbean Region appeared. In Chapter 34 Cuba is treated. He gives a compilation of the geologic knowledge of the island and tries to place it in a scheme of his general conception of the Antillean Caribbean Region. New geological data are not given.

The papers of L. RUTTEN (36, 37, 38) and M. RUTTEN (39, 40, 41) are based on the observations of the same survey as the present paper. Where necessary I quoted them in the text.

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EXPLANATION OF THE PLATE.

Figures 1—11 are micro-photographs of thin sections; figure 12 is taken of the rock-sample. Figures 1, 4, 7, 8, 9, 10 and 11 are taken with nicols crossed, figures 2, 3, 5 and 6 with ordinary polarized light.

fig. 1. Serpentine schist of the Schist Formation with "Gitterstruktur". Serpentine flakes arranged in the direction of amphibole cleavages. 12½ km. N. from El Ingles, A 297 (D. 17019). × 30.

fig. 2. Uralite-porphyrite, with rest of augite phenocryst and many broom-like uralite bundles in the groundmass. 3 km. N. from Manicaragua, L. 338 (D. 16541). × 35.

fig. 3. Garnet-rock, showing the large broken garnet crystals, with zoning at the periphery. The space between the garnet is filled in with quartz. 2½ km. E. from Sancti Spiritus, M. 583 (D. 16759). × 13½.

fig. 4. Pyroxene-hooibergite, showing large amphibole crystals (below) and intergrown pyroxene and amphibole crystals (upper half). 5 km S. from La Moza, L. 302 (D. 16491). × 9½.

fig. 5. Metahooibergite, with a large primary hornblende crystal with a dark rim, and a secondary "groundmass" consisting of amphibole and plagioclase. 4½ km. S. from Manicaragua, M. 217 (D. 16696). × 32.

fig. 6. Quartz-amphibole-biotite-diorite; normal-coarse-grained at the right side, and finer-grained and darker at the left side. Rio Arimao, 1 km. N. from Manicaragua, M. 322 (D. 16748). × 9½.

fig. 7. Gneissic diorite, with mortar structure caused by cataclasis. 4½ km. S. from La Moza, L. 301 (D. 16490). × 11½.

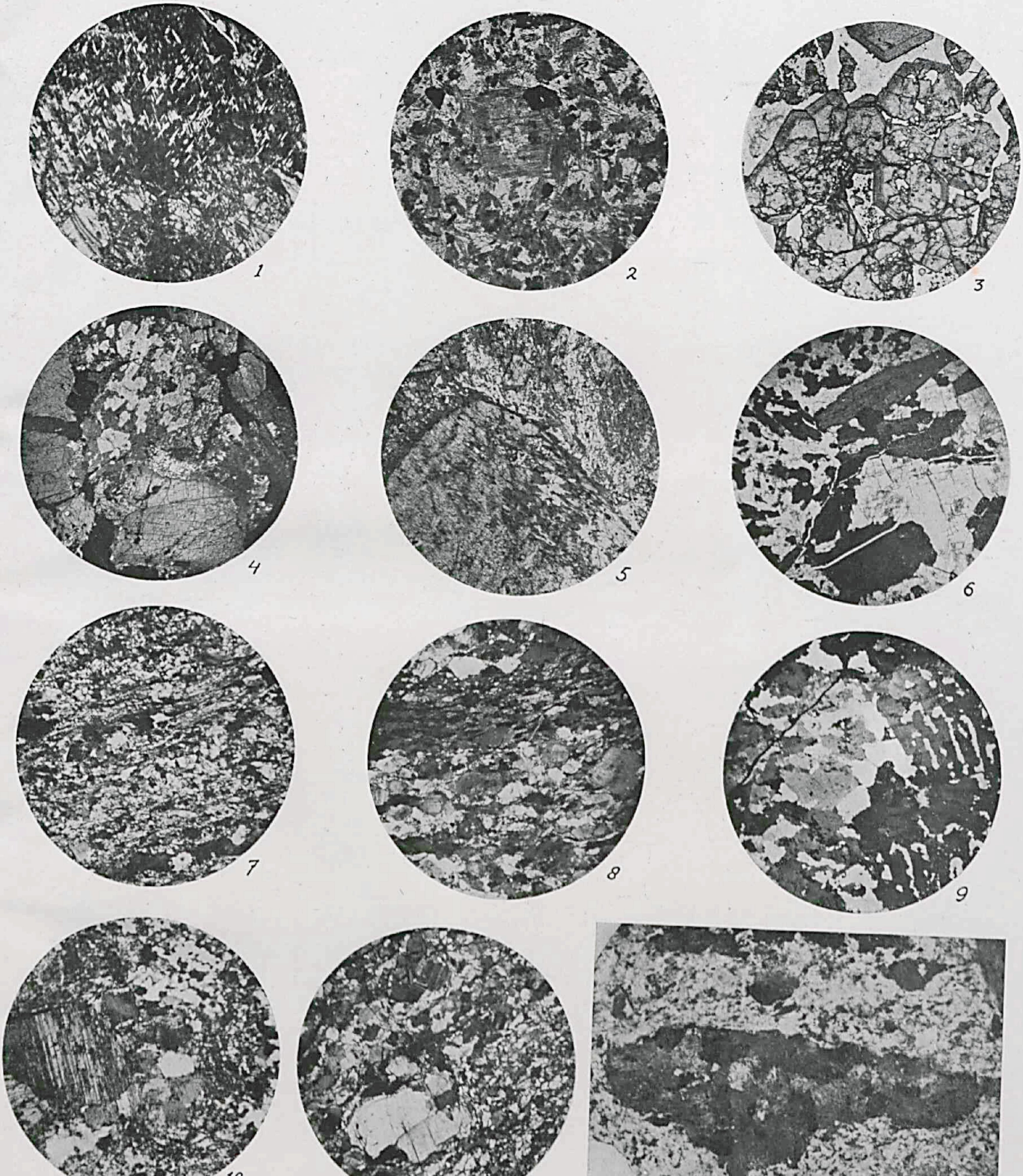
fig. 8. Amphibole-gneiss, with a dark band consisting almost entirely of undulatory hornblende in the upper half part and in the lower half in one with a lighter band showing mortar-structure. 6 km. S. from La Moza, L. 304 (D. 16498). × 28½.

fig. 9. Grano-diorite-aplite with granophyric intergrowth. Carretera Central 2 km. N. from Sancti Spiritus, L. 438 (D. 16583). × 28½.

fig. 10. Cataclastic grano-diorite-aplite, with mortar structure. 10 km. SE. from Manicaragua, L. 291 (D. 16483). × 35.

fig. 11. Cataclastic grano-diorite-aplite, with mortar-structure and beginning of foliation. 6,5 km. S. from Manicaragua, M. 229 (D. 16700). × 35.

fig. 12. Light diorite dike in hooibergite, with inclusion of dark quartz-free pyroxene-hooibergite. 5 km. S. from La Moza, L. 302. × 2.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STELLINGEN

I.

De groote dioriet- en serpentynintrusies in Centraal Santa Clara, Cuba, behooren niet tot de „basement-rocks" van het eiland.

II.

Palaeozoische gesteenten zijn niet op Cuba aangetoond.

III.

De vraag, of de albiet in spilieten primair of secundair is, is niet definitief opgelost. De argumenten voor secundaire genese wegen zwaarder dan die voor primaire genese.

IV.

Het genus *Praebarrettia* moet vervallen.

V.

Ten onrechte noemt Cvijić de morphologische niveaux in de Sumadije abrasie-terrassen. Deze niveaux zijn veeleer te verklaren door fluviatiele werking.

J. Cvijić: Jezerska plastika Sumadije. Glasn. Srpske Kral. Ak. Bd. 79, 1909.

VI.

Het ware toe te juichen, indien de studenten in de geologie reeds tijdens hun studie door middel van practisch werk kennis konden maken met het groote belang van luchtphotographieën voor de geomorphologie en geologie.

VII.

BEDERKES verklaring van de metamorphose in het Altvatergebirge is door haar hypothetische en gekunstelde aard niet te verkiezen boven de vroegere opvattingen.

ERICH BEDERKE: die Regionalmetamorphose im Altvatergebirge. Geol. Rundschau Bd. XXVI, 1935 Heft 1/2.

VIII.

Tusschen *Sorites* en *Amphisorus* bestaan geen generieke verschillen.

IX.

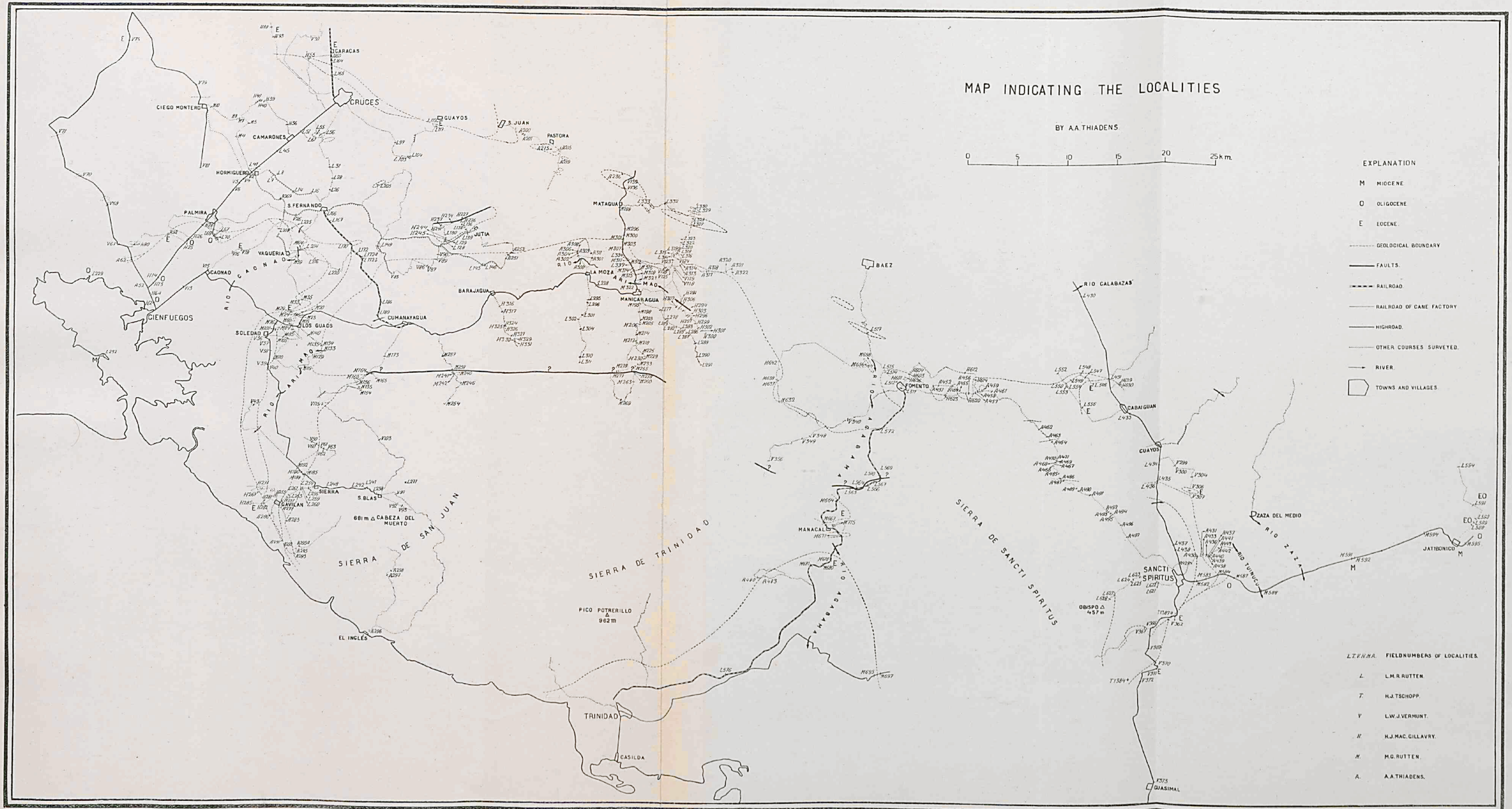
Het bestaan van een Praecambrische geosynclinale langs de Noordkust van Groenland is door KOCH niet voldoende aangetoond.

Geologie der Erde: LAUGE KOCH, Geologie von Grönland 1935.

X.

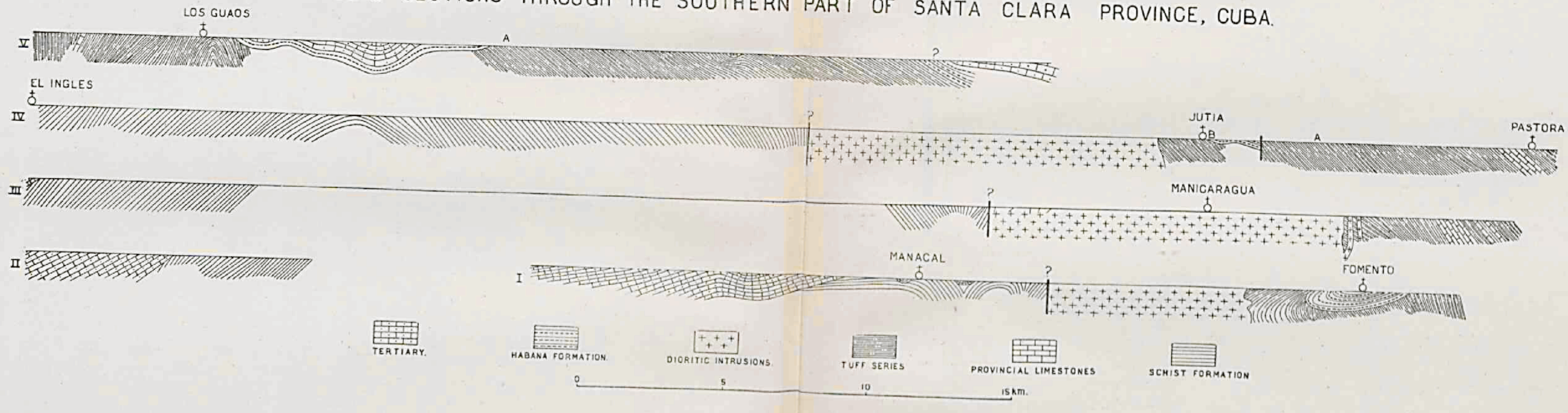
De opvatting, dat men om economische overwegingen de verwerking der grondstoffen zoo dicht mogelijk bij hun productiecentra moet laten plaats vinden, geldt niet voor de petroleumindustrie.

Handwörterbuch der Staatswissenschaften. Artikel Petroleum van ROBERT LIEFMANN.



MAP INDICATING THE LOCALITIES
BY A.A. THIADENS
0 5 10 15 20 25 km.
EXPLANATION
M MIOCENE
O OLIGOCENE
E EOCENE
GEOLOGICAL BOUNDARY
FAULTS
RAILROAD
RAILROAD OF CANE FACTORY
HIGHROAD
OTHER COURSES SURVEYED
RIVER
TOWNS AND VILLAGES
L T V H M A. FIELDNUMBERS OF LOCALITIES
L. L.M.R. RUTTEN.
T. H.J. TSCHOPP.
V. L.W.J. VERMUNT.
H. H.J. MAC GILLAVRY.
M. M.G. RUTTEN.
A. A.A. THIADENS.
CARACAS
CRUCES
CIEGO MONTERO
CAMARONES
HORMIGUERO
PALMIRA
GUAYOS
S. JUAN
PASTORA
S. FERNANDO
JUTIA
VAQUERIA
CAONAO
RIO CAONAO
CIENFUEGOS
SOLEDAD
LOS GUAOS
CUMANAYAGUA
BARAJAGUA
MATAGUA
LA MOZA
RIO ARIMAO
MANICARAGUA
BAEZ
RIO CALABAZAS
FOMENTO
CABAIGUAN
GUAYOS
ZAZA DEL MEDIO
RIO ZAZA
RIO TUINICU
JATIBONICO
SANCTI SPIRITUS
OBISPO 457 m
GUASIMAL
SIERRA DE SANCTI SPIRITUS
RIO AGABAMA
MANACAL
SIERRA DE TRINIDAD
PICO POTRERILLO 962 m
TRINIDAD
CASILDA
SIERRA DE SAN JUAN
681 m CABEZA DEL MUERTO
SIERRA
S. BLAS
CAVILAN
EL INGLES

IDEAL SECTIONS THROUGH THE SOUTHERN PART OF SANTA CLARA PROVINCE, CUBA.



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