THE RELATIONSHIP OF OIL AND SERPENTINE IN CUBA

M. Iturralde Vinent

BY

HARRY WASSALL

Presented
Section III on Petroleum Geology
INTERNATIONAL GEOLOGICAL CONGRESS
México D. F.
September 1956

Arthur A. Meyerhc

ABSTRACT

P L A T E S :

THE RELATIONSHIP OF OIL AND SERPENTINE IN CUBA

HARRY WASSALL

ABSTRACT

Three oil fields and over 50 oil seepages occur in large serpentine bodi in Cuba. Petrographic study indicates that the serpentine is an alteratic product of peridotite. Field mapping in Las Villas Province, Cuba shov that the serpentine is the lower part of a layered sequence of igneous rock The upper part of the sequence is gabbro, and in some areas a middle pa is present which consists of interlayered gabbro and serpentine. This igneo group appears to have resulted from magmatic segregation. It underlies wate laid Cretaceous volcanics and in some areas seems to overlie pre-Cretaceo metamorphics.

Field evidence indicates that the entire sequence of volcanics, serpenti and metamorphics was overthrust northward in the order of tens of mil during the post-Cretaceous to pre-Lower Eocene, over a normal marine lime tone section. The limestones in the underlying thrust plate are in part facies equivalent of the volcanics in the overlying plate and have abunda carbonaceous material. Later tectonics folded and faulted the thrust plat and the overlying plate was eroded away in some areas and preserved others. It is believed that where the overlying plate was preserved in graber oil migrated upward from the fractured limestones of the underlying pla and was trapped in the serpentine. It is also theorized that accumulations m exist below the serpentine in the fractured limestones.

I. INTRODUCTION

Of the six oil fields which have been discovered in Cuba, four of the produce massive serpentine bodies which have never been penetrated. The fields, Santa María, Bacuranao-Cruz Verde, Motembo and Jarahueca were discovered by drilling on oil or gas seeps.

Although the serpentine areas are not as good oil prospects as the Tertia high Upper Cretaceous basins, they still have definite possibilities for sh low and deep production.

Serpentine, a secondary mineral is a hydrous magnesium silicate form by the alteration of non-aluminous magnesium silicates by the addition water. It is commonly found as a mineral in other rocks, or as large ro masses, such as those in Cuba.

Many attempts have been made by geologists to explain the origin Cuban serpentine, and its role in trapping the oil accumulations. Most opinic are about evenly divided as to whether it is an irregularly shaped, massi igneous intrusive or a tabular body of sedimentary origin which was deposit on top of source limestone.

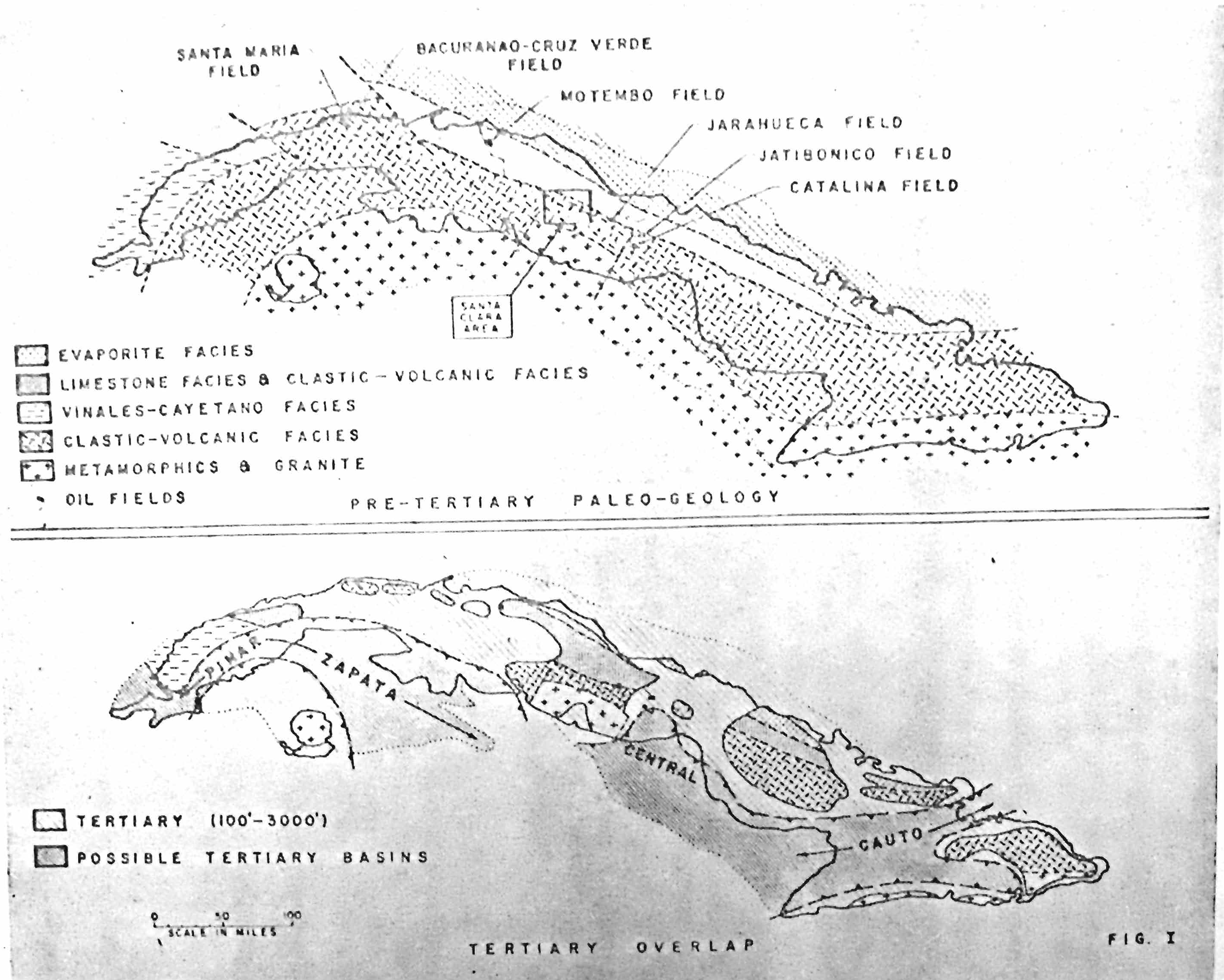

SANTA MARIA FIELD
BACURANAO-CRUZ VERDE FIELD
MOTEMBO FIELD
JARAHUECA FIELD
JATIBONICO FIELD
CATALINA FIELD
SANTA CLARA AREA
EVAPORITE FACIES
LIMESTONE FACIES & CLASTIC-VOLCANIC FACIES
VINALES-CAYETANO FACIES
CLASTIC-VOLCANIC FACIES
METAMORPHICS & GRANITE
OIL FIELDS
PRE-TERTIARY PALEO-GEOLOGY
PINAR
ZAPATA
CENTRAL
CAUTO
TERTIARY (100'-3000')
POSSIBLE TERTIARY BASINS
0 50 100
SCALE IN MILES
TERTIARY OVERLAP

FIG. I

Arguments for the irregular intrusion do not adequately explain seeps and accumulation of oil in serpentine bodies surrounded by volcanic rocks, which by no stretch of the imagination could be called source rocks. On the other hand, theories suggesting a sedimentary origin for the serpentine are based on misconceptions as to its nature. For example, serpentine has been called a conglomerate because of its commonly fragmental texture; a derivative of limestone because of its intermixing with that rock in fault breccias; and a mud flow without any substantiating field evidence.

The writer believes that neither the irregular intrusion nor the sedimentary origin is correct, and that field evidence proves the following points:

1. Cuban serpentine is unquestionably derived from peridotite.

2. The peridotite was part of a sequence of horizontal, tabular-shaped igneous bodies which differentiated from the same primary magma.

3. This igneous mass, together with an overlying clastic-volcanic facies, has been thrust northward over limestones which are the source of the oil that migrated upward into the serpetine.

4. Accumulations may exist in these limestones immediately below the thrust plane, in structurally high configurations of this low-angle thrust contact.

These theories are based on detailed field work in Havana, Matanzas, Las Villas and Camagüey Provinces during four years in Cuba with the Gulf Oil Company and one and a half years as a consulting geologist.

II. Regional Geology of Central Cuba

Figure I shows the location of the oil fields in relation to a paleogeological map of Cuba. The geological strike roughly parallels the trend of the island. The same group of rocks and type of structure are present in the area of each of the serpentine fields, even though three of them are widely separated.

One of the best areas to interpret the origin of the serpentine and its relationship to oil, is in the vicinity of the City of Santa Clara in Las Villas Province. This area lies between the Jarahueca and Motembo fields, and has oil and gas seeps as well as a record of small production from serpentine.

Although the serpentine is restricted to one facies belt it has been thrust into contact with others. For this reason, before discussing the Santa Clara Area, the regional geology of Central Cuba will be briefly mentioned. Paleontological evidence for the interpretation outlined will be available in a detailed report of the Stratigraphy of Las Villas Province which will soon be published by Dr. Paul B. Bronniman, of the Gulf Oil Company.

Miocene, Oligocene, Eocene and in some areas, late Upper Cretaceous sediments, which are relatively gently folded, overlap a truncated section of Upper Cretaceous, Lower Cretaceous and Upper Jurassic sediments and associated igneous rocks.

Figure II-A shows the original deposition of the Cretaceous and Jurassic beds in a basin which had a northern evaporite facies, a central limestone facies and a southern clastic-volcanic facies. Serpentine and gabbro underlie, and are restricted to, the clastic-volcanic facies. Upper Jurassic has not been identified in the clastic-volcanic facies.

Figure II-B shows low-angle faulting which thrust the clastic-volcanic belt northward over the limestone and evaporite facies. At present these facies belts are found as remnants and windows of superimposed low-angle thrust sheets, which strike roughly parallel to the north coast of Cuba.

Figure II-C indicates the high-angle faulting, which cut the thrust plates. It is not completely understood, and may be reverse rather than normal, as shown.

Figure II-D shows peneplanation of the complicated structures and the overlap by the high Upper Cretaceous and Tertiary sediments. Some of the high-angle faults continued to be active throughout the Eocene and as much as 10,000′ of Tertiary shales and sand were found in Trans-Cuba, Sancti Spíritus No. 1, in the south coast area of Las Villas Province.

The main evidence for low-angle thrusting in the above interpretation consists of the definite paleontological proof and lithological corroboration that although the three facies belts are found out of place from north to south, they have equivalent age groups. For example, the southern facies is found north of the central facies in elongate strips. Thus, even though the boundaries of these strips are high-angle faults, low-angle thrusting must have occurred to achieve the horizontal displacement. Further evidence consists of windows of central facies surrounded by southern facies. Lithologically the facies changes are quite evident as there is a progressive increase southward in volcanic constituents in the limestone outcrop strips, and an increase southward in volcanic flows in the clastic-volcanic outcrop strips. Although simplified in this report, the three facies belts mentioned above can be further subdivided into seven readily recognized sub-belts on the basis of lithological groups.

Keeping in mind the background of low-angle thrusts with superinposed high-angle faults, we can proceed to discuss the Santa Clara Area.

III. Stratigraphy of The Santa Clara Area

Figure III shows the geology of the Santa Clara Area and the parallelism of the igneous outcrops to the strike of the sediments. This is the basis for assigning gabbro, serpentine and metamorphics rocks to a place in the stratigraphic column.

A. Upper Cretaceous Clastics. — Approximate maximum thickness is 5,000′. Consists predominantly of thin-bedded shales, sandstones, and porcelaneous and fragmental limestones. Also has interbedded pale-green, pumiceous tuffs and some flows. Best exposed in the Seibabo Syncline south of Santa Clara. These beds overly the volcanics apparently unconformably.

Jurassic
limestone
pro underlie.
has not been

astic-volcanic belt
resent these facies
sed low-angle thrust
of Cuba.

h cut the thrust plates.
rather than normal, as

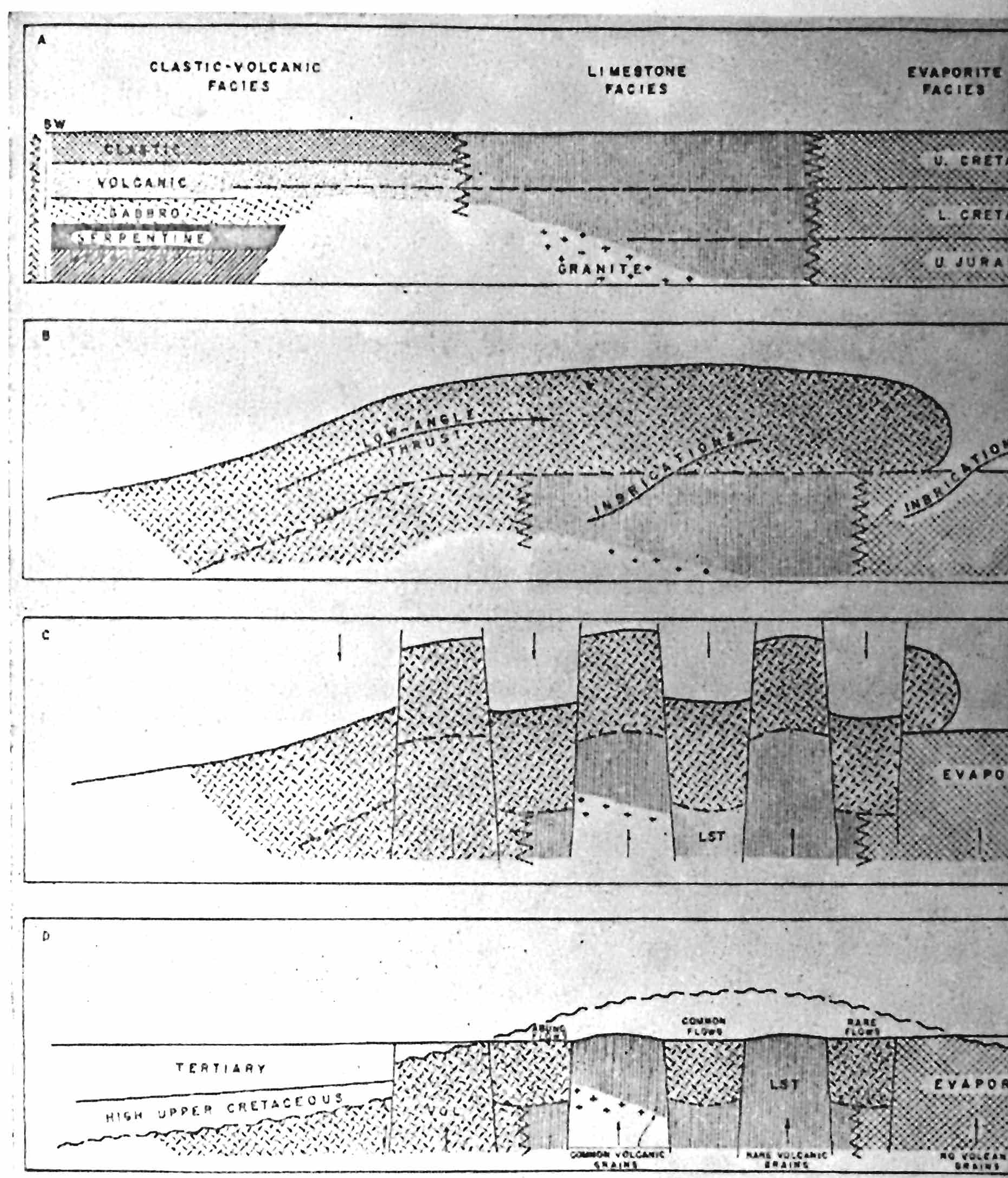
ted structures and the
ediments. Some of the
e Eocene and as much
in Trans-Cuba, Sancti
rovince.

e above interpretation
nological corroboration
ce from north to south,
outhern facies is found
though the boundaries
ng must have occurred
ice consists of windows
gically the facies chan-
southward in volcanic
increase southward in
Although simplified in
be further subdivided
lithological groups.

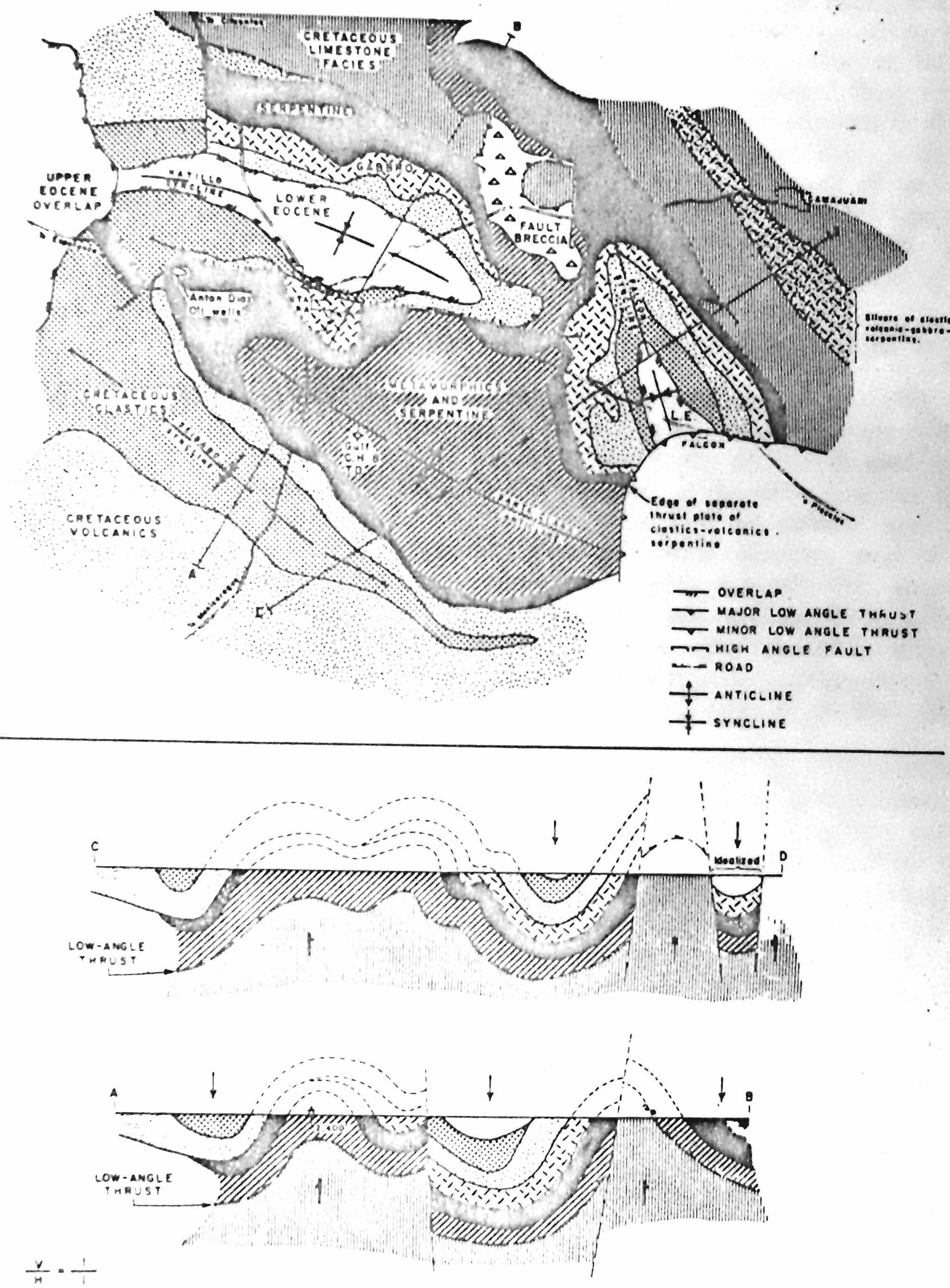
usts with superinposed
a Clara Area.

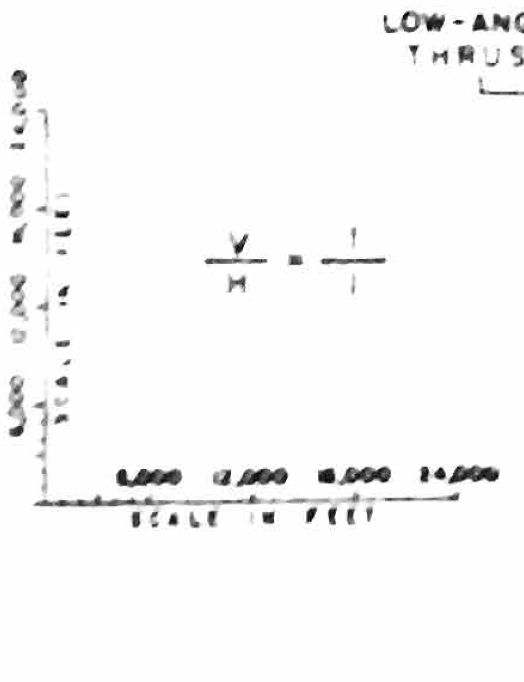
rea and the parallelism
. This is the basis for
to a place in the stra-

maximum thickness is
shales, sandstones, and
has interbedded pale-
exposed in the Seibabo
verly the volcanics ap-



DIAGRAMMATICAL SKETCHES OF THE REGIONAL GEOLOGY OF CENTRAL CUBA





SANTA CLARA AREA - -
GEOLOGICAL MAP
AND
DIAGRAMMATIC
CROSS SECTIONS

FIG. III

B. Upper Cretaceous-Lower Cretaceous Volcanics. — Approximate maximum thickness in excess of 15,000′. The upper part of the volcanic section has dense and fragmental limestones, siliceous shales and interbedded flows. Massive andesite flows occur at the top of the section, and are about 700′ thick on the northern flank of the Seibabo Syncline, increasing to about 3,000′ on the southern flank. The lower part consists of basic, porphyritic, submarine flows interbedded with water-laid tuffs. This lower part is nearly devoid of fossils except for radiolaria, but at least part of the section is Lower Cretaceous. It is about 2,000′ thick on the northern flank of the Seibabo Syncline and 12,000′ on the southern flank.

C. Gabbro-Serpentine Group. — Consists of four units, as follows:

1. Gabbro. — Maximum thickness estimated to be 4,000′. (The thickness of gabbro and serpentine are judged from the width of steeply dipping outcrop bands). The term gabbro is used to include all feldspathic units, and while most of the mass is a true gabbro, rocks identified as dolerite, troctolite and anorthosite are also included in this designation. The gabbro is massive, medium to coarsely crystalline, equigranular, and with a black and white (or green) speckled appearence. It forms low, rolling hills, and weathers to depths of 6′-20′, so that the only outcrops are in road cuts. It underlies the volcanics, but the nature of contact is not clear. Good exposures may be seen on the south edge of the City of Santa Clara.

2. Gabbro and Serpentine Interlayered. — Maximum thickness 1,000′, but not always present. This interlayered band is commonly found between parallel outcrop bands of gabbro and serpentine, and strongly suggests a gradational contact caused by magmatic separation. The gabbro here is harder, finer-grained and has a more sparkly appearance. It occurs as resistant, tabular lenses between swales of softer serpentine, and in many cases has dip and strike conformable to the volcanics which overlie the gabbro. It is best developed south of the Jarahueca field, but may be seen on the east and west flanks of the Falcon Syncline at the gabbro-serpentine contacts. It was not mapped as a unit in this area because it is only a few hundred feet thick.

3. Serpentine. — Maximum thickness estimated to be about 6,000′. (A well which drilled 7,285′ without penetrating the serpentine at Jarahueca Field is believed to have found an exaggerated thickness in one of these bands). Cuban serpentine is an alteration product formed by the addition of water to olivine, a silicate of magnesium and iron. It is massive, translucent to opaque, dark green when fresh, yellow-green when weathered. Its luster is greasy to resinous, and the hardness is 2.5-4.0 depending on impurities. Any of the serpentine areas shown on Figure III are representative localities.

It has the following characteristics which are typical of serpentine derived from periodotite:

a. Net-like structure and olivine pseudomorphs.

b. Common occurrence of unaltered periodotite.

c. Occurrence in large rock masses.

d. Close association with gabbro.

e. Presence of chromite and nickel ores.

4. Metamorphic and Waxy Serpentine Complex.–Maximum thickness is in excess of the 2,400′ found in the Gulf Core Hole No. 8. The type locality occurs south of Santa Clara where metamorphic bodies ranging from about 10′ to 5,000′ in diameter are found surrounded by serpentine which is waxier and more sheared than the reticulate type which apparently overlies this complex.

The metamorphics are gneisses, schists and phyllites, but no marbles are present. They are believed to be Upper Jurassic in age because of lithological similarities with known Upper Jurassic metamorphics in Pinar del Río. They cannot be younger than Lower Cretaceous because Upper Cretaceous volcanics overlie similar metamorphics in the Trinidad Mountain Area. These rocks are believed to be the lower part of an area where feeders of the primary magma came up through the metamorphics to form the present day gabbro-serpentine body. It is not believed that these feeders are responsible for this metamorphism, since the Trinidad Metamorphics, only 15 miles to the south, are associated with granodiorite and not serpentine.

The metamorphics found between the Cretaceous limestone facies and serpentine north of Santa Clara, cannot possibly be considered as metamorphism of the limestone since they are non-calcareous. These metamorphics also appear to be at the base of the overthrust.

D. Cretaceous Limestone Facies. — This group of rocks outcrops north of Santa Clara, and is believed to extend southward under the gabbro-serpentine group, below a major low-angle thrust fault. Thus, although it is an age equivalent of the clastic-volcanic facies it underlies it tectonically.

The thin-bedded limestones, cherts and limy shales present in this facies have been mapped and referred to as the "Aptychus Formation". Actually, the lithological differences easily permit division into numerous mappable units, and the age ranges from Upper to Lower Cretaceous in the Santa Clara Area, and even Upper Jurassic further north.

E. Calcite Mesh. — This rock consists of a porous, sponge-like mass of intersecting calcite veins which are each about 1/16″-1/4″ thick. Green clay is usually found in the interstices.

Calcite mesh is almost always found on the surface at fault contacts of serpentine and limestone, and is an excellent indication of major fault contacts. It is formed by ground water depositing calcite in the fractured serpentine near the contact, and is not well developed in cored contacts below about 100′. It has been erroneously mapped as lava flows by some authors, possibly because of its scoriaceous appearance.

IV. Structures of the Santa Clara Area

The structures formed in the Santa Clara Area clearly show the conformity of the narrow outcrop bands of igneous units, with the overlying volcanics and clastics. These gabbro-serpentine units are repeated on the flank of every structure, except for the south flank of the Santa Clara Anticline, where gabbro is only found in small patches. The conformity, elongated outcrop bands and repetition indicate that the igneous units originally must have had a fairly horizontal, tabular shape, which was later folded into synclines and anticlines. The overlying volcanics and clastics have dips ranging from 30°-80° with the majority of them steep. Dips in the Lower Eocene are mostly below 30° and it is believed to be an overlap which was folded upon rejuvenation of the synclines. Because of the massive units and steep dips involved, it is theorized that the major folding occurred after thrusting. Consequently, the thrust plane itself may be roughly conformable with the surface structure.

In the *Seibabo Syncline*, to the south, formational units are coherent and repeated individually on each flank, in spite of a complicated fault pattern.

In the *Hatillo and Falcon Synclines*, to the north, deformation is more intense and the repetition observed is in the groups of clastics and volcanics rather than in the formations.

The *Santa Clara Anticline* is made up of igneous and metamorphic units. It has been designated an anticline because of its position between two synclines, the nearly continous band of serpentine which surrounds the core of metamorphics and the appearance of the northwestern end, where the serpentine broadens as if it were a plunging nose.

A round shaped outcrop of Cretaceous limestone facies occurs half way between Santa Clara and Camajuaní, north of the highway. It is surrounded by highly deformed, brecciated slivers of limestones, shales, serpentine and metamorphics. This deformed belt is surrounded in turn by serpentine and the metamorphic-serpentine unit. The limestone facies is believed to be a *window* and the deformed belt around it a large scale *fault breccia* at the base of the low-angle thrust.

A separate thrust plate of the clastic-volcanic facies truncates the southern part of the Falcon Syncline as well as the southeast trending limestone facies. This strongly suggests continuation of these limestones under this thrust plate.

Stratigraphic units of the Falcon Syncline are also present as slivers in a highly deformed belt to the northeast of the adjacent limestone facies belt. Since both belts have equivalent age units, but no similarity in lithology,

this horizontal displacement northward of a southern facies belt (clastic-volcanic) can best be explained by low-angle thrusting.

V. Origin and Age of the Serpentine and Associated Rocks

Any theory on the origin of the serpentine must explain certain concrete facts which are found in the field.

1. The gabbro-peridotite mass differentiated from a primary magma indicating a slow period of cooling and consequently an intrusion.

2. The medium to coarse crystallinity of the gabbro also strongly suggests slow cooling.

3. The gabbro-peridotite in most areas is underlain by metamorphics of possible Jurassic age, and overlain by flows and tuffs which are Lower Cretaceous or older.

4. At least large areas, if not all of the gabbro-peridotite body originally had a horizontal tabular shape and a total thickness in excess of 5,000′.

5. Contacts in the field of volcanics overlying gabbro or serpentine practically all appear to be faults because of the extreme brecciation and occasional slickensides which are present.

6. No contact metamorphism has been found between volcanics and gabbro-serpentine. However, white, feldspathic porphyritic dikes (trachyte) are found cutting across the volcanics, but not the clastics.

7. No basal conglomerates are ever found between contacts of volcanics and gabbro-serpentine.

It is believed that the theory which best explains these facts is as follows:

1. A primary magma intruded along the contact of volcanics overlying metamorphics, digesting part of both and occupying a fairly horizontal tabular position. Trachyte porphyry dikes intruded the volcanics. This intrusion occurred in the middle of the Upper Cretaceous post-volcanic and preclastic deposition.

2. Medium to coarsely crystalline gabbro and periodotite were formed by differentiation and slow cooling.

3. When major low-angle thrusting took place, minor fault slippage occurred between the massive gabbro-periodotite unit and the less competent, bedded volcanics. This obliterated or covered up the traces of contact metamorphism.

D. E. Flint, J. F. Albear and P. W. Guild, in their excellent paper on the Chromite Deposits of Camagüey, Cuba (U.S.G.S. Bull. 954-B, 1948) recognized the igneous origin of the gabbro-serpentine. They theorized south-

ward thrusting, but there are not enough facies belts exposed in the Camagüey area to demonstrate that the thrusting is northward. Regarding the origin of the gabbro-serpentine, in order to provide a cover for crystallinity and differentiation, they theorized a sill-like intrusion in the middle of metamorphics, erosion of the overlying metamorphics and deposition of the volcanics. This explanation does not agree with the field evidence since neither metamorphics nor basal conglomerates are ever found above the gabbro-serpentine units.

Other geologists familiar with the problem have theorized that the gabbro-serpentine body is a huge submarine flow or part of the original basement, over which the volcanics were deposited. The absence of a basal conglomerate could be explained by the lower units being lava flows, but the crystallinity and differentiation of the gabbro-peridotite cannot be explained in this manner, since the cover needed for slow cooling would not be present.

Many previous interpretations of the origin of serpentine concentrated on the serpentine contacts with the Cretaceous limestones facies. These contacts were believed to be intrusive and the oil was supposed to have migrated into the serpentine from the sediments it had penetrated. The writer has traced many miles of these contacts, and supervised core drilling along them, without ever seeing any evidence to support this belief. On the contrary the following evidence indicates that these contacts are faults.

1. The horizontal trace of most of the contacts are straight lines indicating steeply dipping planes. Only occasionally are the low-angle fault contacts exposed.

2. The plane of most of the contacts when cut by three or four core holes maintains a uniform dip suggesting a fault plane.

3. The dip and strike of the contacts approximates that of the adjacent limestones as would be expected from drag along a fault.

4. The extreme brecciation of the limestones and serpentine near the contact and the presence of the calcite mesh mentioned above indicates faulting.

5. The absence of any marbleization of the limestone at the contacts argues against intrusion. Metamorphics are sometimes present, but they are completely unrelated to the limestone belt.

VI. Oil Occurrences

Oil occurrences are numerous in the Santa Clara Anticline. About 1,000 barrels of high gravity oil were produced from about four wells less than 1,500′ deep at Antón Díaz, about 3 miles west of Santa Clara. Gas seeps are still active there, and one of the wells has been supplying gas to two houses, since it was drilled in 1940. These seeps and wells are located in serpentine in the northwestern part of the Santa Clara Anticline.

Escuela de Geofísica

The Gulf Core Hole No. 8, located in the core of this anticline, produced about ten barrels of 40° API gravity, paraffin-base crude oil from metamorphics and serpentine at 240′. Many other gas, oil and tar seeps are known in this core.

VII. Relationship of Oil and Serpentine

It is believed that the oil occurrences mentioned above are most likely migrating upward from an underlying source, because of the following reasons:

1. The metamorphics and serpentine in the core of the anticline can be ruled out as possible source rocks.
2. The clastics and volcanics nearest to Gulf Core Hole No. 8, lie 1½ miles to the southwest and four miles to the north.
3. The structural position of the clastics and volcanics on the flank of the Santa Clara Anticline does not favor migration into its core.
4. The lithology of the clastics and volcanics does not favor them as a source rock.

The source rock must lie below a low-angle thrust fault because:

1. Faulting is the only available mechanism which could superimpose metamorphics on sediments.
2. Northward low-angle thrusting is indicated north of the City of Santa Clara by the close contact of abrupt facies changes, and the northern displacement of a southern clastic-volcanic facies.

The source rocks are probably the Cretaceous limestone facies which outcrop north of the City of Santa Clara.

1. These limestones are carbonaceous, and have numerous showings of gas, oil and tar. It is generally agreed that they are the most probable source rocks in Cuba, among those that are found outcropping.
2. The outcrop pattern north and east of Santa Clara indicates that these limestones were covered by metamorphics and serpentine before they were uplifted by high angle faults. It is reasonable to expect this same situation to continue southward under the Santa Clara Anticline.

It is believed that the low-angle thrust plane itself may be roughly conformable to the surface structure. If so, accumulations of oil may exist in structural highs under this fault plane. The reservoir would be fractured Cretaceous limestones or fault breccia, and the cap rock the more impervious mixture of metamorphics and waxy serpentine.

Summing up, it is believed that in the Santa Clara Anticline oil occurring in serpentine and associated rocks, has migrated upward from source beds of Cretaceous limestone lying below a folded, major low-angle thrust fault, which may have accumulations in structurally high configurations of the fault plane.

The evidence for this interpretation is not as complete around the four serpentine oil fields in Cuba. For example metamorphics only outcrop in one of these fields, so that in the other fields the lower unit in the thrust sheet may be serpentine. Nevertheless, enough similarities exist to be reasonably certain that the same general relationship found between serpentine and oil in the Santa Clara Area should be true for these fields.

HARRY WASSALL