

## OCCURRENCE OF OIL IN IGNEOUS ROCKS OF CUBA<sup>1</sup>

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### ABSTRACT

The seepages of oil, the asphalt deposits, and the two oil fields, Bacuranao and Motembo, are described with special reference to the association of oil and asphalt with igneous rocks. Production in both oil fields is from serpentine and no commercial production has been found in sedimentary rocks. It is estimated that more than 200,000,000 barrels of asphaltic oil was required to form the asphalt deposits and seepages.

### SUMMARY

A great number of seepages of oil and many commercial deposits of asphalt occur in Cuba. Part of them are associated with serpentine and ferromagnesian igneous rocks. One commercial oil field, Bacuranao, and one semi-commercial naphtha field, Motembo, have been developed in serpentine. In spite of the abundance of residual oil, exploration has failed thus far to find commercial oil in normally bedded sands in the sedimentary rocks. The geology of Cuba has been described in a separate article by the writer,<sup>3</sup> and the petroleum geology by DeGolyer.<sup>4</sup> Many of the data have been taken from the latter publication. The writer acknowledges receipt of assistance from several friends who were studying the geology of Cuba at the time of his investigation.

### IGNEOUS ROCKS

Hundreds of seepages of oil and gas are found in central and western Cuba. Several asphalt deposits have been mined and two are still being mined. Most of the surface occurrences of petroleum are found within or close to areas of serpentine or ferromagnesian igneous rocks which probably have the form of plugs, dikes, denuded laccoliths, and possibly

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<sup>3</sup>J. Whitney Lewis, "Geology of Cuba," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 6 (June, 1932), pp. 533-55.

<sup>4</sup>E. DeGolyer, "The Geology of Cuban Petroleum Deposits," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2 (1918), pp. 133-66.

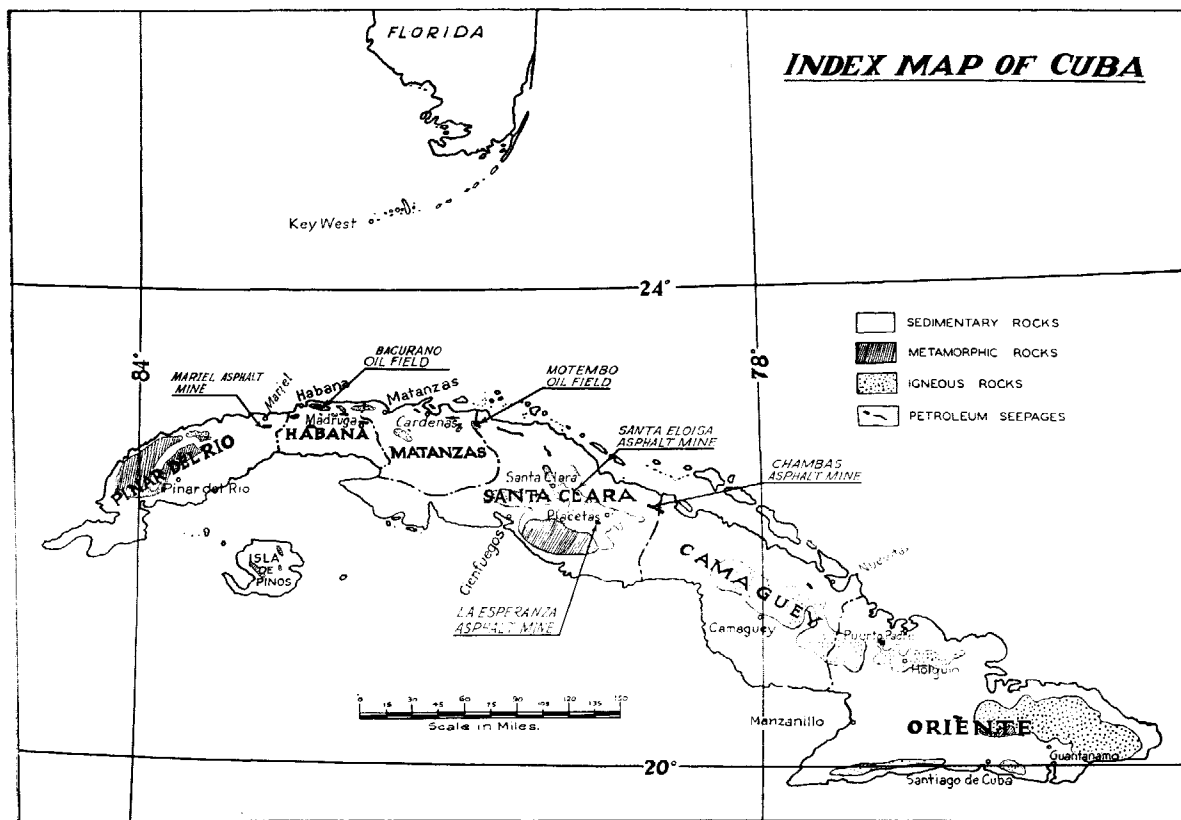


FIG. 1.—Map of Cuba, showing oil seepages, oil fields, most important asphalt mines, and generalized geology.

lava flows. The intrusive rocks have penetrated or partly covered sedimentary rocks.

Granitic rocks and serpentines are found in the Basement complex. These, and the serpentines in the sedimentary rocks, have been cut by younger dikes. A diorite (?) dike cuts serpentine east of Habana and oil seeps to the surface along the walls of the dike and through crevices in it. Other dikes are known on the island. "Obsidian," which is probably an olivinitic rock, was encountered in wells drilled at Motembo.<sup>1</sup>

#### GEOLOGIC HISTORY

The writer has described the geology of Cuba in a separate article<sup>2</sup> and only a very brief summary is given here. The Basement complex consists of granite rocks, metamorphosed schist, shale, and marble. This is overlain by the Vinales limestone, of Jurassic age, consisting of 1,500 feet or more of highly bituminous limestone and shale. Unconformably on the Vinales, basal conglomerates, bituminous sands, and shales of Cretaceous age crop out on the flanks of the mountain areas. Within the Cretaceous there is one unconformity. Eocene limestones, marls, and shales are separated by a major unconformity from the older rocks. Cavernous Miocene limestones rest unconformably on Eocene rocks. In general, structure in the Tertiary rocks reflects that in the older rocks.

Intrusions of ferromagnesian igneous rock are of several ages. Fragments of Jurassic and Cretaceous limestones have been found in serpentine near Cardenas, yet arkose and conglomerate of Lower Cretaceous age in Santa Clara Province contain serpentine pebbles.<sup>3</sup> Also, as previously stated, dikes are known to cut serpentine. Therefore, some of the igneous rocks must be of pre-Cretaceous age and must have been serpentinized in pre-Cretaceous time; other igneous rocks must be post-Lower Cretaceous and are probably of post-Eocene age.

The source rock of petroleum is believed to be either Jurassic limestone or Cretaceous shale, or possibly both. Cretaceous sands are considered to be the most probable sedimentary reservoir rocks, although they have not yet been proved to contain oil. In most places these sands are believed to lie within 4,000 feet of the surface.

#### STRUCTURE

The general structure of the island is asymmetrically anticlinal with several systems of folding superposed. The older igneous, metamorphic, and sedimentary rocks are complexly and steeply folded and deeply

<sup>1</sup>E. DeGolyer, *op. cit.*

<sup>2</sup>J. Whitney Lewis, *op. cit.*

<sup>3</sup>E. DeGolyer, *op. cit.*, p. 138.

truncated where exposed in the central part of the island. The Cretaceous and older rocks are cut by many intrusions of diorite and ferromagnesian rocks, most of which are serpentinized. The final uplift of the island must have taken place in late Tertiary or post-Tertiary time.

Much more exploration will be required to prove or condemn the oil possibilities of Cuba.

#### SEEPAGES

Surface manifestations of petroleum are live seepages that vary from gas to colorless naphtha, light oil, and heavy oil. Extinct seepages are asphalt and gilsonite. Seepages may be individual or in groups. Asphalt and gilsonite deposits are frequently of large size, as described later in this paper.

Most oil and gas seepages are related to fissures or systems of fissures. Some of the fissures which cut or abut igneous rocks are believed to have developed during the intrusion and subsequent hydration of these rocks. In some places oil has migrated and accumulated along the fissures and in the adjacent igneous and sedimentary rocks.

The fissures are believed to be Eocene or post-Eocene because in several places the intrusions cut the Eocene rocks. Most of the asphalt deposits observed in mines are laminated horizontally with little or no indication of vertical flow structure; hence they have not been compressed since formation.

The seepages actually associated with intrusive rocks must have commenced with and continued during the intrusion, hydration, and cooling. It seems probable that most of them became inactive either because of the exhaustion of the source supply or the sealing of the outlets by residuums. This probably took place within a few years after the cooling of the intrusions. Recurrent minor deformations of the island appear to have caused repeated rejuvenations of many of the sealed seepages and to be responsible for those that are active to-day. In the cases of asphalt and gilsonite deposits which occupy large tension fissures the purity of the material and the dimensions of the fissures indicate that they were probably formed very rapidly, for the most part within a few years after the formation of the fissures. More than 30,000,000 barrels of heavy asphaltic oil such as Panuco crude, or, in other words, an amount equal to that in a fair-sized oil field, must have evaporated and oxidized to form a single deposit, like Mariel, containing more than 2,000,000 tons (10,000,000 barrels) of gilsonite.<sup>1</sup>

<sup>1</sup>It has been estimated that 20,000,000 to 30,000,000 barrels of oil must have been oxidized to leave this residue (Albert Wright, Jr., and P. W. K. Sweet, "The Jurassic as a Source of Oil in Western Cuba," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 4 (July-August, 1924), pp. 516-19). The present known reserves of this deposit are at least three times what they were when the foregoing estimate was made.

Other smaller asphalt deposits represent the draining of additional millions of barrels of oil. The light oil which is now produced may be the volatile part of either relic oil fields, or only partly depleted pools.

Description of the better known petroleum occurrences in both igneous and sedimentary rocks are given by DeGolyer<sup>1</sup> and little more has been learned concerning them since his visit in 1915. Official bulletins<sup>2</sup> give descriptions of the more important of the 30 or more asphalt deposits which have been exploited. Therefore, only the most important and typical asphalt deposits are described here, the Mariel mine being in sedimentary rocks.

#### FAVORABLE RESULTS OF EXPLORATION<sup>3</sup>

During 1881, in the first well drilled for oil in Cuba, located close to gas seepages, natural naphtha was found at the site of the present Motembo oil field. Several wells were drilled in 1890-96 in the Lagunillas district west of Cardenas and one well produced some oil. In 1913 a considerable flow of gas was encountered at Puntas Grandes in the western part of the city of Habana at a depth of 60 feet. The Bacuranao field 10 miles east of Habana was discovered in 1915. Other significant showings of oil and gas in wells besides those mentioned have been found at the following localities: oil on the Alvarez properties 6 miles west of Cardenas; oil and gas in the Williams well at Guayabal, 25 miles west of Habana; oil in the Cuban Petroleum Company well No. 1, 4 miles west of Santa Clara in serpentine; and gas in a well drilled near seepages from fissures at Bejucal, 19 miles south of Habana. Of these all but the Guayabal well started near or in known serpentine.

#### OIL FIELDS

*Motembo oil field.*—This field is on the line between Santa Clara and Matanzas Provinces 34 miles east of Cardenas. It is situated on a rounded highland which is approximately 3 miles in diameter and rises 325 feet above the flat coastal plain. This highland is composed of serpentine which is cut by numerous secondary intrusions of "obsidian" (probably olivinitic rock) and in which cracks and small fissures are numerous. The surrounding area is covered with maroon clay marls and alluvium much of which is capped with a thin mantle of hematite pebbles. A hematite gossan, in many places having a thickness of 4 feet, covers the serpentine. There are few if any exposures in the flats that indicate

<sup>1</sup>E. DeGolyer, *op. cit.*, pp. 148-57. See also, H. C. Brown, "Mineral Resources of Cuba in 1901," in *Civil Report of Military Governor, Brig. Gen. Leonard Wood, 1902*, Vol. 5, Pt. 2.

<sup>2</sup>*Dirección de Montes y Mines, Republica de Cuba Boletín* 13, 14 (Habana, 1928-1929).

<sup>3</sup>Summarized from E. DeGolyer, *op. cit.*

the nature and structure of the underlying formations. Small quantities of inflammable gas seep from cracks in the serpentine at several places within an area of 6 acres and the wells that have been drilled to date are located close to them. The hematite is spoken of locally as "volcanic cinders" and a sink hole in this material near the wells is called "the volcano" (both terms being misnomers). The serpentine appears to be an intrusion situated on the faulted crest of an east-west trending anticline. In all probability the serpentine has moved upward through a fissure and spread in mushroom fashion on approaching the surface and then been denuded by erosion.

In 1881, in the discovery well, 26 gallons per day of colorless naphtha was encountered at 285 feet, and there were several other deeper showings. The total depth of this well was 1,000 feet. Five other wells were drilled to depths of 950, 800, 400, 700, and 1,905 feet respectively.<sup>1</sup> The logs of these wells were similar: diorite to 85 feet, altered diorite (?) and "obsidian" 85 to 142 feet, altered serpentine (?) and "obsidian" 142 to 173 feet, serpentine to the bottom of the hole. Of these five the first and second had insignificant showings of naphtha. The third developed production, but was lost through a fishing job. The last produced at the rate of 4-5 barrels of 56° Bé. gravity oil per day for some time. The total production has been about 5,000 barrels. Recently one well has been cleaned out with the view of deepening it and the operators state that it is now flowing at the initial rate, and has filled all available storage. The naphtha production is accompanied by appreciable quantities of inflammable gas.

An analysis of the naphtha from the Cuban-American Oil Company No. 3, has been published. The analysts consider the naphtha to be a fractionation product derived from the filtration of heavy petroleum through clay which acted like fuller's earth.<sup>2</sup>

Naphtha, very pale yellow color, from a mixture of 72 per cent oil, 28 per cent water depth, 1,560 feet.

Sp. gr. 0.732      *ND* 25° 1.4092

<i>Temperature</i>	<i>Per Cent Weight</i>	<i>Engler Distillation</i>		<i>ND</i> 25°
		<i>Sp. gr. 15.6°</i>	<i>Sp. gr. 20°/20°</i>	
75°	3.5			1.3900
75°-100°	18.9	0.72		1.4002
100°-125°	51.3	0.739	0.7372	1.4094
125°-150°	18.4	0.75	0.7497	1.4166
150°-160°	1.2			1.4242
Residue	2.1			1.4492

<sup>1</sup>Subsequent information is that seven more wells have been drilled and that present production comes from one of them.

<sup>2</sup>C. Richardson and K. G. MacKenzie, "A Natural Naphtha from the Province of Santa Clara, Cuba," *Amer. Jour. Sci., Ser. 5*, Vol. 29 (1910), pp. 439-46.

An analysis of naphtha which seeps from Sandalwood Spring, Santa Clara Province, and which is used as an illuminating oil without refining is as follows.<sup>1</sup>

Sample 2 liters, oil and water; sp. gr. oil at 33/33 0.901.

*Fractions*

Under	250°	3.3	290-300	18 0
	250-260	6.0	300-310	8 4
	260-270	11.2	310-330	13 1
	270-280	12.1	Residue	11 3
	280-290	16.6		

Hard, dried oil contains 86.9 per cent C., 12.7 per cent H., 0.6 per cent O., N., et cetera.

Higher paraffines absent.

*Bacuranao oil field*.—This field is 10 miles east of Habana. Since the discovery of the field in 1915, about 40 wells have been drilled within an area of less than 160 acres. They are owned by the Union Oil Company, a local concern.

The field is situated on the north edge of a serpentine mass which is approximately  $3\frac{1}{2}$  miles in diameter. The serpentine at the outcrop is fractured and recemented with calcium carbonate. The solid rock contains globules of oil. Just north of the field are limestones and marls of Tertiary age which dip regionally northward, though there are a few local dips toward the serpentine. One interpretation of structure places a fault between the limestone and the serpentine. A small mass of older rock (Cretaceous?), found in the middle of the oil field, may be a large inclusion in the serpentine.

The wells were located because of light-oil seepages which have since been obliterated by drilling operations. The production is generally encountered at a depth between 200 and 800 feet in fissures in the serpentine. The initial flows range from 25 to 200 barrels per day with a very rapid decline to 10 barrels. In January, 1930, a well was completed at 713 feet which filled a 1,250-barrel tank in 36 hours. This well was near the north edge of the field. The gravity of the oil was 28° Bé. whereas that of the oil from the other wells was 34° Bé. The field is making approximately 30 barrels per day at the present time. Salt water has been encountered in several wells.

An analysis of the oil is as follows.<sup>2</sup>

<sup>1</sup>N. H. Stokes, "On Petroleum from Cuba," *U. S. Geol. Survey Bull.* 78 (1891), pp. 98-104.

<sup>2</sup>*Rep. de Cuba Boletín de Minas Num.* 13, p. 70.

## BACURANAO FIELD—DECEMBER, 1926

Density at 15° C.	.8845
Density at 25° C.	.8908
Flash point	20° to 22° C.

Distillation	Per Cent		Specific Gravity
80° to 150° C.	13	Gasoline and benzene	0.7345
150° to 300° C.	31	Illuminating oil	0.8162
300° to 400° C.	41	Lubricating oil	0.898

These oils contain much paraffine which solidifies completely upon refrigeration. The residue (from distillation) is 12.4 per cent. This contains paraffine asphalt, carbon, and 0.5 per cent mineral matter.

The production by years has been as follows.

## OIL PRODUCED IN CUBA\*

Year	Barrels	Year	Barrels
1916	113†	1924	3,877†
1917	20,386†	1925	3,501†
1918	23,108†	1926	2,000‡
1919	9,226†	1927	3,000†
1920	10,278†	1928	4,527
1921	5,365†	1929	1,952
1922	4,063†	1930	7,006
1923	3,307†	1931	11,209
		Total	112,918

\*These figures were very kindly furnished by Frederick G. Clapp. See A. H. Redfield, Report III, Federal Oil Conservation Board, Washington, 1929.

†*Republica de Cuba Boletín de Minas* 13 (Habana, 1929).

‡*Mineral Resources of United States*.

||American consul at Habana.

## ASPHALT MINES

*Santa Eloisa*.—This mine is 8 miles east of Santa Clara. The asphalt occurs as a northwest-striking vertical vein in serpentine. It averages 10 feet in thickness, has been exploited to a depth of 130 feet and drifted 325 feet without defining the limits of the deposit. The asphalt is brilliant to lusterless. It has a strong petroleum odor and melts easily. More than 500 tons have been mined, most of which was used as a gas enricher in Santa Clara. The mine was abandoned and flooded. There are several other similar, but undeveloped, deposits in the vicinity.

*La Esperanza*.—This asphalt deposit is 5 miles southwest of Placetas, Santa Clara Province. The country rock is serpentine. The main deposit occupies a fissure which extends N. 60° W. and dips 80° S. The mine is being operated by the Mariel Asphalt Company, and its manager, Sr. Guillermo Prieto, states that the main shaft is 308 feet deep and



that the 260-foot level has been drifted more than 2,000 feet. The average width of the vein at this depth is 25 feet. No attempt has been made to measure the reserve. The asphalt is a high grade grahamite averaging 98 per cent pure. Enough gas is present in the workings to require the use of safety lamps. During the early part of 1931, 300 tons per month were shipped to the United States for the paint and varnish industry.

*Chambas.*—This mine is in the northern portion of Santa Clara Province, near the eastern boundary. The deposit occurs in serpentine about 650 feet south of its contact with limestone of Cretaceous (?) age which has been metamorphosed by the intrusion (?). There are several veins of asphalt in this vicinity. The one which is being mined strikes N. 30° E. and the workings have proved the deposit to be at least 1,000 feet long and 560 feet deep, with an average width of 4 feet. About 30 tons per day were being mined in 1931 and it is estimated that 5,000 tons have been mined to date. A 40,000-ton reserve is proved. The material is brilliant grahamite which has a strong petroleum odor. Maltha oozes from the walls of the workings in appreciable quantities. This description is taken from Boletín de Minas, No. 13.

*Madruga see page.*—A typical example of the occurrence of petroleum in serpentine is located a short distance north of Madruga in the eastern portion of Habana Province. The serpentine plug is approximately 2 miles long from east to west and  $\frac{1}{4}$  mile wide. This intrusion lies slightly north of the axis of the Madruga-Guines-Bejucal anticline. Miocene rocks crop out north of the intrusion and Cretaceous rocks south of it. The Central Highway cuts an excellent section through the south flank of the anticline.

Within the serpentine there are many outcropping fragments of dark blue metamorphosed limestone saturated with petroleum. It is stated that light oil seeped out of the serpentine during the excavation for the highway. Within the serpentine area at a point  $\frac{1}{2}$  mile east of the town a pit dug in black limestone is partly filled with maltha. The limestone is probably of Jurassic (possibly Cretaceous) age and appears to have been carried upward from a great depth by the serpentine.

A short distance east of Madruga a well was drilled on the axis of the Madruga anticline to a depth of 2,400 feet and, according to reports, had showings of oil and gas in the Upper Cretaceous. However, it did not reach the depths at which the Cretaceous basal conglomerates and sands could reasonably be expected.

*Mariel.*—Six miles south of the port of Mariel, in Pinar del Rio Province, there is a group of six gilsonite veins. These trend approx-

imately N. 70° E. and incline slightly north. They cut Cretaceous shales, sands, and limestones. Much of the region is soil-covered and in cultivation and there are not sufficient exposures to determine the areal geology in a hurried reconnaissance. The outcrops of most of these veins have been quarried and in the case of the largest, a shaft was sunk to 400 feet and drifts and stopes developed at each 100-foot level. These workings have proved the deposits to be more than 1,400 feet long and from 10 to 70 feet wide. Core drilling has outlined the deposit to a depth of 800 feet and a length of more than 4,000 feet without defining its limits.

The east parts of the workings are said to have encountered coarse limestone conglomerates. As far as the writer is aware, there are no igneous rocks closely associated with the veins; however, there is a small serpentine plug approximately 1 mile northeast of the mine and it is not improbable that other small intrusions are present in the soil-covered areas near by. The mine was closed at the time of the writer's visit in 1931 because of a fatal gas explosion. At that time the mine superintendent stated that soft asphalt, together with a small quantity of inflammable gas, exuded from the walls of the lower levels. He also stated that between 250,000 and 450,000 tons had been mined prior to December, 1930, and that a reserve of between 3,000,000 and 6,000,000 tons was estimated. The official report<sup>1</sup> states that 200,000 tons have been mined and that 2,400,000 tons are in reserve. These mines are owned by the Oil Trust, Ltd., London.

<sup>1</sup>*Republica de Cuba Boletín de Minas* 13 (1929), pp. 67-68.