Petroleum Industry of Trinidad

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Trinidad, British West Indies, is an island near the north coast of South America, situated between latitudes 10° and 11° N., and opposite the numerous outlets of the Orinoco River Delta. It is separated from Venezuela by the Gulf of Paria (salt water) and straits over 5 mi. (8 km.) wide. The area of the island is approximately 1750 sq. mi. (453,-250 hectares) and the population is approximately 400,000. The climate is tropical with an annual rainfall of from 45 to 60 in. (114 to 152 cm.).

The oil fields consist of several units, or fields, located in the southern half of the island. Approximately 90 per cent. of the total production has been yielded by fields situated within 7 mi. (11.3 km.) of the famous asphalt lake and on the southwest peninsula.

The most important producing fields, or units, are the following, which are shown on the accompanying map:

Brighton, or Pitch Lake Field, operated by the Trinidad Lake Petroleum Co., Ltd., is situated beside the famous Pitch Lake; it even encroaches on the lake.

Vessigny Field, operated by the Trinidad Lake Petroleum Co., Ltd., is situated 2 mi. (3.2 km.) south of Pitch Lake.

Lot One Field, operated by the Petroleum Development Co., Ltd., the United British Oilfields of Trinidad, Ltd., and Stollmeyer, Ltd., is situated 3 mi. south of Pitch Lake upon Lot One of Morne l'Enfer Forest Reserve and adjoining properties.

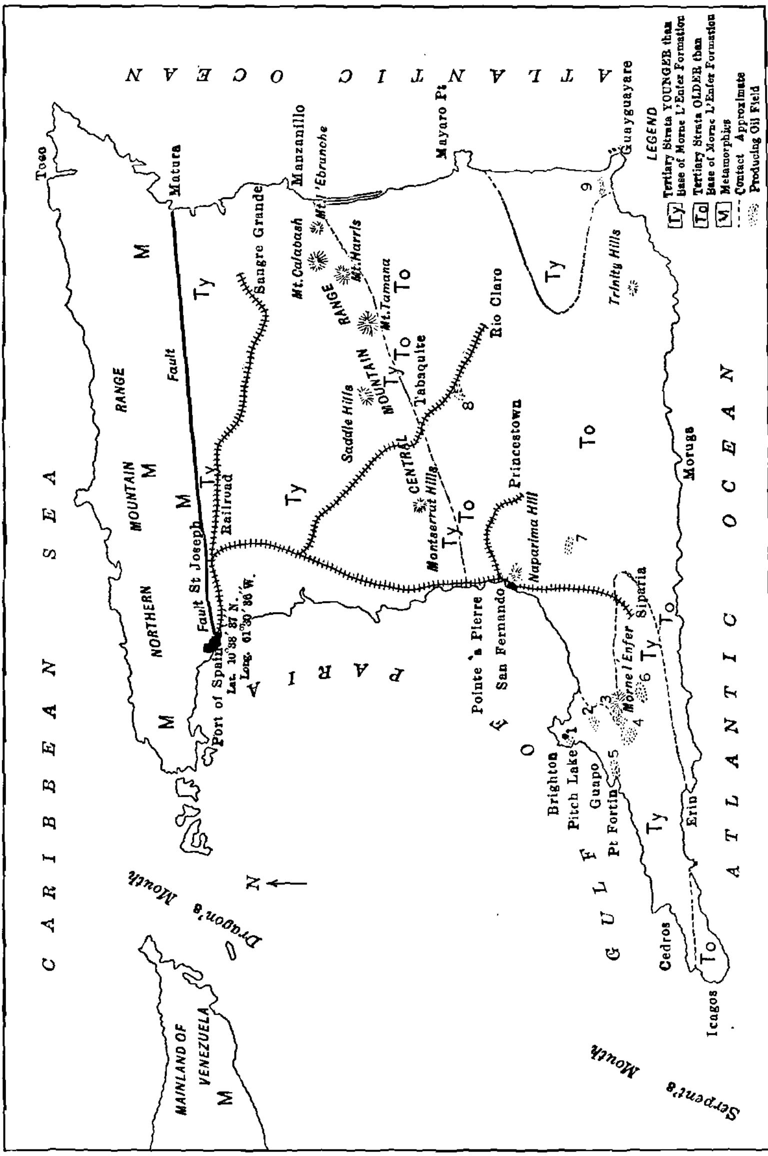
Parry Lands Field, operated by the United British Oilfields of Trinidad, Ltd., and the Petroleum Development Co., Ltd., is situated 3½ mi. south of Pitch Lake on Lot Three of Morne l'Enfer Forest Reserve and adjoining properties.

Point Fortin Field, operated by the United British Oilfields of Trinidad, Ltd., is situated at Point Fortin, 6 mi. southwest of Pitch Lake.

Fyzabad Field, operated by Trinidad Leaseholds, Ltd., is situated several miles southwest of Fyzabad Village and 6 mi. south-southeast of Pitch Lake.

Barracpore Field, operated by Trinidad Leaseholds, Ltd., is situated several miles south of San Fernando and 15 mi. (24.14 km.) east of Pitch Lake.

Tabaquite Field, operated by Trinidad Central Oilfields, Ltd., is situated 4 mi. southeast of Tabaquite Railroad Station, and 30 mi. (48.28 km.) northeast of Pitch Lake.



MAP OF TRINIDAD, SHOWING LOCATIONS OF OIL FIELDS AND APPROXIMATE DISTRIBUTION OF GEOGLOICAL FORMATIONS

1. Brighton Field
2. Vessigny Field
3. Lot One Field
4. Parry Lands Field
5. Point Fortin Field
6. Fyzabad Field
7. Barracpore Field
8. Tabaquite Field
9. Guayaguayare Field

Guayaguayare Field, operated by Trinidad Leaseholds, Ltd., is situated in the extreme southeast corner of the island 45 mi. (72.42 km.) from Pitch Lake.

From 1870 to 1900, several attempts were made to obtain oil on Trinidad but although small quantities of oil were encountered, no commercial production resulted, and most of the wells were abandoned. An attempt was also made to obtain oil from the crude lake asphalt, probably by a cracking process, but without commercial success.

The present industry can be said to commence with wells drilled since 1900 near Guayaguayare, in the extreme southeast corner of the Island. Several years later wells were drilled near Point Fortin, southwest of Pitch Lake, which yielded commercial quantities of oil but not sufficient for export.

In 1908, the New Trinidad Lake Asphalt Co., Ltd., commenced drilling at the Pitch Lake and encountered an excellent flow of oil in its second well. Other wells were drilled and, in 1910, this company exported the first steamship cargo of oil from Trinidad. Since then, the quantity of oil produced and the number of companies exporting has increased. The production in 1908 was 169 bbl., in 1912, 436,805 bbl.; and in 1917, 1,599,455 bbl.

Geology

Stratigraphy

All petroleum produced by Trinidad has been yielded by strata of Tertiary age. In general, the Tertiary strata consist of clays, shales, marls, and sandstones; conglomerate is extremely rare and limestone is uncommon. The sandstone is usually composed of small quartz grains uniformly sorted. Cretaceous and metamorphic rocks underlie the Tertiary. The most important portion of the Tertiary strata consists of sandstone and shale, which grades upward into marl and shale containing marine organic material and evidences of petroleum. The organic material in this shale is probably the primary, or "mother," source from which Trinidad petroleum is derived. The upper portion of the shale contains sandy strata into which petroleum has migrated and accumulated in quantities sufficient for commercial exploitation. Eocene fossils occur in the lower part, but the upper part may extend into the Oligocene. This includes the Naparima clay, Cruse oil zone, and Stollmeyer oil zone.

The Morne l'Enfer formation unconformably overlies the above-mentioned, and consists of sandstone and clay shale in approximately equal proportions. The lower sandstones are often heavily impregnated with asphalt and often outcrop as "pitch sand" cliffs. The author believes that this asphalt has migrated from the underlying shales and marls. Near Pitch Lake, some oil may be produced from this formation. Strata younger than the Morne l'Enfer have not yielded commercial quantities of oil and are unimportant.

The accompanying tabulation describes the geological formations of

Trinidad in more detail. The areal distribution of the formations is shown approximately on the map.

Structure

The areal geology of the island is separated into two parts by the great east-west fault passing near Port of Spain and Matura, and extending from the Atlantic Ocean into Venezuela. North of the fault is the area of Metamorphics, forming the Northern Mountain Range. South of the fault is a great undulating blanket of Tertiary strata.

The dominating features of the Tertiary structure are: A synclinal or monoclinal trough between the Central and Northern Mountain Ranges; an anticlinal uplift along the south side of the Central Range striking east-northeast by west-southwest, from Pointe à Pierre to Nariva Swamp; an undulating synclinal structure between San Fernando, Mayoro Point, Guayaguayare Bay, and Icacos Point with an east-west strike; the magnitude of erosion at the unconformity below the Morne l'Enfer formation. Numerous local folds, faults, kinks, anticlines, and synclines modify the broader features and are very important in the concentration of petroleum.

Occurrence of Petroleum

All the producing oil fields of Trinidad (except Tabaquite Field) are within or on the flanks of the great synclinal trough or basin of the southern part of Trinidad. Most of them are on the southwest peninsula. This undulating synclinal structure is underlain by Naparima clays, marls, and organic shales. It forms the drainage area from which petroleum has accumulated. This petroleum has concentrated in commercial quantities near anticlinal folds.

The location and richness of each productive area are modified by the magnitude and condition of the unconformity below the Morne l'Enfer formation; by the channels of migration; by the local conditions of porosity of reservoir sands; by the lenticular condition of the oil sands; by the facility with which connate salt waters were displaced by oil. There are three principal horizons in which petroleum usually, but not always, is concentrated in commercial quantities.

The Cruse oil zone is persistent because its proximity to the organic shales permits ready saturation, has permitted much time for connate waters to be forced out, and Tertiary erosion has not attacked it as frequently as higher strata. Its thinness and high gas pressure increase operating cost. This condition applies at Parry Lands, Morne l'Enfer Forest Reserve, and Point Fortin.

The Stollmeyer oil zone overlies the organic shales and the sands are lenticular. The porosity and saturation of the oil sand varies locally.

It may or may not, locally, be conformable below the Morne l'Enfer formation or it may be entirely missing. Where apparently conformable below the Morne l'Enfer formation, conditions are simple and anticlinal structures may prove very rich, as in the Morne l'Enfer Forest Reserve. As the unconformity increases, modifications occur. Part of the Stollmeyer sand may have been removed by erosion and the remainder sealed by the clayey base of the Morne l'Enfer formation. One flank of an anticline may prove richer due to better drainage area on that side, as may be the case at Lot One. A flank of the anticline may be enriched but the apex barren because the sand is missing; such may be the case at Point Fortin, Barracpore, and possibly at Brighton. Connate salt water has not been completely forced out of all the sand lenses but usually remains only in the lowest lenses.

The Morne l'Enfer formation is enriched by oil migrating from the underlying organic shales. Where the organic shales lie close below as a result of Tertiary erosion and the Morne l'Enfer sands are not too thick or too clayey at the base, saturation may be sufficient for commercial production; such may be the condition in fields near Pitch Lake. Where the sand is too thick and petroleum has migrated slowly, saturation may not be sufficient for commercial production; such may be the condition of pitch sands in the Forest Reserve.

Near Tabaquite, petroleum has concentrated in sands closely associated with organic shales but too distant from other fields for correlation.

Technology

Drilling

The rotary system of drilling has proved most successful in the productive fields. Cable tools are usually confined to some, but not all, isolated test wells, to special work, and to repairing damaged wells; but in the early days many wells were drilled and finished with them. Portable drilling machines have been successful for shallow wells in the central and extreme southern portions of Trinidad. Some wells have been drilled with Canadian and Galacian outfits.

Some difficulty is encountered in penetrating pitch strata. If sandy, they are hard and wear off rotary bits. If clayey, they are plastic and squeeze slowly but persistently into the hole and grip the drill pipe above the bit; this has been overcome by using hot water circulation and driving casing through the pitch.

For wells expected to be over 1000 ft. (305 m.) deep, it is common practice to drill with rotary and set 15½ in. 70-lb., 13-in. 54-lb., or 12½-in. 50-lb. screw casing as the outside string. Either this or the succeeding one is used to shut off water preferably, but not always, by cementing. Wells are usually drilled into the oil sand using 6-in. (15.24-cm.) or 8-in.

perforated drill pipe equipped with a blow-out preventer on an outer string. With all in readiness to receive a big flow of oil, drilling proceeds until the oil sand is drilled through or the flow of oil and gas prevents farther progress. Then the drill pipe is left as it is and the wash pipe recovered when convenient. In shallow fields, a common practice is to set about 100 ft. (30.5 m.) of 12½-in. (31.75-cm.) casing as a conductor and then to drill through the oil zone. Perforated casing is substituted for drill pipe and the well tubed to pump or flow as the case may be.

Casing is not perforated in the well if it can be avoided; the usual practice is to set shop perforated casing. Screen casing has not been successful because of clogging with clay. Explosives are never used to increase production and rarely to break up junk.

For a well 1500 ft. (457.2 m.) deep, 60 days is a fair average time from first actual drilling until production begins. This includes usual delays, casing setting, changing crews, waiting, etc. The actual number of days in which hole is dug may be as low as fourteen. In 1918, $15,000 was a fair average cost to the depth of 1500 feet.

Production

Wells in the thin deep sands usually begin production with a large initial flow or gust under great gas pressure, yielding up to 100,000 bbl. in the first few days and later choking with sand or shale. During the first year, the production is dependent largely on spasmodic flows aided by bailing or tubing agitation, but after the first year few wells yield over 100 bbl. daily. The shallower wells with thicker oil sands begin production sometimes as pumpers and sometimes by flowing. The initial flow averages much less than for the deeper wells, but is less spasmodic and less costly to control. Few wells flow for over a year.

After wells cease flowing they are usually pumped by the walking beam. Sand and mud must be cleaned out frequently for two years or more. None of the southwest fields have been successful in pumping from a central power or jack. Few wells have produced over eight years and many cease producing in the second or third year. The production of individual wells is greatly influenced by the local porosity of the oil sand and the size of individual oil-sand lenses.

Character of Petroleum

Trinidad petroleum varies greatly in specific gravity, not only in different fields, but also within the same field. It is (with one exception) of asphaltic base. Oil from the Trinidad Central Oil Fields, Ltd., near Tabaquite has little asphalt but some paraffine, and yields much gasoline and kerosene by distillation. The average specific gravities for

Geologic Column of Trinidad

Age	Name of Formation	Thickness, Feet	Lithology Petroleum Evidence Folding	Miscellaneous Remarks
Recent	Alluvium	40	Principally soft clay, silt, vegetable remains. Less sand. Rarely conglomeritic. Asphalt cones and seepages and mud volcanoes occur by breaking through from underlying formations. Never tilted.	Consists of stream alluvium and swamp deposits.
			Unconformity	
Pleistocene (?)	Llanos Formation	100	Ferruginous sands, clays and conglomerates. Evidences of asphalt occur by breaking through from underlying formations. Usually nearly flat; rarely tilted to 5°.	The Llanos formation consists of material deposited in the basin of which the present Orinoco Valley was a portion. Large areas occur in Venezuela, particularly in the Llanos, or plains, of the Orinoco River Valley, but in Trinidad where the formation appears thinner, erosion has dissected it until only hill-top remnants and a few larger areas remain. When seen from the Gulf of Paria, the topography of southern Trinidad has the appearance of a former flat surface, such as a sea bottom, uplifted to a plateau 100 to 300 ft. above sea level through which "islands" or peaks of older resistant rocks project. (Erin Peak, Morne l'Enfer, Soldado Rock, Naparima Hill for example.) The present drainage system has dissected this plateau into a low, but steep topography gentler than canyon topography.
			Unconformity	
Pliocene (?)	Upper Tertiary Formation	400	Porcellanite, lignitic clay, lignite, partly altered wood, shale, clay, and sandstone exhibiting great lateral variation in character. Conglomerates not known. Rarely contains asphalt and has no commercial oil horizons. Usually found tilted but rarely over 35°.	Usually occurs within synclines flanked by the l'Enfer formation. It may be of fresh-water origin of material derived from the older tertiary rocks. In troughs, or synclines, deposition may have been uninterrupted between this and the Llanos formation. This formation corresponds to the upper tertiary strata in reports of E. H. Cunningham-Craig. Porcellanite has not been proved to exist in other formation in Trinidad.
			Unconformity (locally)	
Oligocene (?) or Miocene? or both	Morne l'Enfer Formation	2500	Sandstones of uniform small quartz grains separated by bands of clay shale and rarely by lignite. No conglomerate known. The lowest sands are commonly saturated with asphalt. Near Morne l'Enfer 300 ft. of "tar sand" has been observed in the lowest 700 ft., some of which was very rich. Some of the oil fields nearest the Pitch Lake may derive production from sands of this formation. Tilting is commonly over 20° but rarely as much as 90°.	The following thicknesses have been measured: 2500 ft. at Erin Bay, 1200 ft. at Guapo Bay, 900 ft. at Vessigny Bay, 800 ft. at Morne l'Enfer. Fossils of doubtful Oligocene age have been found near this formation. In the Central Range mountains, Miocene fossils occur in what may be the equivalent formation. Because of the great unconformity below this formation, the author prefers to regard it as Miocene. The name of this formation is selected because of its occurrence in the Morne l'Enfer Forest Reserve.
Eocene or Oligocene	Forest Clay	500	Blue and gray clay often very sticky.	This forms the impervious cover over the Stollmeyer oil zone. The author is convinced that there is a great unconformity below the Morne l'Enfer formation, but owing to the clayey non-resistant nature of the

Age	Name of Formation	Thickness Feet	Lithology Petroleum Evidence Folding	Miscellaneous Remarks
Eocene or Oligocene	Forest Clay			strata the exact horizon is difficult to identify. It probably occurs in these clays, below the lowest Morne l'Enfer sand. This condition was observed by the author on a much smaller scale at a small island which rose overnight from the sea near Trinidad in 1911. A few weeks later waves had eroded it completely and deposited tne material on similar adjacent clayey material.
			Unconformity	
Eocene or Oligocene	Stollmeyer Oil Zone	500	Overlapping pancake-shaped lenses of sand and shale alternating. The sands contain oil and salt water, the best saturation of oil being in the upper part of tne zone and not far from an anticlinal axis. Salt water is usually confined to the lower lenses, but has been found at the top of the zone.	This is the most profitable oil formation on Trinidad. It is difficult to correlate individual lenses from well to well but the group or zone can easily be traced through a field.
Eocene or Oligocene	Stollmeyer Cruse Shale	600	Principally clay shales with occasional lenses of sand. Foraminifera occur in the lower part of these shales. Some of the sand lenses are highly saturated with petroleum and gas under great pressure. Lenses occasionally contain salt water.	Several oil wells yield production from restricted sand lenses in this formation.
Eocene or Oligocene	Cruse Oil Zone	40	Sand. Often saturated with petroleum and gas under great pressure. Salt water may occur.	This is the most persistent oil horizon on Trinidad, but its thinness, depth, and violent gas pressure increases the cost of exploitation. It is identified over a large area in the northern portion of the Morne l'Enfer Forest Reserve where it occurs 1000 to 1200 ft. below the top of the Stollmeyer oil zone. Many of the gas-mud volcanoes of Trinidad may occur near the outcrops of this horizon.
Eocene or Oligocene	Naparima Clay	4000	Clay, shale, and marl containing marine organic matter. Outcrops often with a perceptible odor of kerosene and where an irridescent film of oil covers pools of water. Manjak veins occur near San Fernando. Commonly tilted to vertical with abrupt changes and overturns.	Large areas outcrop near San Fernando. Folding is so complex and abrupt that it is difficult to obtain a reliable measurement of thickness. This formation may be the "mother rock" from which the petroleum of Trinidad is derived. Some of the light oil from Trinidad may come from wells in this formation.
Eocene			Clay and shale and hard gritty sandstone.	Eocene fossils occur in or below the Naparima clay The author has not made extensive studies of the Tertiary strata below the Naparima clay.
			Unconformity	
Cretaceous			Dark, black or brown shale and limestone.	Cretaceous strata have been reported in limited areas in the Central Range of Trinidad and doubtfully farther south. Large mountainous areas of Cretaceous occur in Venezuela.
			Unconformity	
Pre-Cretaceous	Metamorphics		Schist, gniess (Pre-Cretaceous volcanics near Toco).	The Northern Range of Trinidad consists of a metamorphosed complex bounded on the south by an east-west fault passing near Port of Spain and Natura Bay, and extending into the Atlantic Ocean and Venezuela.

different fields are: 0.9524, 0.9722, 0.9589, 0.9459, 0.9333, 0.9211, and 0.8092; or, 17°, 14°, 16°, 18°, 20°, 22°, and 43° Baumé,.

Transportation and Utilization

The Trinidad Lake Petroleum Co., Ltd., and the Petroleum Development Co., Ltd., together operate a 6-mi. (9.66 km.) pipe line from the Morne l'Enfer Forest Reserve to a tank farm at Brighton near Pitch Lake beginning as 4 in. (10.16 cm.) and increasing to 10 in. (25.4 cm.). At Brighton pier are facilities for docking and loading steamers up to 35,000 bbl. in 24 hr. Much of this oil has been exported to the United States for industries using asphalt and its products.

The Trinidad Leaseholds, Ltd., operates approximately 28 mi. (45 km.) of 6-in. (15.24 cm.) pipe line from the Morne l'Enfer Forest Reserve to Pointe à Pierre, with a short side branch from Barracpore. At Pointe à Pierre is a tank farm and pipe trestles to a loading station 1 mi. (1.6 km.) from shore where full-size tank steamers can be loaded. Most of this oil has been taken by the British Admiralty, although considerable has been disposed of as bunker fuel to steamships and some has been refined at Pointe à Pierre.

The United British Oilfields of Trinidad, Ltd., operates a 6-in. (15.24 cm.) pipe line 6 mi. (9.66 km.) in length from the Morne l'Enfer Forest Reserve to Point Fortin, with an additional branch contemplated. At Point Fortin, oil is loaded in barges and towed to tankers anchored in the Gulf of Paria. Loading a tanker requires several days. A refinery at Point Fortin produces "navy fuel." Most of this oil has been taken by the British Admiralty, but some of it has been disposed of as bunker fuel oil to steamships and some early shipments went to various places.

The Trinidad Central Oilfields, Ltd., operates a 3-in. (7.62 cm.) pipe line from the Tabaquite oil field to a loading pier at Claxtons Bay. This oil is very high in gasoline and is nearly all refined for petrol, kerosene, and fuel residue.

Stollmeyer, Ltd., operates a 2-in. pipe line 2 mi. (3.22 km.) in length from near the Morne l'Enfer Forest Reserve to Guapo Bay where sail lighters can be loaded.

Future Possibilities

The future of the petroleum industry of Trinidad depends on the discovery of new oil fields or units as much as on complete exploitation of the known fields. The most obvious oil fields are already in exploitation. The writer is confident that a thorough search will result in the discovery of other oil fields which will compare favorably with the known fields.

The discovery of new oil fields necessitates the drilling of isolated test wells of which most will be barren. Exploratory drilling should be guided by a thorough geological study of a broad area with special attention to: The magnitude and trend of the unconformity below the Morne l'Enfer formation, character of strata below this unconformity, and geologic folding. Such geological study will reduce the number of barren wells, which is the greatest expense of exploration. In the known fields a continuous drilling program will be necessary to maintain the production with declining wells.

DISCUSSION

Ralph Arnold, Los Angeles, Calif.—The Trinidad field has been the graveyard of the reputation of many drillers and production men. Apparently the effort to hold back this clay and sand by the use of strainers is unsuccessful because the well will gradually plug up to such a point that every known method will fail to loosen the pores and allow the oil to come in. As wells put down near old producers will show large initial production, the ultimate yield of oil will be increased by putting down secondary wells.

In one field, a perfect dome, the sand is in lenticular form. At first the wells showed considerable water but now the oil pumped is free from water.

E. DeGolyer, New York, N. Y.—I have understood that the chief difficulty in Trinidad operations was to find any strainer that would hold back the sand, which is of uniformly fine grain. The ordinary sand is composed of grains of assorted sizes. The strainer lets the fine sand pass through and holds a sponge of the larger grains outside so that after a well starts producing, this coat of larger grains on the outside does as much straining as the strainer itself.

R. Van A. Mills, Washington, D. C.—It seems probable that several factors enter into the sanding up of wells. Underground changes in the gravities and viscosities of the oils incident to the operation of wells may play a part in this trouble. In California there are instances of the Baumé gravities of oils issuing from wells in new fields undergoing reductions of 7° in the first months of production. Under these conditions the deposition of residual matter from the oils would influence the sanding up of the wells.

A more important point is the deposition of inorganic matter (mineral salts) together with silt in the sands. This induced effect is accomplished through the agency of the waters accompanying the oils—concentration and chemical reactions being responsible for the deposition of the salts.

Water interferes with the movements of the oils to the wells especially where the oils are of high viscosity. The shutting off of the oils through the agency of waters is probably the worst of these underground troubles with which we have to deal. I believe that by reducing the rapid flows of oil and gas we can largely eliminate these troubles.

R. A. Conkling,* St. Louis, Mo.—Mr. Macready has not made any mention of the Tabagie field, which has a very light oil, 35° to 40°, that comes from Cretaceous and other sands much higher in the Tertiary.

Ralph Arnold.—In the principal producing area, there is enormous production during the first three or four days and very light production thereafter. Many of the wells have given as high as 15,000 to 20,000 bbl. per 24 hr. for the first three or four days, and but a mediocre production after that.

Arthur Knapp, Shreveport, La.—One other place where the same thing occurs is Louisiana. The trouble is not sand but squeezing clay. The clays in Trinidad are contaminated with oil and pass through the perforated casing. It is useless to place a screen for the clay squeezes through and appears in the overflow in the form of paper-thin sheets.

E. DeGolyer.—I have wondered if sanding-up is not often a case of the pinching together of top and bottom clays rather than any blocking of the well sand or something of that sort. These wells, when they come in as gushers, produce large amounts of sand, so that if all the sand is blown out, there is nothing to hold up the overlying clay or mud. There must be some considerable tendency for them to close together and, where the sand had been imperfectly exhausted, a small production would continue.

Ralph Arnold.—We operated on that theory at one time and tried to control the flow of the wells at the start, and by holding back the sand allowed the production to be slower, but I think the records show that the wells that ran wild at the start gave the greatest ultimate production.

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