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GEOLOGICAL SURVEY

# THE PETROLEUM GEOLOGY OF TRINIDAD AND TOBAGO

By Philip R. Woodside

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## FOREWORD

This study of the Petroleum geology of Trinidad and Tobago is one of a series of studies under the Foreign Energy Supply Assessment Program prepared for the Department of Energy.

# PETROLEUM GEOLOGY OF TRINIDAD AND TOBAGO

by

Philip R. Woodside

Abstract

Oil and gas production in Trinidad and Tobago has been obtained from reservoirs ranging in age from Cretaceous (a very nominal amount) to possible Pleistocene; the latter has been from sandstone reservoirs in the offshore area east and south of Trinidad. Essentially all hydrocarbon production in Trinidad and Tobago is from Miocene and younger sediments.

Structurally, Trinidad is an eastward extension of eastern Venezuela and a part of the Caribbean geosynclinal island-arc system. The gross structural and stratigraphic units of Trinidad and Tobago can be catalogued into five morphologic units that are from north to south:

1. The Northern Range
2. The Northern (Caroni) Basin
3. The Central Range
4. The Southern Basin (including Naparima Thrust Belt)
5. The Southern Range

The Margarita-Tobago trough, the offshore area north of Trinidad, is a sixth morphologic unit. The offshore area east and south of Trinidad can be considered a seventh stratigraphic and structural unit. The Los Bajos fault is a right-lateral strike-slip (wrench) fault with a displacement of at least 6.51 miles on the north side. This fault has been mapped from the North Soldado-North Marine Fields in the Gulf of Paria to Point Ligoure on the west coast through Point Negra on the south coast. Its extension south-eastward into the Atlantic Ocean is not traced with certainty.

The oil fields in Trinidad are on a trend that parallels those oil fields along the mobile northern rim of the eastern Venezuelan Basin. Sedimentation in both areas was strongly influenced by intermittant tectonic activity throughout most of Hauterivian, Albian-Upper Cenomanian and Campanian times as well as Tertiary times. At least four major unconformities are recognized within the Cretaceous sequence of formations, part of which has been subject to low-grade metamorphism. The Paleocene deposits are mostly calcareous claystone-shale and marl. The Late Eocene unconformity is overlain by transgressive Oligocene-Miocene calcareous claystones with a minimum of sandstone development in the lower sections. However, the sand content increases in the upper part of the section. These claystones, shales, siltstones and sandstones grade into an overlying claystone which is void of any sandstone development. The succeeding Pliocene is marked by three depositional cycles each of which increases in sandstone content towards the end of each cycle. The last cycle is predominantly continental. A distinctive sandstone-siltstone Pliocene facies occurs in the southeast and in the adjacent offshore area.

Over 90 percent of the cumulative oil production has come from the lenticular and deltaic sandstones of the Pliocene Forest and Cruse Formations and the Moruga Group.

# INTRODUCTION

Petroleum activity in Trinidad began in 1866 when the first wells were drilled near the oil seeps at Pitch Lake in southwest Trinidad. From 1860 to 1865 kerosene was distilled from the pitch at Pitch Lake. In 1903, a rotary rig was first used in Trinidad to drill the Guayaguayare No. 3 well. Not until 1908 was the first commercial well drilled at the western edge of Pitch Lake (near Brighton). This was followed by oil discoveries in the Point Fortin-Parrylands area. In 1911, the Tabaquite Field was discovered. This remains the most northerly onshore commercial field discovered in Trinidad. The Forest Reserve Field was discovered in 1914. The first major discovery of the Middle Miocene, Herrera sandstone member (Upper Cipero Formation) which resulted in oil production was in 1941 in the Penal Field. In 1954, the first Trinidadian marine well was completed in the Gulf of Paria at Soldado (figure 1). The first commercial discovery was completed in 1963 off the southeast coast.

The period 1912-1920 was the boom period for Trinidadian oil development, and activity again peaked from 1937 to 1942 and again in the late 1950's. Finally, in 1972, offshore east-coast production went on stream. Over 11,335 wells have been drilled cumulatively in Trinidad and Tobago; the data from these wells have contributed to a detailed understanding of the petroleum geology over most of the country.

Oil and gas production in Trinidad and Tobago has been obtained from reservoirs ranging in age from Cretaceous (a nominal amount) to possible Pleistocene, the latter has been from sandstone reservoirs in the offshore area east and south of Trinidad. Trinidad and Tobago's 1980 annual production rate was 78.4 million barrels of oil (b/o).

The offshore area has seen no significant oil and gas discoveries since the Teak (1968), Samaan (1971), and Poui (1972) Fields (figure 1); however many promising offshore structures have yet to be drilled. For example, recent drilling has revealed the following results: a 12,625-foot test in the Samaan Field tested three zones with a combined flow rate of 5 million cubic feet per day (cf/d) of natural gas, 509 barrels per day (b/d) of condensate and 2,074 barrels of water per day from Pliocene sands. The Poui No. 2 well cored 332 feet of oil sand but was abandoned at a subsea depth of 7,566 feet because of mechanical problems. The Galeota Field is currently producing oil at the rate of 400 to 3,250 b/d per well from the Pliocene Gros Morne and St. Hilaire sands at subsea depths from 450 to 4,500 feet. The rates at the Galeota No. 3 well 11 miles off the east coast and 4 miles away from Galeota No. 2 on a separate fault block were tested as follows (Quarterly Economic Review of Oil in Latin America and the Caribbean, Nov. 2, 1980):

| Depth Interval (subsea) | Oil | Gas |
|---|---|---|
| 4,818 ft. | 1,772 b/d | 687 Mcfgd |
| 4,668 ft. | 500 b/d | 194 Mcfgd |
| 4,682 ft. | 40 b/d | 12 MMgfgd |

The offshore Teak, Poui, and Samaan Fields alone are believed to have ultimate recoverable reserves of oil in excess of 500 million b/o (William Dietzman, DOE, Dallas). Notwithstanding the possibilities of new production in the offshore area, the government of Trinidad and Tobago issued a report in early 1979 stating that AMOCO'S fields off the east coast will peak at around 128,000 b/d in 1979 and decline to 75,900 b/d by 1983 (Quarterly Economic Review of oil in Latin America and the Caribbean, 2nd Quarter, 1979).

Likewise, the offshore area north of Trinidad and west of the island of Tobago has promise of being a gas-producing province. Only 12 wells have been drilled, two of which tested commercial quantities of nonassociated gas and one of which tested 37.5 million cf/d of gas. Further development of this area has been delayed pending resolution of sovereignty rights of this offshore area between Trinidad and Tobago, Grenada, Barbados, St. Vincent and St. Lucia. Presently this inter-arc basin is considered a high-risk area because of insufficient information as to stratigraphic objectives, size of expected fields, and the low quality of exploration information.

# STRUCTURAL GEOLOGY

## Introduction

Structurally, Trinidad is an eastward extension of eastern Venezuela and a part of the Caribbean geosynclinal island-arc system. The structural configuration of Trinidad is the result of several periods of orogenic activity over geologic time. This activity has resulted in a combination of parallel Andean en-echelon thrust and fold belts, diapiric and disharmonic deformation cut by numerous faults that make the structural interpretation complicated. The Permian to Triassic Dragon Gneiss Formation is the earliest rock known in Trinidad (Kugler, 1979).

A negative gravity anomaly trends west-southwestward into Venezuela (figures 2 and 3). The axis of this gravity minimum corresponds to the geosynclinal axis. This gravity minimum also approximates the main geosynclinal axis of southern Trinidad.

The east-west mountain range system in north Trinidad is part of the Caribbean arc-system which includes the Parras, the Greater Antilles Coastal Cordilleras, and the Cochabamba Ranges. This deflection, as indicated by this mountain range system being deflected to the northeast, created an accumulation of stresses which found a release in the creation of the Naparima thrust belt, the diapir ridges, and subsequently the Los Bajos wrench fault and associated faults. Geologically, the Northern Basin and the Central Range form one structural unit equivalent to the Serrania del Interior of Venezuela.

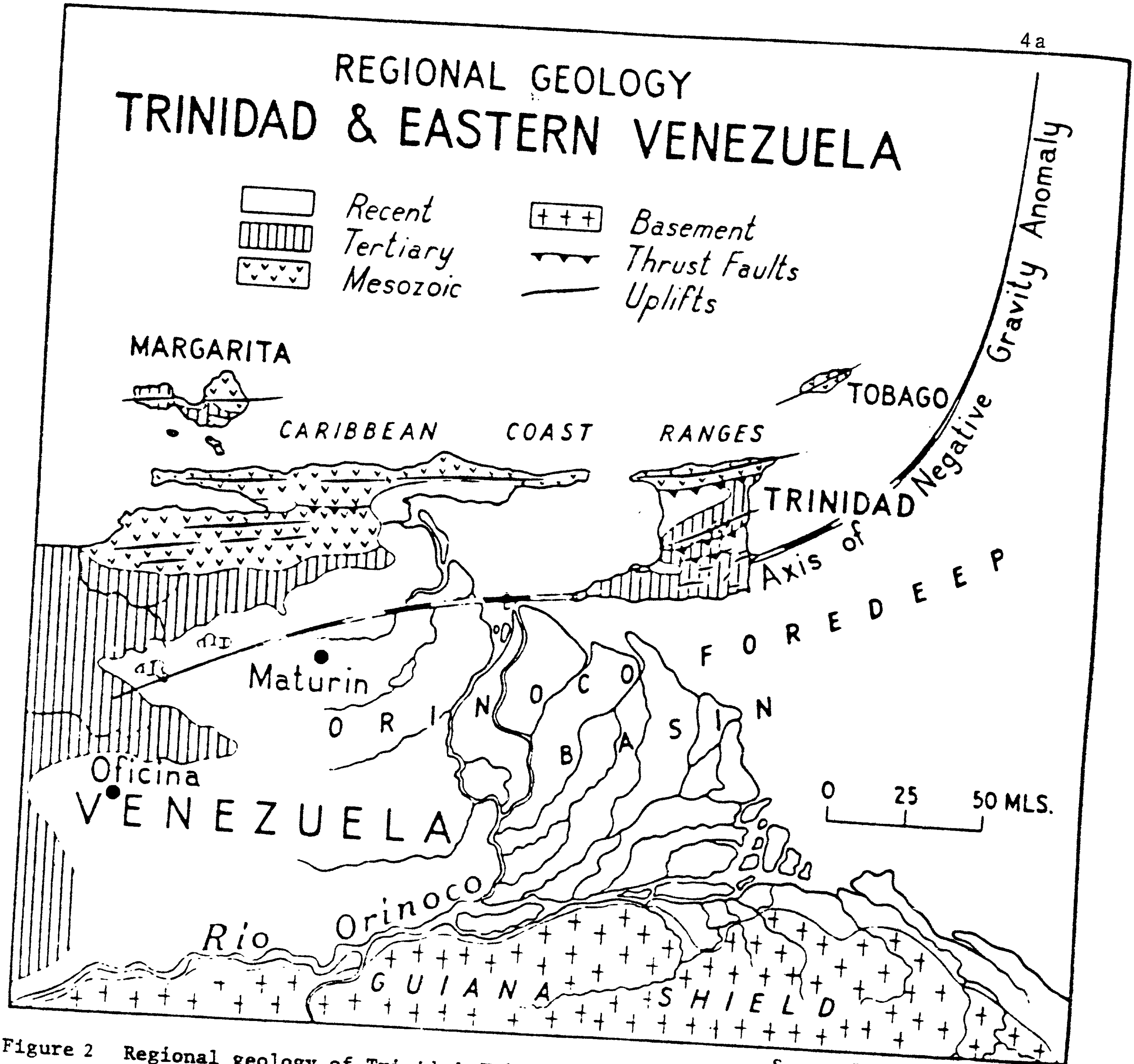



Figure 2 Regional geology of Trinidad, Tobago and Eastern Venezuela.

Source: Barr, and others, 1958

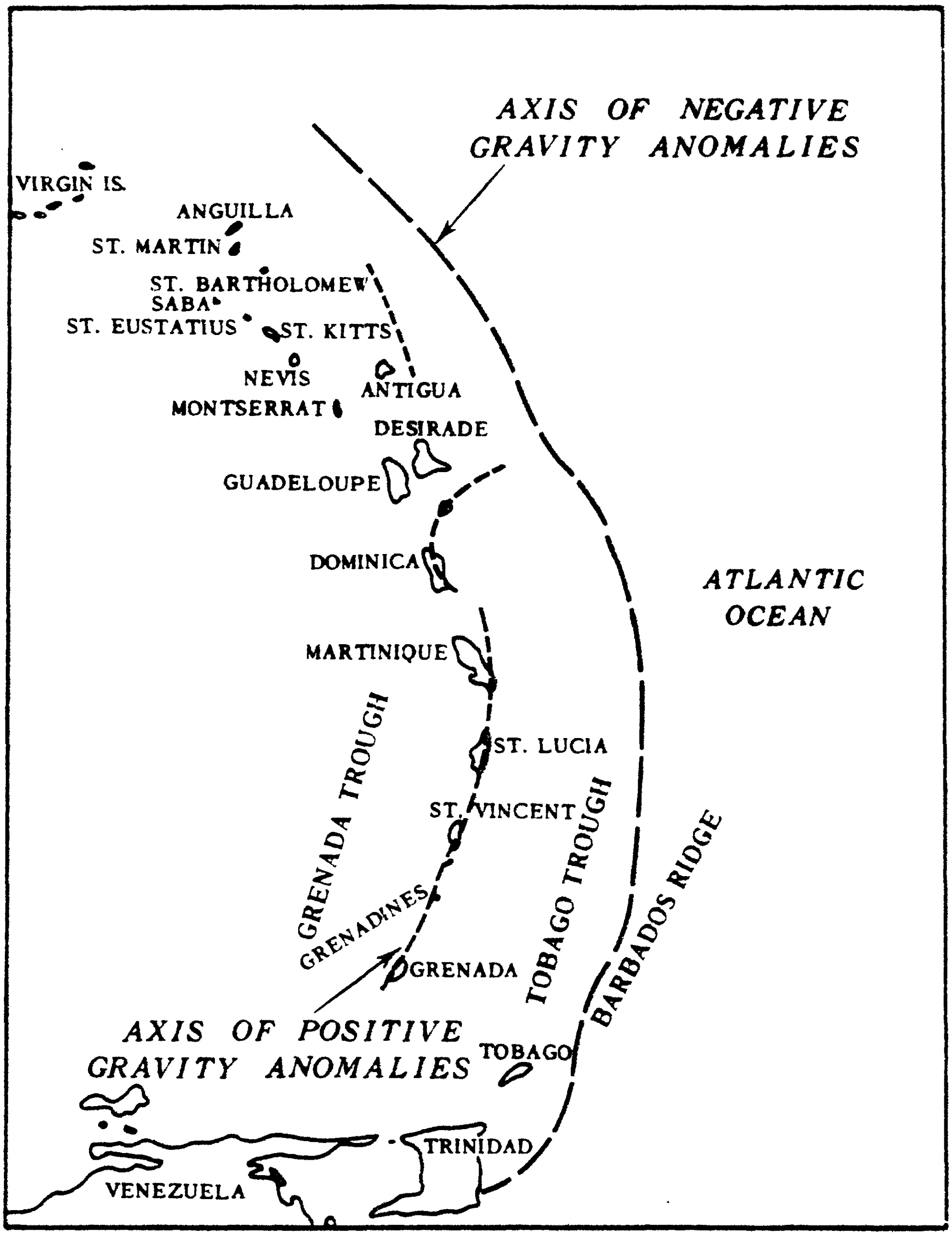



Figure 3

**Relationship of Trinidad and Tobago to Eastern Caribbean Arc system.**

Source: Walper,(1980)– after Tomblin,(1975) (modified)

## Structural Areas of Trinidad

The gross structure and stratigraphic units of Trinidad can be catalogued into five morphologic units that are from north to south (figures 4 and 5):

1. The Northern Range
2. The Northern (Caroni) Basin
3. The Central Range
4. The Southern Basin (including Naparima Thrust Belt)
   a. Los Bajos Fault
   b. Shale Diapirs
5. The Southern Range

The Margarita-Tobago trough, the offshore area north of Trinidad, is a sixth morphological unit. The offshore area east and south of Trinidad can be considered a seventh stratigraphic and structural unit. These areas will be discussed in the chapter concerned with oil and gas occurrence.

### The Northern Range

The Northern Range is for the most part a series of Upper Jurassic-Lower Cretaceous, low-grade metamorphic rocks that essentially strike east and dip southward. It is an eastward continuation of the Venezuela Coast Range. Going eastward, the Northern Range deflects northeast to become part of the Caribbean island arc system. Both the north and south boundaries are marked by east-trending faults. The fault bounding the northern limits of the North Range has a 6,000-foot vertical displacement. The southern boundary of the Northern Range is marked by a fault that may have horizontal displacement. This southern boundary is an eastward extension from Venezuela of the El Pilar fault system. Movement on this fault had its inception in the Eocene or at least Early Miocene based on stratigraphic evidence.

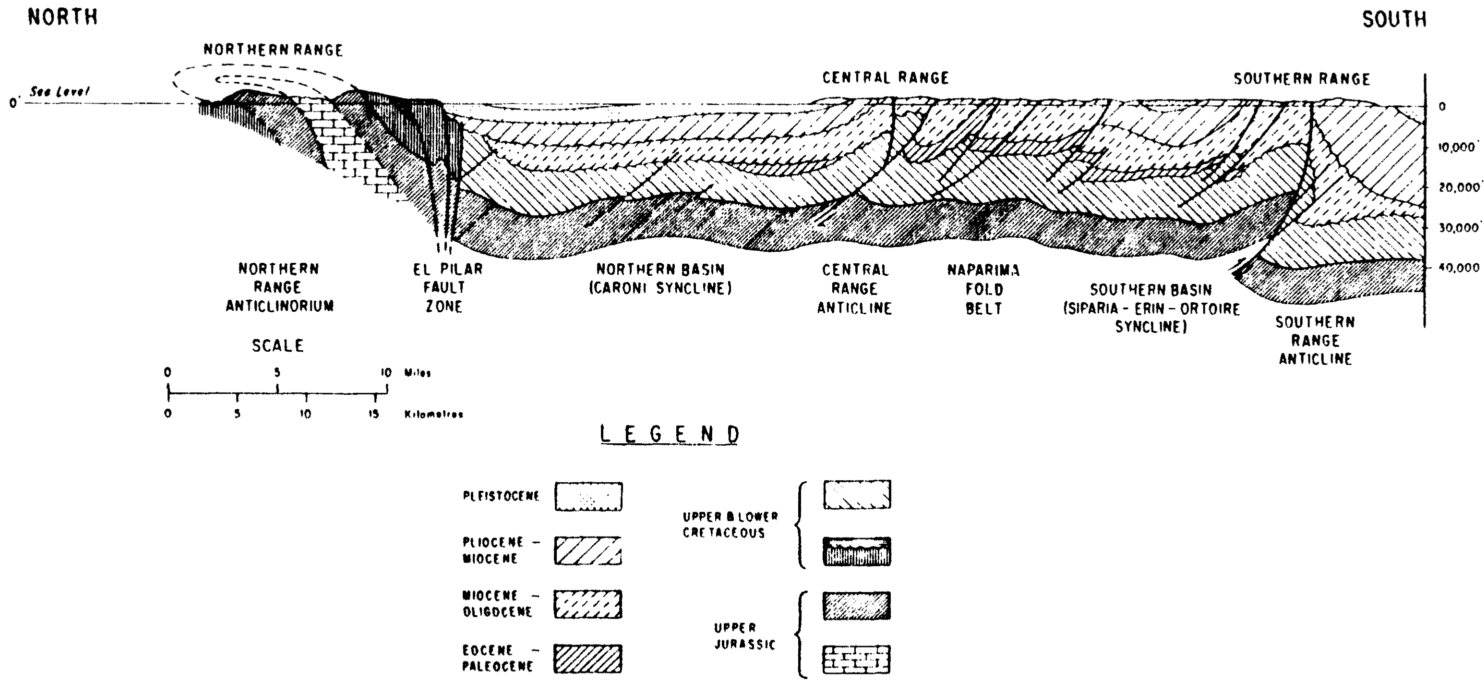



Figure 4 Schematic north-south cross section of Trinidad, incorporating Potter's interpretation of the structure of the western Northern Range (1973).

Source: Carr-Baromi & Frampton (1979)

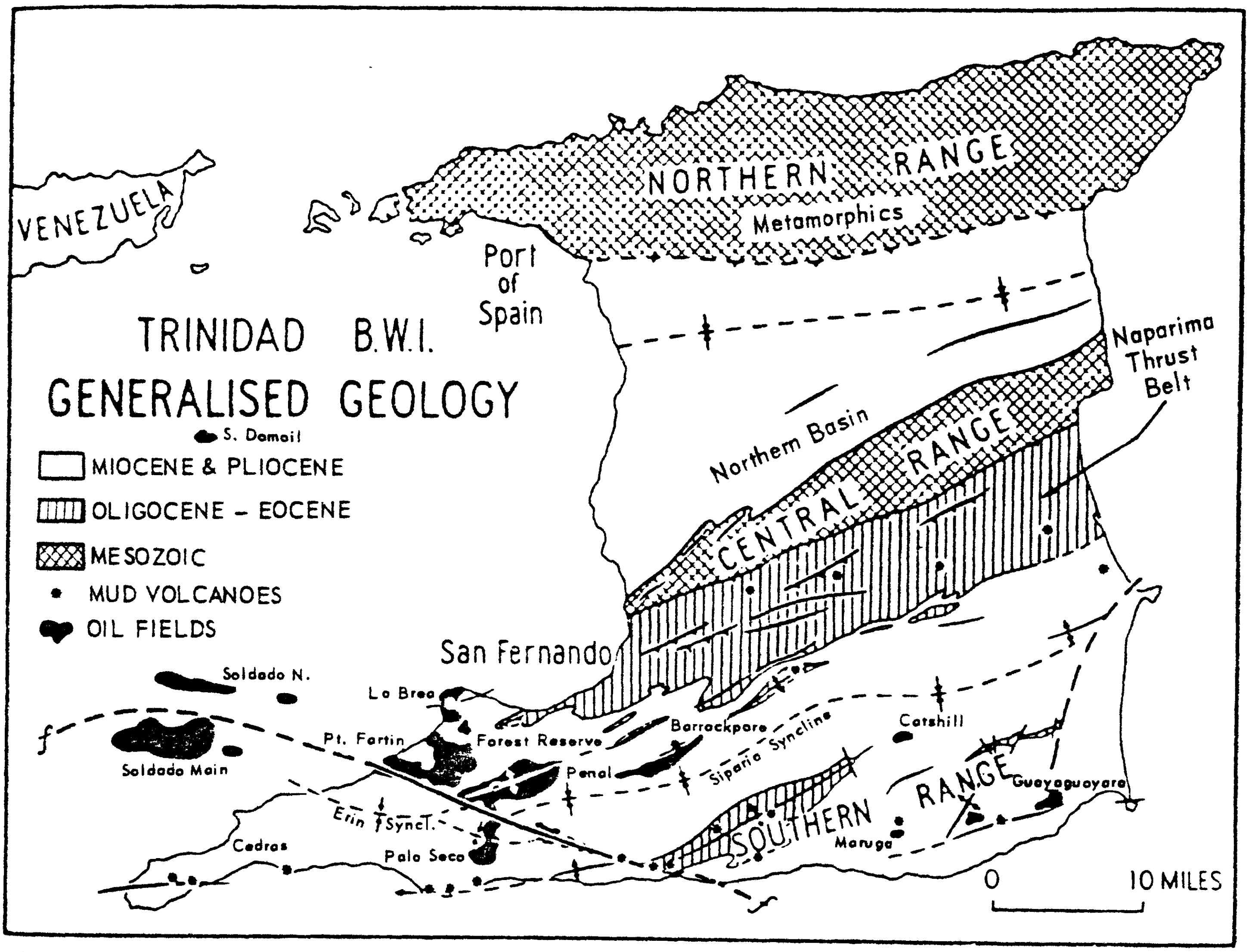



Figure 5 **Generalized geology of Trinidad.** Source: Barr, and others, 1958

The Northern (Caroni) Basin

The Northern Basin (Caroni syncline) lies immediately south of the Northern Range. Here Tertiary sedimentary rocks overlie with strong unconformity the complexly structured Jurassic and Cretaceous sedimentary rocks, which are locally altered to meta-sedimentary rocks. The north dipping limb of the Caroni syncline is the north flank of the Central Range structure. Along this flank is a series of en-echelon anticlines with steep dips. These Dips increase from 40° to 45° as the core of the Central Range is approached.

The Central Range

Structures in the Central Range include fan folding and complex overthrusting to the south. In this area strongly folded Upper Tertiary sedimentary rocks rest unconformably on Lower Eocene and Paleocene rocks. Along the southern flank, Lower Cretaceous shales are strongly sheared. Extreme compression is evident in the west portions where the structure becomes sharply pinched and dips approach the vertical.

The Southern Basin

The southern boundary of the Central Range is a 4 to 6 mile wide fold belt called the Naparima Thrust Belt. Strongly folded and faulted Oligocene and Lower Tertiary beds are typical, and locally folds and overthrusts are overturned to the south.

Around the periphery of the Naparima Thrust Belt westward plunging folds are loci of most of Trinidad's onshore oil production. These anticlines include, among others, the folded, oil-bearing structures at Pitch Lake of Brighton, Forest Reserve, Point Fortin, Penal and Barrackpore and Balata Fields. Penal-Barrackpore anticline is faulted and/or compressed to the point that beds have been overturned, which is particulary evident at the Middle Miocene Herrera sandstone level. Mud flows are associated with with most of these folds (Suter, 1960).

However, in the base of the Siparia-Erin syncline south of the Naparima fold zones, the results of drilling have indicated truncated anticlines, and thrust faults involve rocks of Oligocene age. This syncline extends for 50 miles with a significant displacement by the Los Bajos fault. The present axis of this syncline roughly corresponds to the axis of the center of deposition of sedimentary rocks of the Pliocene Cruse and Forest Formations (Barr and others, 1958; Barr and Saunders, 1965). The synclinal basin north of the Los Bajos fault is known as the Siparia syncline; the basin south of the Los Bajos fault is called the Erin syncline. The Siparia-Erin syncline is the most extensive structural basin in onshore Trinidad.

Los Bajos Fault

Similar compressive forces were active in both Venezuela and Trinidad though these forces were somewhat earlier in Venezuela than in Trinidad. This spasmodic compressional orogeny continued from Cretaceous to at least Pliocene (Salvador and Steinforth, 1965). In Trinidad this fold system at times intensified, as reflected by the thrusting showing stress from the north. Evidence of this compression can be traced westward for 500 miles in the Serrania del Interior of Venezuela. The emergence and southward advance of the geosynclinal borderland common to both Trinidad and Venezuela reflects this compression.

The various facies and structures in the Trinidadian sediments indicate that compressive stress continued here after it had stopped to the west in Venezuela. The correlative La Pica and Las Piedras Formations in Venezuela are not compressively deformed; structures in these formations are gentle folds, occasionally broken by normal faults which were the result of compaction. In Trinidad, however, the Cruse and Forest Formations commonly seen crop out in asymmetric folds that are cut by reverse faults.

The Los Bajos fault in Trinidad is similar in character to several wrench faults in eastern Venezulea which have similar type displacements. Several of these Venezuelan lineaments are known as Gualtoco, Urica, and San Francisco. These wrench faults are related to the Cretaceous through Miocene orogeny common to both areas. But the actual horizontal displacement occurred in Lower Pliocene time (Saunders, 1974). This is a right-hand, strike-slip (wrench) fault, with displacement of at least 6.51 miles (Lau and Rajpaulsingh, 1976) on the north side. Much lesser and more dependable values are found in the Soldado Field area and the Forest Reserve producing area. These values were less than three miles. This Los Bajos fault is an excellent example of the importance of wrench fault tectonics in respect to hydrocarbon accumulation, as significant oil-producing areas in onshore Trinidad are in the vicinity of this fault. This fault with its horizontal displacement acted as a feeder between the organic shales and clay source rocks and the Pliocene sandstone reservoirs of the Morne L'Enfer Formation (Barr and others, 1958).

This fault has been mapped from the North Soldado-North Marine Fields in the Gulf of Paria southeastward to Point Ligoure on the west coast through Point Negra on the south coast. Its extension southeastward into the Atlantic Ocean is not traced with certainty. One possible interpretation of the eastward extension of the Los Bajos fault is that it splinters into a number of northeast-trending faults.

The Los Bajos fault is deep seated and extends across the country without regard for the competence of formation and surface structures; this fault cuts and offsets all structures which it intersects. The tectonic stresses that initiated this fault could well have commenced before the main Andean orogeny. The folds in southern Trinidad suggest that the greatest intensity of fault movement occurred after the folding. The Los Bajos fault is a result of Naparima thrusting (Lau & Rajpaulsingh, 1976). For example, the folding, as evidenced by the Point Fortin and Los Bajos anticlines which existed prior to the Los Bajos fault, in all probability created a line of weakness that determined the direction of this fault zone (Barr and others, 1958). Thus it would appear that the Erin-Siparia basin was subject to one set of tectonic conditions, and the Los Bajos fault cuts across this basin.

The Southern Range

To the south of the Siparia-Erin syncline is a broad line of anticlinal folds called the Southern Range of which the largest feature is the Rock Dome-Herrera anticline that is strongly faulted and overthrust to the south. The Rock Dome anticline is best known for the Herrera oil-sand development in the Moruga-West Field. Eastward, the Rock Dome anticline passes into a series of en-echelon folds. The Lizard Springs Field is associated with these folds. To the south is another fold-trend extending from Moruga through Guayaguayare eastward out into the offshore Atlantic shelf area. The Moruga-East, Guayaguayare, Beach, and Galeota Fields are associated with this fold-trend.

Westward, a strongly folded anticline related to diapirism is located south of the Morne Diablo-Quinam Erin Field. This anticlinal trend continues west southwestward to the Pedernales Field in southeast Venezuela (Barr and others, 1958). To the northeast, the Southern Range separates into a southern branch that continues to the Beach Field and the northern trend that passes through the Lizard Springs, Navette and Mayaro Fields.

## Shale Diapirs

Much of the tectonic activity in southern Trinidad is reflected by the trend of ridges, anticlines (with diapiric cores) and sedimentary volcanoes. According to Kerr and others,(1970), Kugler (1965), and others, the formation of shale diapirs results when compacted mud sediments under pressure expel interstitial pore-fluid water. Permeability is decreased as the compaction increases. The host muds and/or shales become over-pressured and undercompacted in relation to the surrounding sediments when the escaping fluids from a mud or shale body fail to keep up with the increased fluid pressure. The generation of methane gas creates additional internal pressure added to these overpressured and uncompacted shales/muds. The creation of this methane gas, a second phase to the water, further impedes fluid expulsion. Consequently, mud or shale diapirs or mud volcanoes result because of the unstable, semifluid nature of the methane-charged, undercompacted shales/muds. These diapiric piercement structures are the result of stresses and strains in excess of those necessary for folding. More diapirs are associated with areas barren of hydrocarbons than they are with areas which are associated with hydrocarbons (figures 6 and 7). The mud volcanoes are aligned in east-northeast parallel trends. These lines are reflected by faults and/or diapir ridges and are related to deep-seated structures.

The Asphalt Lake at Brighton represents a different kind of sedimentary volcanism in which gas and oil are acting on asphalt mixed with clay. This asphalt lake cuts across Miocene/Pliocene formations overlying a rather complicated thrust structure. An estimated 10 billion tons of asphalt of variable viscosity are contained in this lake.

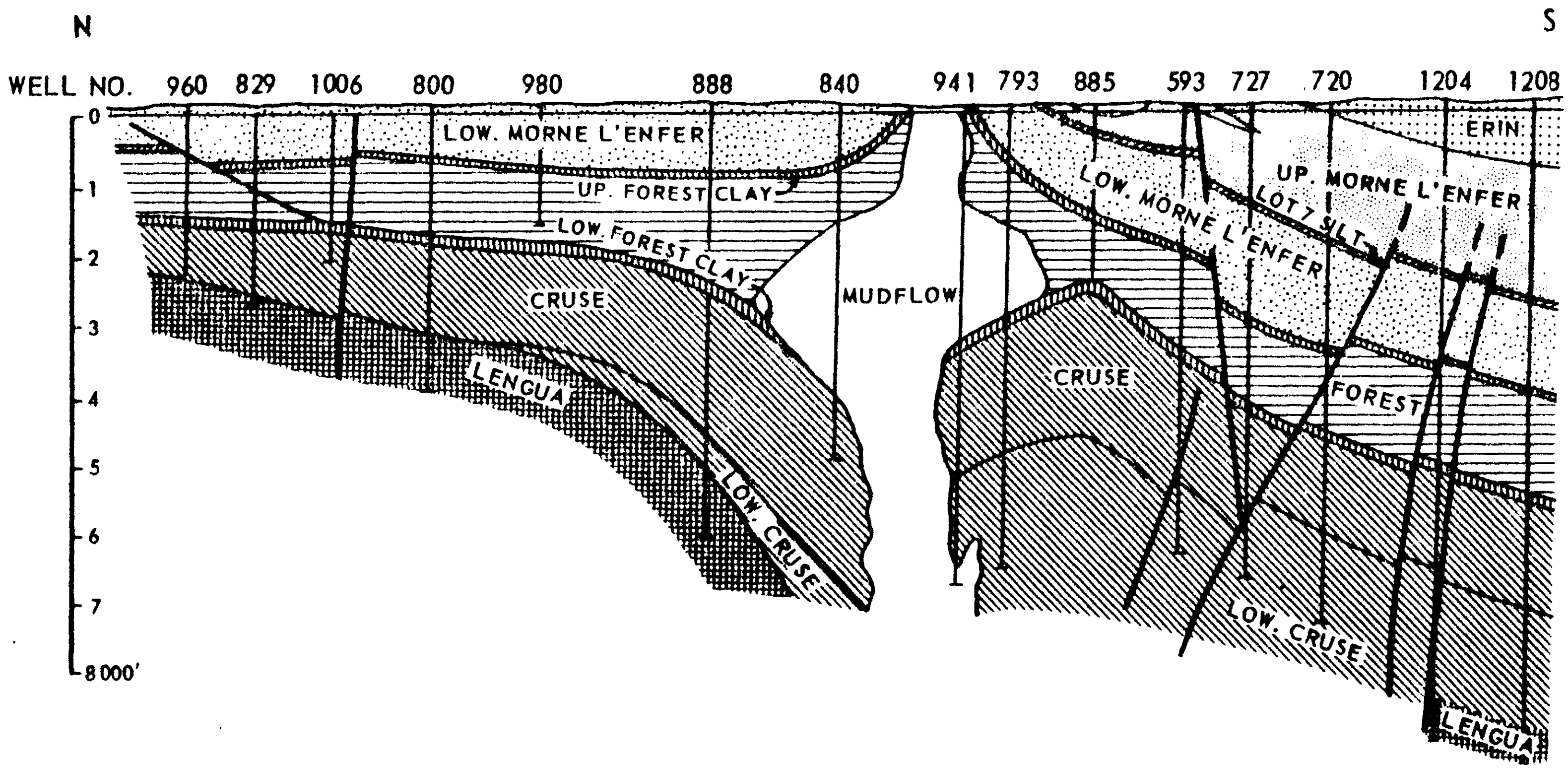



Figure 6

Generalized North-South Cross Section
Forest Reserve Field

Source: Bower (1965)

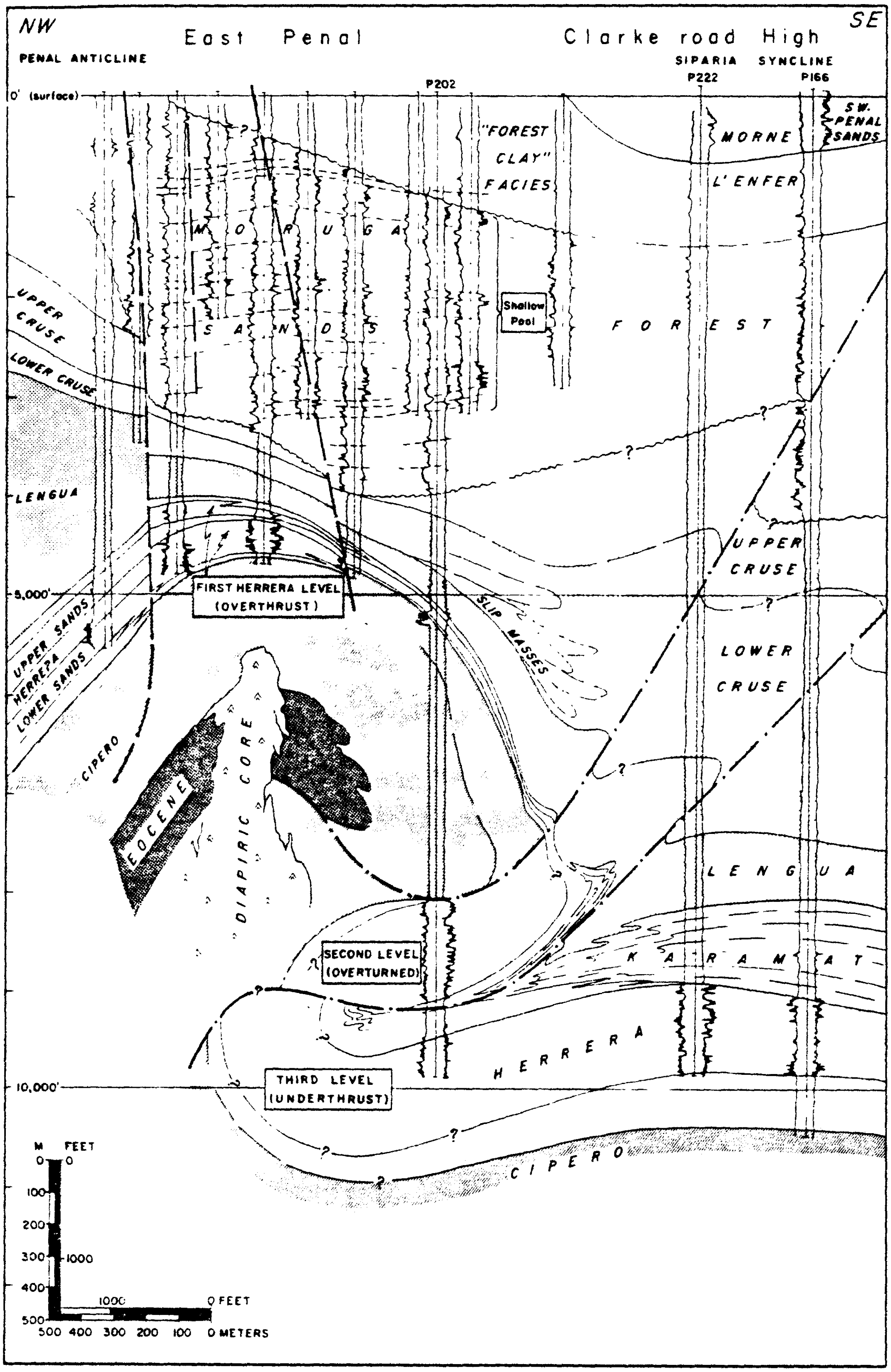



Figure 7 Combined cross section through East Penal Field, Trinidad
Source: Bitterli (1958)

# STRATIGRAPHY
(Figure 8)
(Appendix 3)

Geologically, the Island of Trinidad occupies a position on the northeast flank of the eastern Venezuela basin. Sedimentation in both areas was strongly influenced by intermittent tectonic activity throughout most of Hauterivian, Albian-Upper Cenomanian and Companian times, as well as Tertiary time. The oil fields in Trinidad are on a trend that parallels those oil fields along the mobile northern rim of the eastern Venezuela Basin.

## Northern Range and Northern Basin

Jurassic deposits here consist of metamorphic marble, quartzite, and phyllite and are not prospective for hydrocarbons. The Cretaceous rocks along the southern portion of the Northern Range consist of a semiphyllitic shale, the Laventille Limestone, and phyllites, and to the north, the unmetamorphosed Toco/Tompire Formations. These Cretaceous formations or their facies equivalent are recognized over most of Trinidad.

The Northern Basin (Caroni Plains) is a synclinal basin filled with young Tertiary (Carr, Brown and Frampton, 1979), (Kugler, 1965) to Recent sedimentary rocks. Along the north rim of this syncline, Upper Miocene-Pliocene and locally Oligocene sedimentary rocks are separated from the underlying Cretaceous deposits by a pronounced unconformity. This Cretaceous-Tertiary unconformity has also been penetrated in several wells drilled offshore east-northeast of Trinidad (Carr and Frampton, 1979, Kirmani, 1979). The Cretaceous stratigraphy is better known from work done in the Central Range to the south. The transgressive, thin, calcareous siltstones and claystones of the Oligocene-Miocene Brasso Formation

# STRATIGRAPHIC CORRELATION CHART

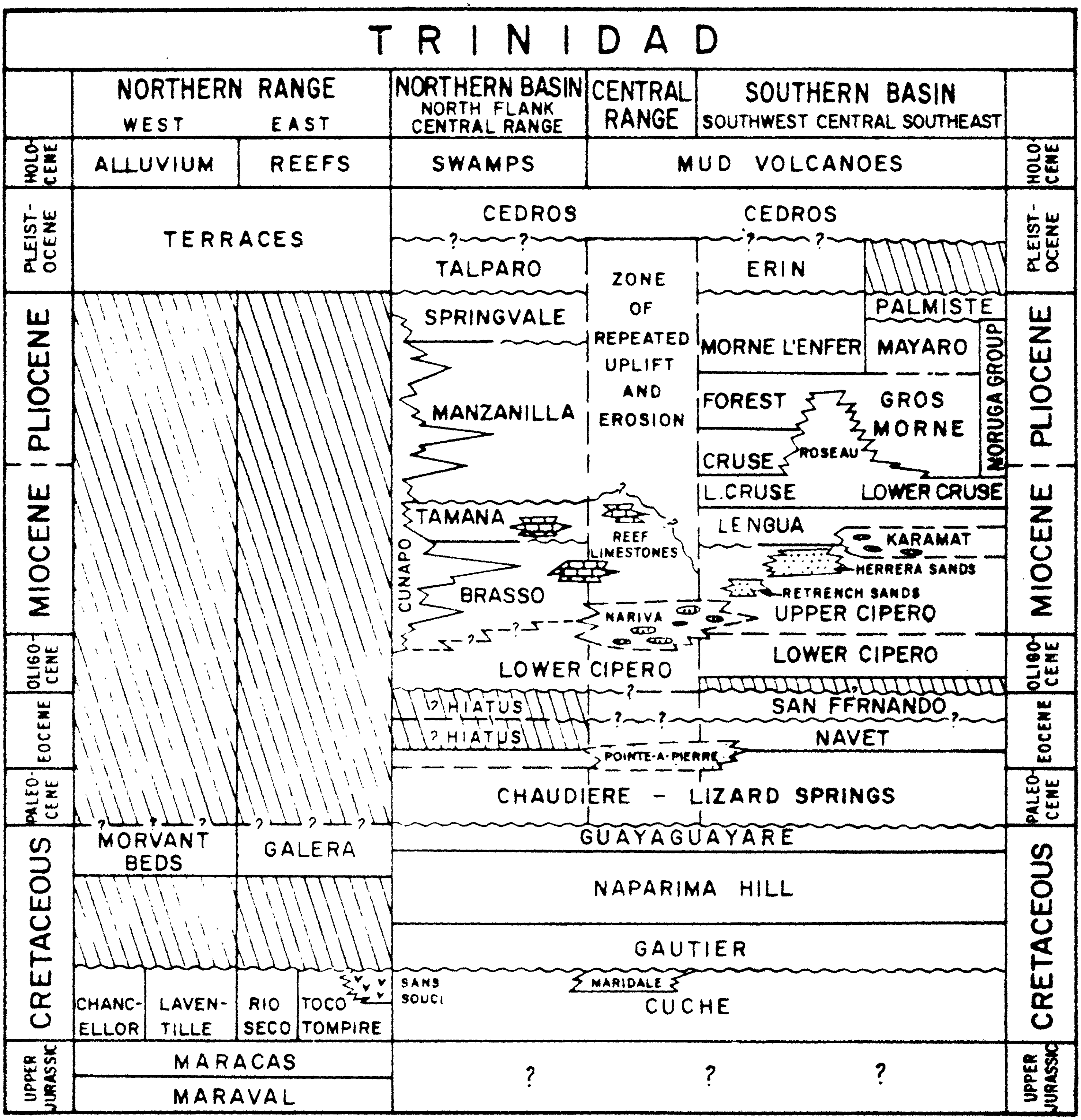



Figure 8.

Source: Carr–Brown and Frampton, 1979

contain few sandstones. In the Northern Basin, the base of the Brasso is a conglomerate. Brasso rocks reflect deposition in a neritic environment. The upper Brasso section grades transitionally into the overlying 300-foot thick reefal Tamana Limestone and claystone Formation.

The Miocene-Pliocene Manzanilla sandstone and claystones, restricted to the Northern Basin, reflect deltaic deposition and were probably derived in part from a Northern Coastal Range uplift. Manzanilla sandstones are not as widespread as their age equivalents, the Cruse, Forest and Morne L'Enfer sandstones to the south; however, the Manzanilla sandstones do not have the same areal extent.

## Central Range

Immediately to the south is the Central Range which is essentially an asymmetrical anticline extending for 35 miles across the Island in a north-east-southwest direction. The environment of deposition patterns indicate that there may have been no Central Range from post-Eocene to Middle Miocene (Bower, 1965). Severe faulting is reflected in the strongly sheared Lower Cretaceous Cuche Shales. From Middle-Miocene to recent times the Central Range area, sometimes emergent and during other times a shoal area, effectively separated the Northern and Southern Basins. Thus, from Oligocene time onward, the deposition sequence was different than in pre-Oligocene time. With the Oligocene uplift, the Central Range became a persistent barrier between the northern and southern depositional basins; the sources of sediments therefore came from different areas. In post-Oligocene times, north of the Central Range in the Northern Basin, deposition reflected progressively shallow-shelf conditions, while deposition south of the Central Range shows a persistent deeper-water environment (i.e., Herrera sandstones). Thus from Oligocene to Upper Miocene time there may have been a consistent deepening from north to south with a shore line at the center of what is now the Northern Basin (Kugler, 1953; Suter, 1980).

Cretaceous shales, limestones, and quartzites constitute the core of many structures in the Central Range. Exact thickness of the Cretaceous sequence is not possible because formation boundaries are obscure. This is so because at least four major unconformities are recognized within the Cretaceous sequence. The Cuche Shales overlie the Cretaceous Gautier Shales.

The calcareous Gautier Shales grade transitionally into the overlying rocks of the Naparima Hill Formation, a silicified siltstone/claystone in the upper part of the formation. (The Lower Member of the Naparima Hill Formation has some similarity to the Querecual Formation in Eastern Venezuela.) The Naparima Hill silicious siltstones reflect a uniform quiescent depositional environment. The unconformably overlying Cretaceous Guayaguayare calcareous Shales are lithologically constant throughout the whole section. The Paleocene Chaudiere and Lizard Springs Formations disconformably overlie the Guayaguayare Shales. These formations are facies equivalent of each other. The Lizard Spring is a calcareous claystone shale and marl, whereas the Chaudiere consists mainly of grey shales with occasional sandstones and grit layers. The Chaudiere Formation is restricted to the Central Range, whereas the Lizard Springs is found ubiquitously over South Trinidad and even in parts of the Central Range. The Lizard Spring Shales contain fauna of a planktonic type; in contrast, the Chaudiere Shales were deposited in a relatively deep turbid-water condition.

The Paleocene-Eocene Pointe-a-Pierre Sandstone Formation is restricted to the Central Range. This consists of a flysch-type deposit of shallow-water origin and is in transitional contact with the underlying Chaudiere-Lizard Spring Shales and sandstones which are disconformable with the overlying Eocene Navet Formation. The Point-a-Pierre is a flaggy quartzitic coarse sandstone to limestone conglomerate flysch-type facies that is at least 635 feet thick. A series of calcareous claystone 1,500 to 8,400 feet thick, known as the Cipero Formation, represents the initial Late Eocene transgression over the Eocene Jackson unconformity. A minimum of sandstone deposition occurred in the Lower Cipero Formation along the north flank of the Central Range. The lower portion of the Central Range Cipero facies is equivalent to the 6,300-foot Nariva facies, which consists of marls, chalks, siltstones, and pebbly siltstones with thin layers of graded sandstones. Heavy mineral assemblages indicate a schistose source, probably from the north. The Nariva facies becomes increasingly arenaceous in a southward direction. The Nariva interdigitates with the overlying calcareous claystone and marls of the Upper Cipero Formation.

## Southern Basin and Southern Range

The rocks in this area immediately south of the Central Range (figure 9) consist of a rather uniform sequence of sharply folded young Tertiary claystones and sandstones and older Tertiary and Cretaceous deposits. The area is known as the Naparima Thrust Belt. Further south, the Southern Basin spans the Island from east to west where younger Tertiary deposits infill this syncline. The 370-foot-thick reefal limestone, siltstone, sandstone and conglomeratic Upper Eocene San Fernando Formation are recognized in the Southern Basin and probably in parts of the Central Range.

The Oligocene Lower Cipero deposition common to all of Trinidad south of the North Range continued in the Southern Basin well into Middle Miocene

## SCHEMATIC SECTION SHOWING SOUTHWARD DISPLACEMENT OF FOREDEEP

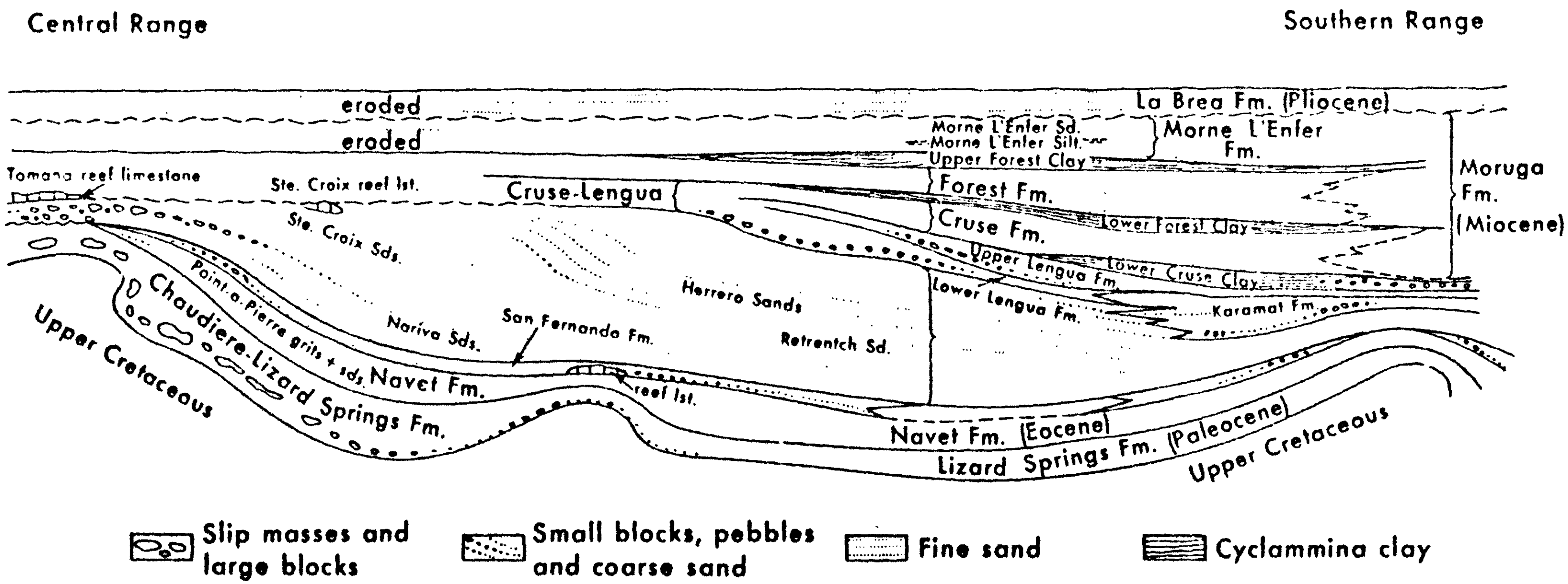



Figure 9

Source: Kugler and Saunders, 1967

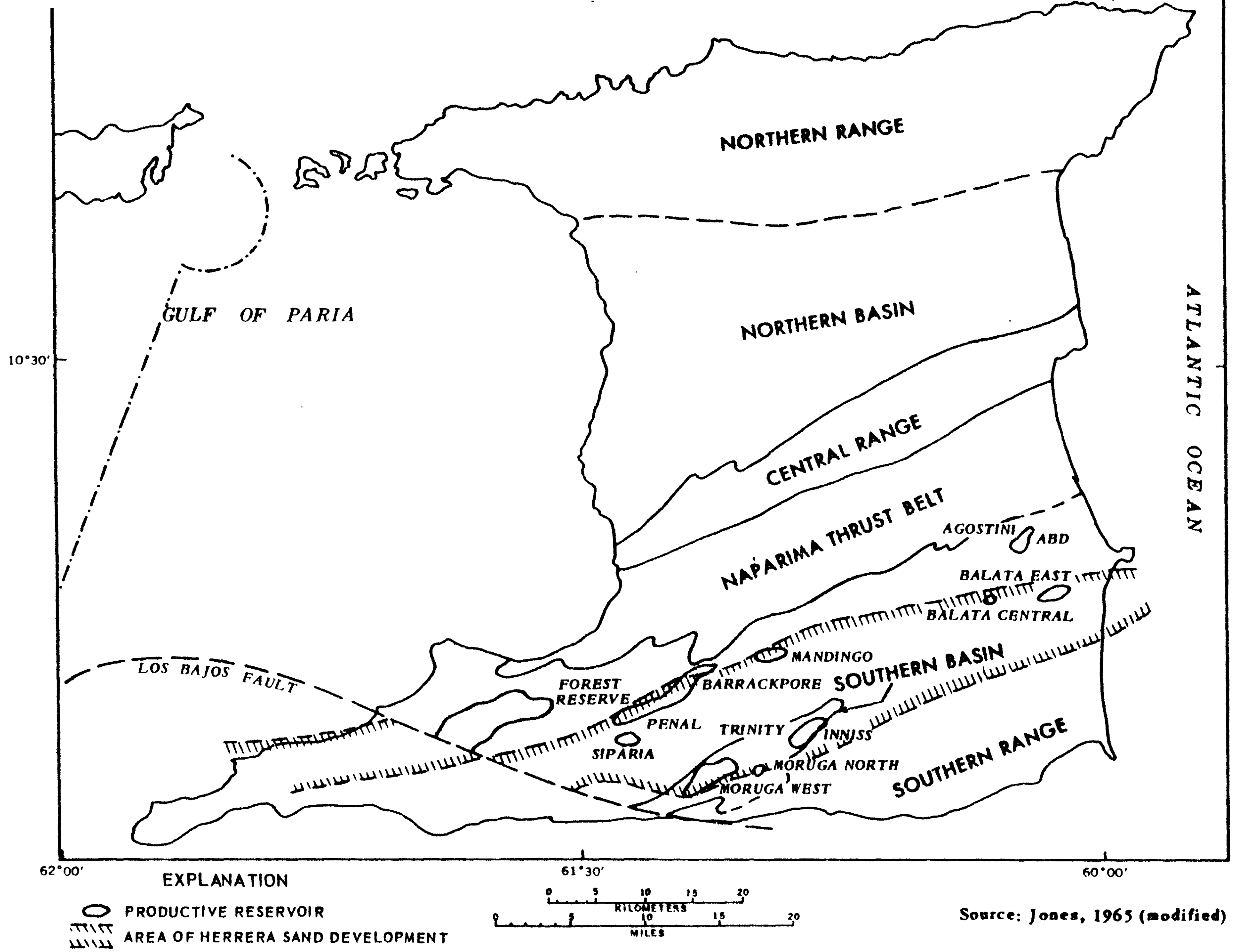
time. The Upper Cipero rocks reflect deposition in waters of several thousand foot depth. Sandstones and conglomerates are present at various stratigraphic intervals; the largest sandstone depositions are known as the Herrera, Retrench and Karamat sandstone members. Towards the end of Cipero deposition, Herrera sandstone deposition was restricted to the Siparia syncline (figure 10) and is similar to the older Oligocene, Lower Miocene Central Range Nariva sandstones. The Herrera sandstones, up to 1,000 feet thick, reflect deposition by turbidity currents; interbedded calcareous and noncalcareous claystone reflects a deep-water origin. The younger Herrera sandstones are siltier and thinner than the older Herrera sandstones found in the north.

The overlying 3,400-foot-thick Karamat shales, claystones, and subordinate sandstones and conglomerate deposits interfinger both with the Cipero and overlying Lengua Formations. Claystone boulders within the Karamat Formation contain angular blocks of older claystone slump masses.

The overlying 4,200-foot-thick Miocene Lengua claystones and calcareous siltstones are void of any sandstone deposition west of Iceos Point and therefore probably are not prospective for hydrocarbons exploration.

The succeeding Miocene-Pliocene deposition begins with the Lower Cruse Shales and claystone Formation. The Pliocene depositon can be grouped into three major cycles (Barr et al., 1958) (figure 11) of claystone, siltstone and sandstone sequences, each cycle being separated above and below from the others by local unconformities. The time-stratigraphic and rock-stratigraphic cycles are synonymous, and the average 15,000-foot interval from oldest to youngest is divided as:

| Formation Cycle | Thickness (Feet) | Percent Sandstone |
|---|---|---|
| Lengua-Cruse | 1,000-10,000 | 20 |
| Forest | 800- 3,000 | 30 |
| Morne L'Enfer | 3,000- 5,000 | 60 |




Source: Jones, 1965 (modified)

Figure 10

**FIELDS OR POOLS IN HERRERA SANDSTONE RESERVOIRS**

# SUMMARIZED PLIOCENE STRATIGRAPHY OF SOUTHERN TRINIDAD

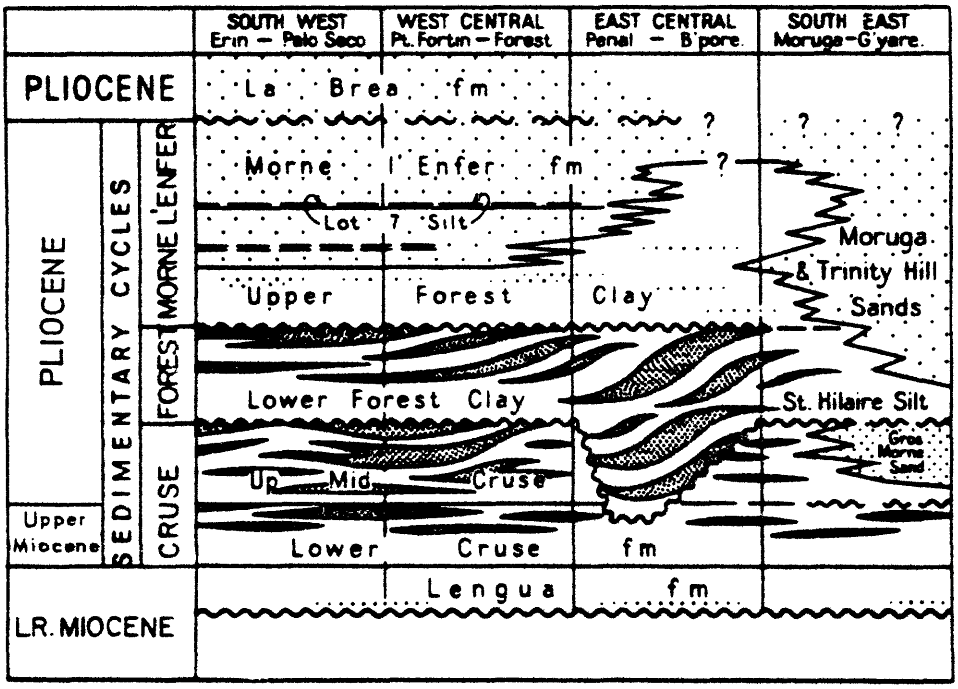



**Figure 11** Schematic Pliocene stratigraphy of Southern Trinidad.

Source: Barr, and others, 1958

The Lengua-Cruse Cycle deposits consist for the most part of thick homogeneous foraminifera claystone, containing lenticular sandstone beds that increase in quantity towards the top of the section or at the end of the depositional cycle, where they become sheet sandstones. Toward the southeast, the Moruga siltstones and sandstones are the equivalents of the Middle and Upper Cruse Forest and Morne L'Enfer Formations to the west. The Moruga deposition represents the west advancing front of sediments carried by longshore currents from the Guayana Shield. The thick Cruse Cycle sandstones in the Guayaguayare area thin rapidly over pre-Pliocene uplifts, particularly in the Southern Range area.

Cruse elongate sandstone trends have an east-northeast alignment. In an area (figure 12) between the thick sandstones in the east and the Cruse oil reservoirs in the west, Cruse sandstone thickness decreases markedly. Also, Cruse sandstones wedge along the northern rim of the Siparia syncline. Cruse deposits originated mostly from the east and southeast, and a lesser source originated from the west and southwest. The end of the Cruse Cycle was marked by erosion followed by renewed subsidence that initiated the Forest cycle with clay deposition. Similar to the first Lengua-Cruse Cycle, Forest sand deposition increased towards the end of the cycle. These uppermost sandstones show evidence of brackish-water deposition, whereas in contrast the Lower Forest sandstones are marine. Both the middle and upper lenticular Forest sandstones show slumping. These Forest sandstones originated from the southeast. The Forest sandstones, similar to the earlier Cruse sandstones, grade toward the southeast into the Moruga lithofacies. Two sandstone thickenings are evident from a map showing the ratio of sand to shale (Barr and others, 1958), (figure 13): one a thick sandstone accumulation in the south east Guayaguayare area and Moruga

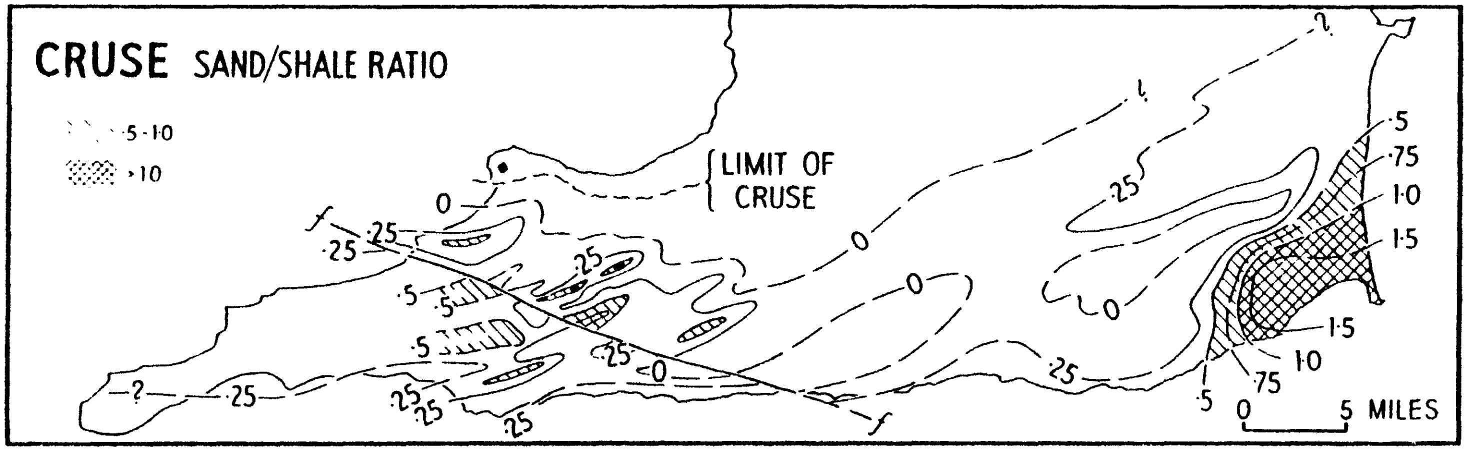



Figure 12

Source: Barr, and others, 1958

The Cruse cycle, showing sand/shale ratio.

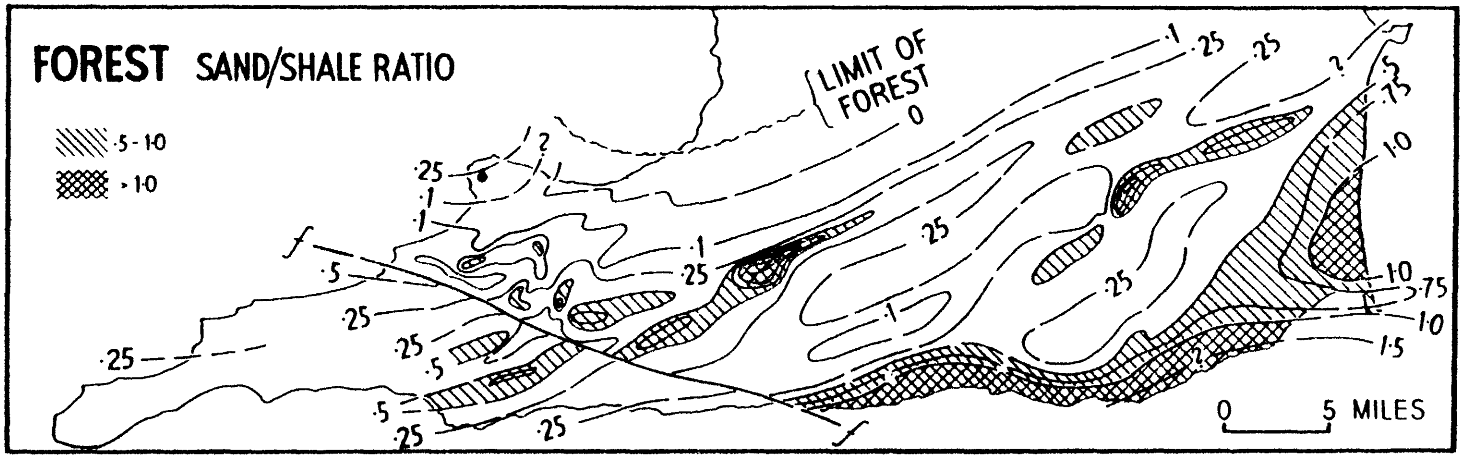



Figure 13

Source: Barr, and others, 1958

The Forest cycle, showing sand/shale ratio.

districts, and the other, sandstone development in the Penal trend in the southwest.

Michelson (1976) indicates that the source of the Penal sandstone trend originated from an east and southeasterly direction (figure 14). The Forest-Point Fortin producing area and sandstone trend parallels the Penal sandstone trend. In the Penal producing area, the Forest cycle is thicker than in the Forest Reserve, whereas by contrast the Cruse cycle is not only thinner but shalier than the overlying Forest Formation. The third cycle, the Morne L'Enfer, represents mostly a sheet sandstone of continental origin. However, the Morne L'Enfer cycle, similar to the earlier depositional cycles, begins with deep-water clays at its base which rapidly develop into well-sorted, cross-bedded sheet sandstone. Morne L'Enfer sediments originated both from the southeast and from the southwest. A marine shale in the Penal area separates the Morne L'Enfer sandstone from the underlying sandstone of the Forest cycle (figure 15).

The Pliocene Moruga Group is found in southeast Trinidad and in the offshore area east and southeast of Trinidad. The Moruga Group is the facies equivalent of the Cruse, Forest and Morne L'Enfer Formations. This group is divided from the youngest to the oldest as follows:

| | |
|---|---|
| Mayaro | siltstone |
| Trinity Hill | sandstone |
| Goudron | sandstone |
| St. Hilaire | siltstone |
| Gros Morne | sandstone |

Not all of the above are present in any one location. The Gros Morne sandstones are interbedded with siltstones and claystones which increase with depth. In the Beach Field area, the Gros Morne sandstones and siltstones have a thickness of over 4,500 feet, whereas in the Navette Field area the Gros

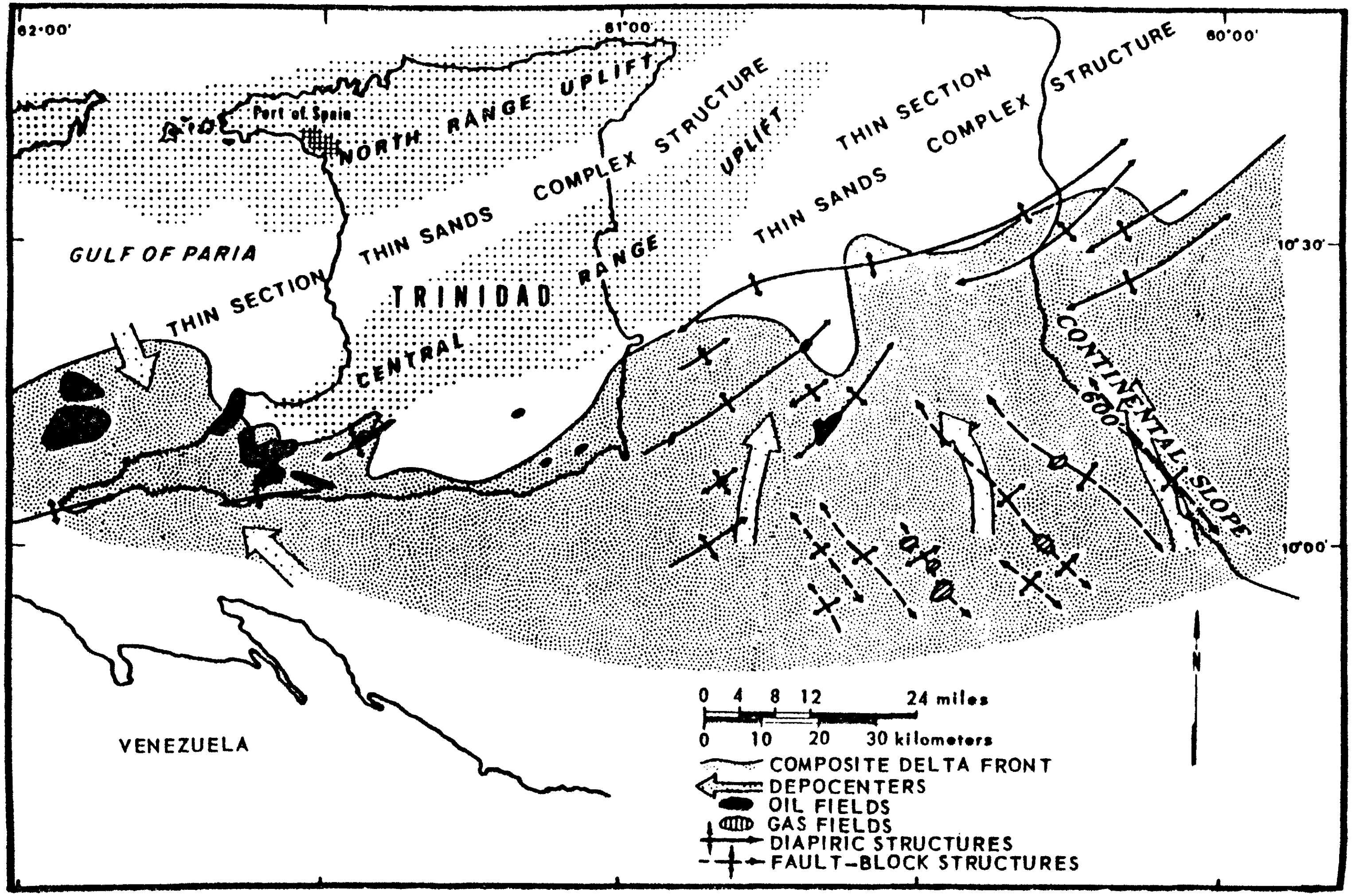



Figure 14 Geologic summary map showing relation of oil and gas production to Pliocene sedimentary facies and structural style.

Source: Michelson (1976)

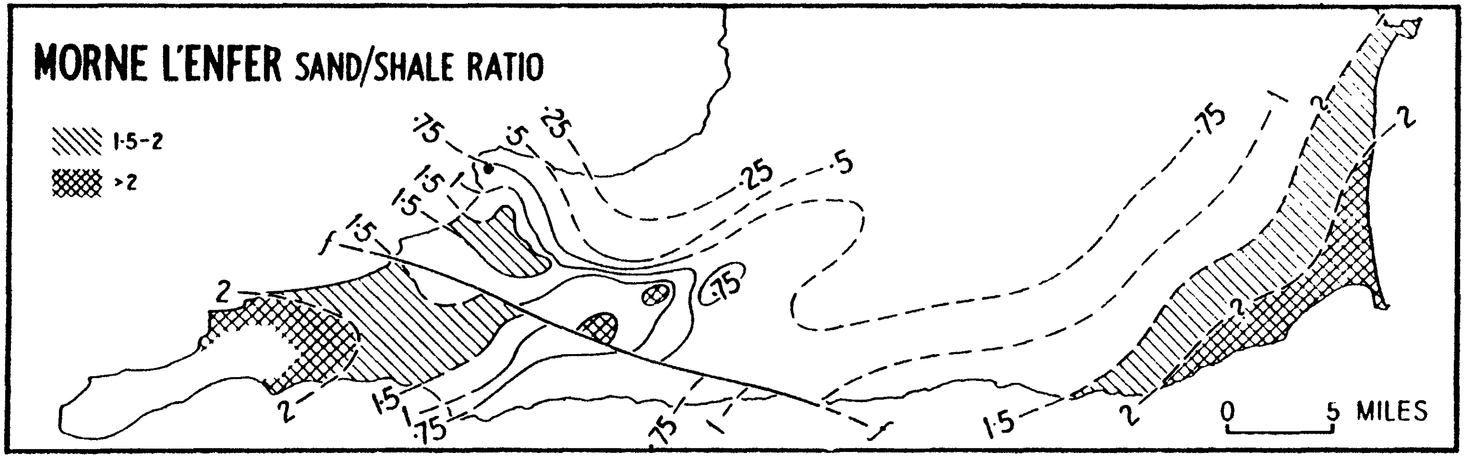



Figure 15

Source: Barr, and others, 1958

**The Morne l'Enfer cycle, showing sand/shale ratio.**

Morne Formation ranges from 0 to 1,000 feet. The Gros Morne Formation thickens to the southeast.

## Summary

The stratigraphy and depositional history in Trinidad is for the most part distinctive in each structural area: the Northern Range, the Northern (Caroni) Basin, the Southern Basin, the Southern Range, the Margarita-Tobago Trough, and to some extent the offshore area east of Trinidad. At least four major unconformities are recognized within the Cretaceous sequence of formations, part of which has been subject to low-grade metamorphism. The Paleocene deposits are mostly calcareous claystone-shale and marl. The Late Eocene unconformity is overlain by transgressive Oligocene-Miocene calcareous claystones with a minimum of sandstone development in the lower sections. However, the sand content increases in the upper part of the section. These claystones, shales, siltstones, and sandstones grade into an overlying claystone which is void of any sandstone development. The succeeding Pliocene is marked by three depositional cycles each of which increases in sandstone content toward the end of each cycle. The last cycle is predominantly continental. A distinctive sandstone-siltstone Pliocene facies occurs in the southeast and in the adjacent offshore areas.

# OIL AND GAS OCCURRENCE

## Introduction

Oil and gas accumulations with minor exceptions are restricted to those onshore and offshore areas south of the Central Range uplift. Most of the oil and gas produced in Trinidad and eastern Venezuela is from Middle Miocene through Pliocene formations. Over 90 percent of the cumulative oil production has come from the lenticular and deltaic sandstones of the Pliocene Forest and Cruse Formations and the Moruga Group. These formations (that at least onshore include both source and reservoir rocks) are thick wedges of deltaic and deltaic-associated sandstones, siltstones and claystones. The occurrence of diapirism appears to be independent from hydrocarbon occurrence. Oil distribution in southern Trinidad is largely controlled by sandstone distribution (i.e., stratigraphic) and structure. The Los Bajos wrench fault has had a major influence onshore in the redistribution of the oil by migration along the fault. Away from the area of the Los Bajos fault, much of the oil is indigenous to the formations in which it is reservoired (Appendix 3). However, migration along faults is evident in the highly faulted anticlines in the eastern Guayaguayare onshore area. Some of the oil in the offshore area east and south of Trinidad may have migrated into the Pliocene-Pleistocene sandstone reservoirs from deeper Miocene shales and claystones.

Exploration and development in the onshore operations have been difficult because of structural complications resulting from overthrusting and underthrusting that have been compounded by lenticular sandstones and faulting. In addition many structures are involved with diapirism. Drilling problems include hydration and swelling of surface-active claystones in the shales and the abnormally high pressures. The high number of wells in Trinidad can be attributed to the close spacing of wells, which has been necessary due to the rapid lateral changes from sandstone to impervious siltstone or shale (Ablewhite and Higgins, 1965). Many onshore oil and gas fields have been produced close to their ultimate recovery.

Onshore oil fields in Trinidad are located along the axis of three Tertiary fold belts. The Brighton, Cruse, Parrylands and Point Fortin Fields are along the northernmost belt. The Forest Reserve Fyzabad (Apex) producing area is located along the central belt and is a third anticlinal axis which includes the Penal and Barrackpore Fields.

The following oil fields are associated with the Los Bajos fault:

| | | |
|---|---|---|
| Point Fortin | Forest Reserve-Fyzabad | Los Bajos |
| Morne Diablo | Grand Ravine | Coora |
| Soldado | Soldado-North | Quarry |

Reservoir rocks in these fields are for the most part sandstone beds of the Pliocene Cruse Formation (figure 16). In the Forest sandstones, hydrocarbon occurrence is usually confined to structural highs and major fault zones related to the Los Bajos fault (figure 17). Oil saturation in Upper Pliocene sandstones is highest in those oil fields that lie close to the Los Bajos fault (Barr and others, 1958) (figures 16, 17, 18). The sheet sandstones of the Upper Pliocene Morne L'Enfer and Pleistocene La Brea Formations are for the most part strong aquifers, and therefore do not contain hydrocarbon accumulations except where those sheet sandstones are in direct contact with the Los Bajos fault. Migration along the Los Bajos fault zone has resulted in a belt of oil accumulation in the Morne L'Enfer sandstones along either side of the fault (figure 18). Hydrocarbons in the Cruse formations were probably generated from source rock within that unit, and this applies to a lesser extent to the overlying Forest deposits (Appendix 3).

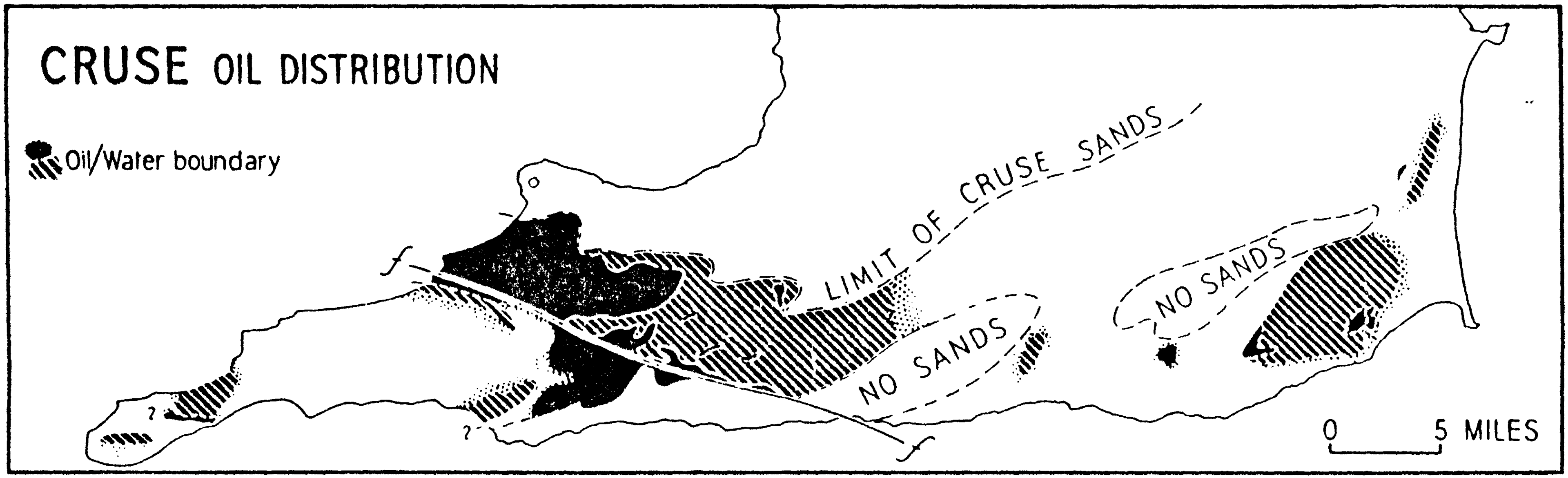



Figure 16 The Cruse cycle, showing oil distribution.

Source: Barr, and others, 1958

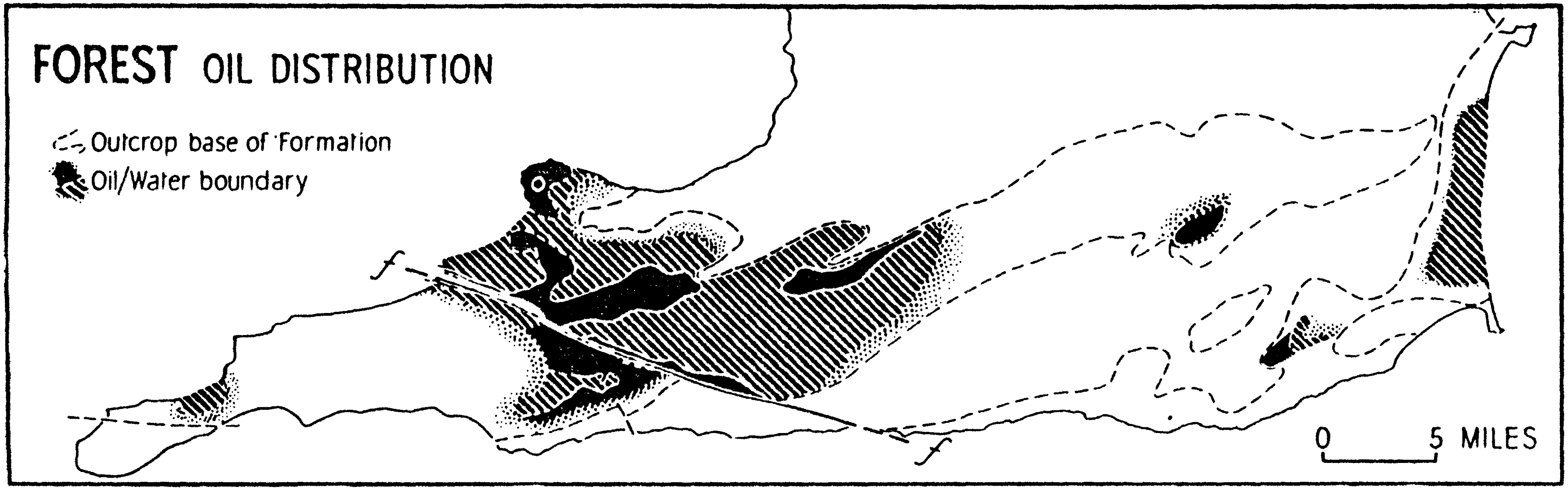



Figure 17 The Forest cycle, showing oil distribution. Source: Barr, and others, 1958

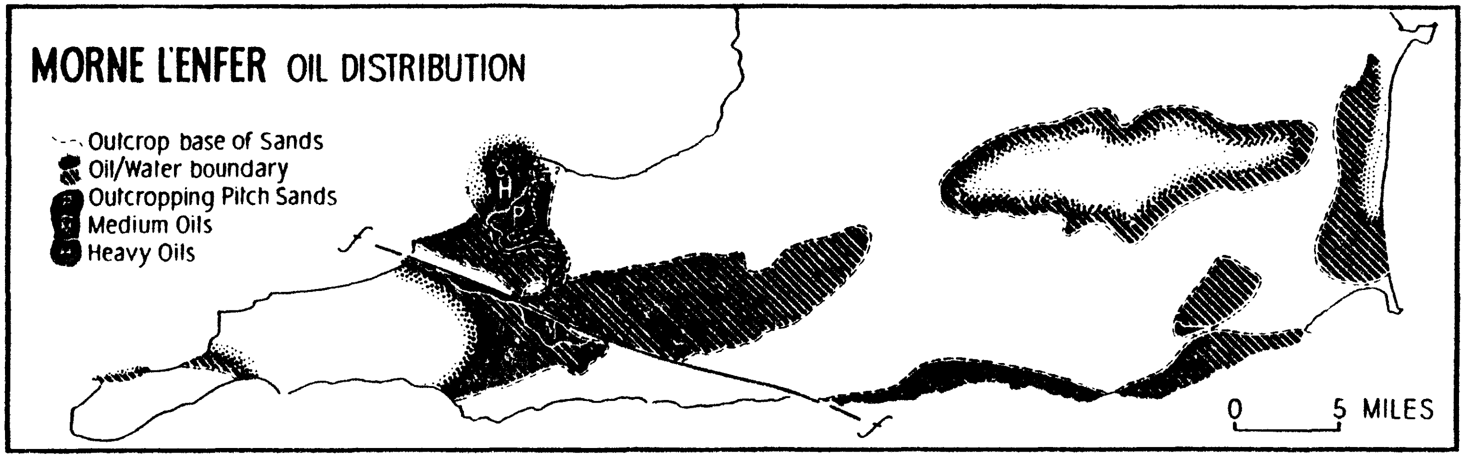



Figure 18

Source: Barr, and others, 1958

The Morne l'Enfer cycle, showing oil distribution.

Thus, oil impregnation in these younger beds was the result of the horizontal movement of the Los Bajos fault. The oil accumulations in the Southern Range fields are essentially stratigraphic (i.e. Grande Ravine Field).

Hydrocarbon Considerations by Formations
(figures 19 through 26)

Cretaceous

Several wells have been drilled into the Cretaceous Gautier Shales and numerous wells have penetrated into the Cretaceous Naparima Hill siltstone/claystone Formation. These wells encountered poor porosity and permeability and yielded salt water on several production tests and noncommercial hydrocarbon shows on others (i.e., deep test in the Beach Field). In a Cretaceous Naparima Hill test in the Point Fortin Central Field, located in the Southern Basin, a well was drilled to a total subsea depth of 11,042 feet into the the Naparima Hill Formation. Because no shows of hydrocarbons were reported from the Cretaceous section, this well was plugged back and completed in Pliocene Cruse and Forest sandstone reservoirs at subsea depth intervals ranging from 1,500 to 7,500 feet. Over 73,000 b/o were produced from Cretaceous formations in the La Brea (Brighton) area.

Paleocene-Eocene-Oligocene-Lower Miocene

The Chaudiere-Lizard Springs Formation is essentially a shale and marl, and only locally an occasional sandstone is found. This sandstone is a hydrocarbon reservoir in only one field, the Lizard Springs, and the reservoir in this abandoned field was a faulted shale complex. (Note: The low production from the Lizard Spring Field indicates that the sandstone reservoirs are probably erratic blocks of porous material, the saccharoidal sandstone of the Nariva facies of the Lower Miocene within the Lizard Springs Shale.)

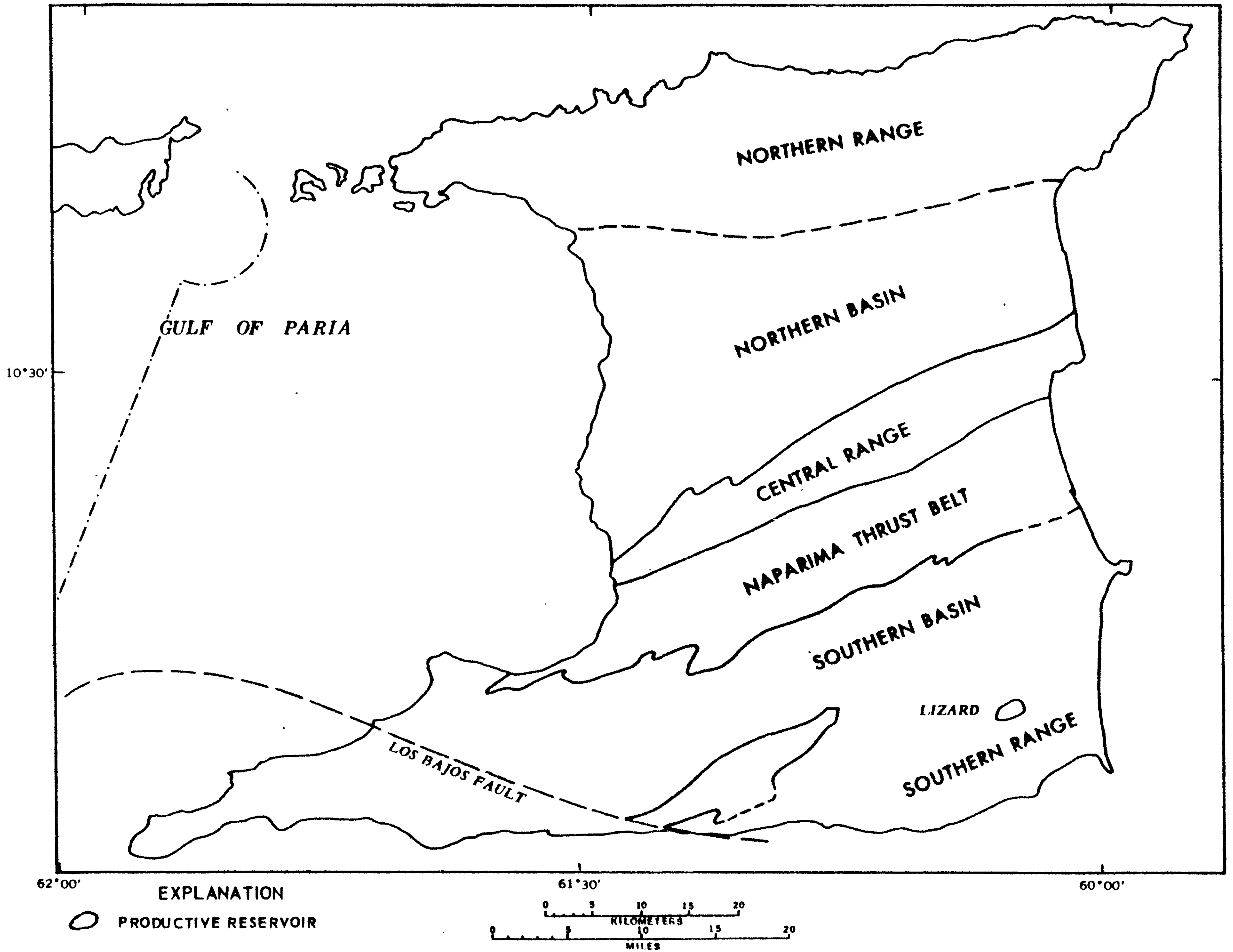



Figure 19 POOL IN LIZARD SPRINGS SANDSTONE RESERVOIR

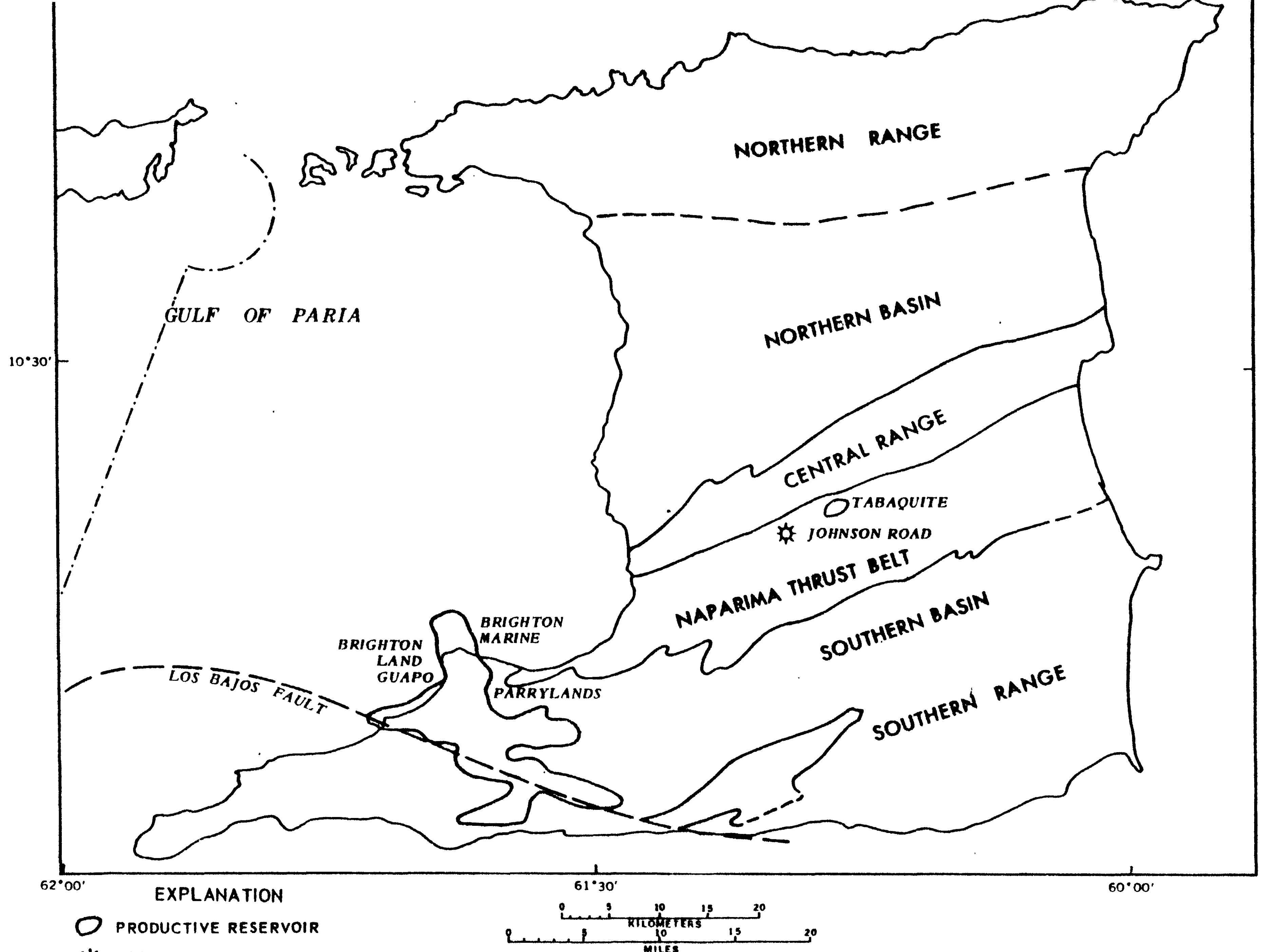



Figure 20

**FIELDS OR POOLS IN NARIVA SANDSTONE RESERVOIR**

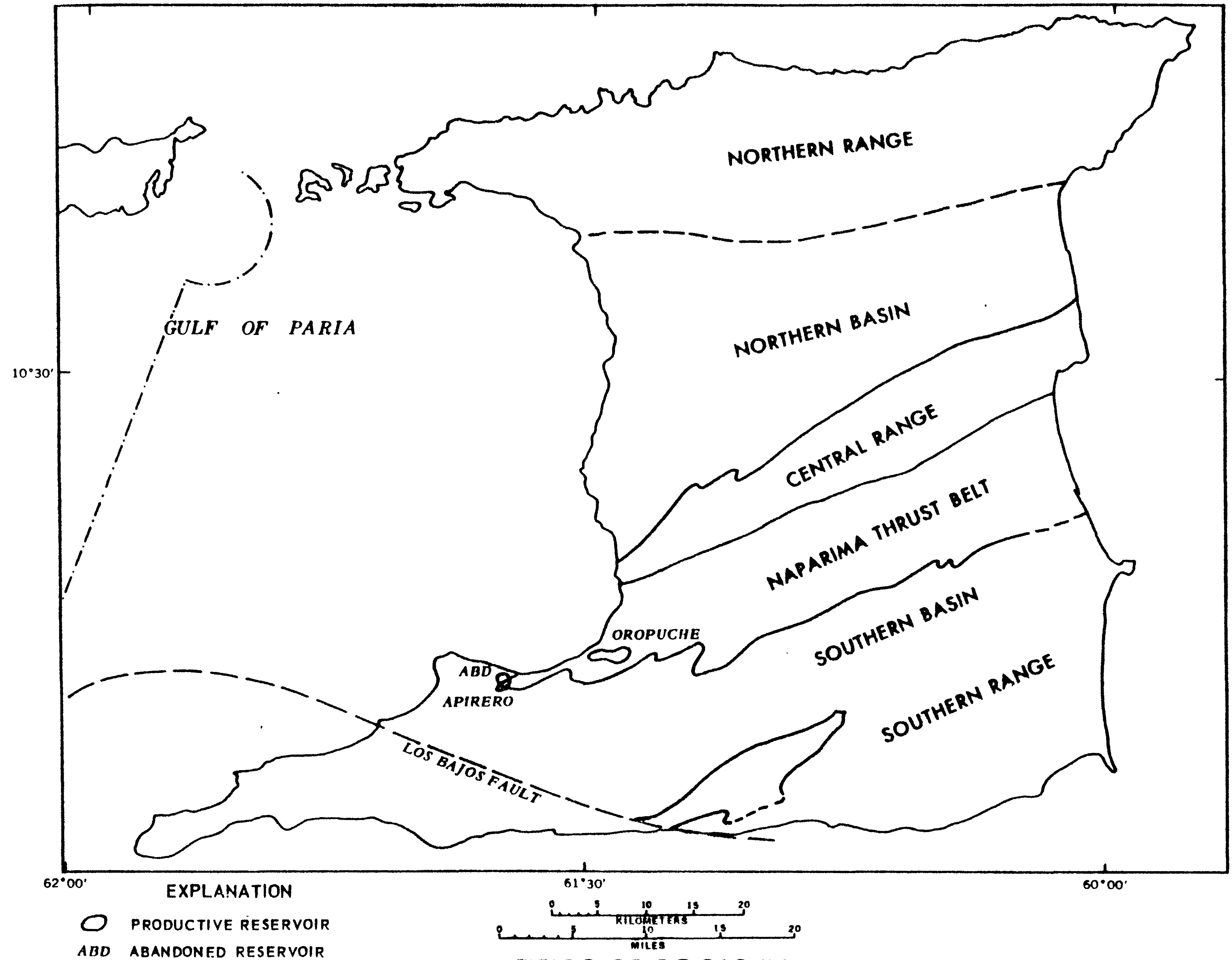



Figure 21

**FIELDS OR POOLS IN RETRENCH SANDSTONE RESERVOIR**

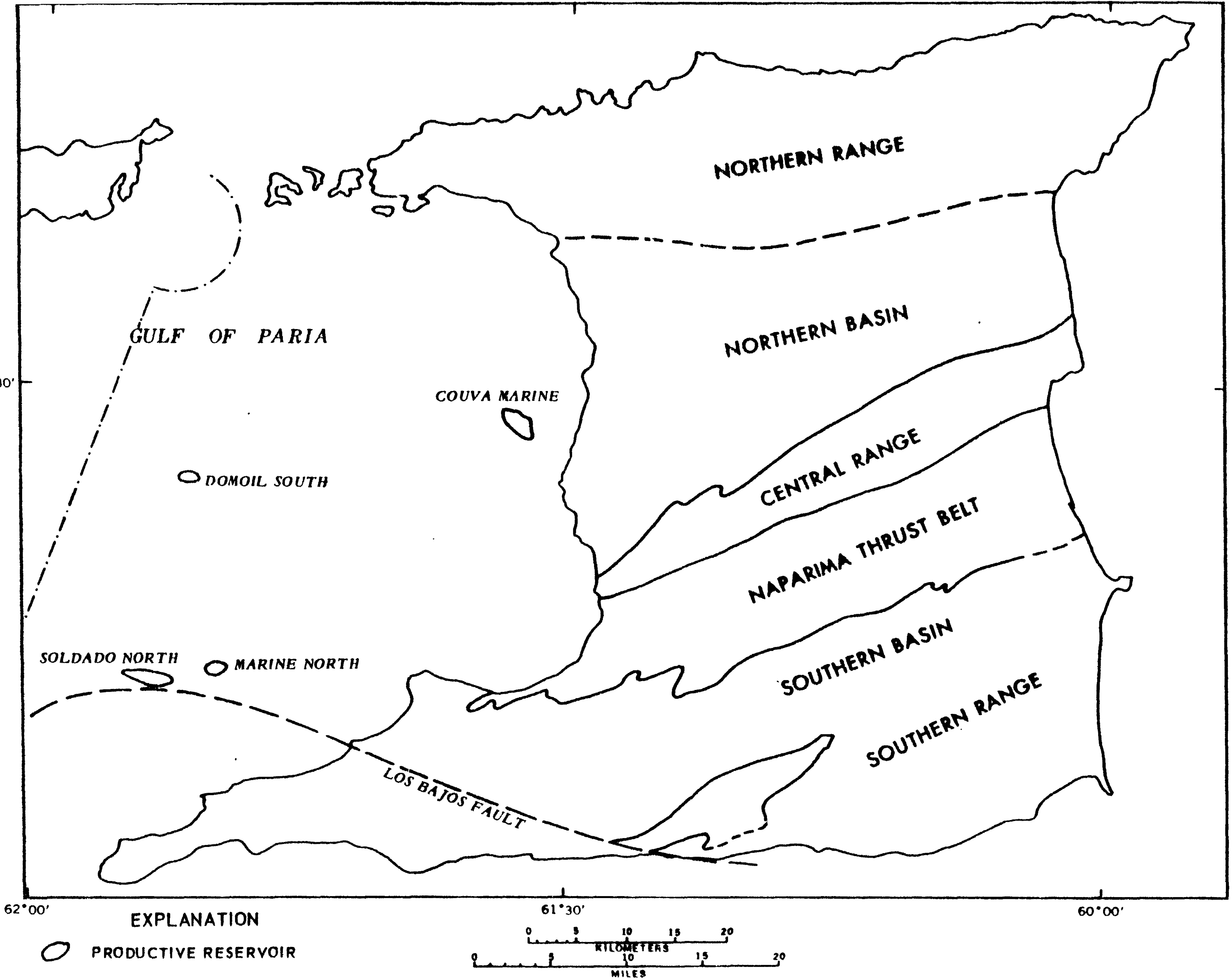



Figure 22

**FIELDS OR POOLS IN MANZANILLA SANDSTONE RESERVOIR**

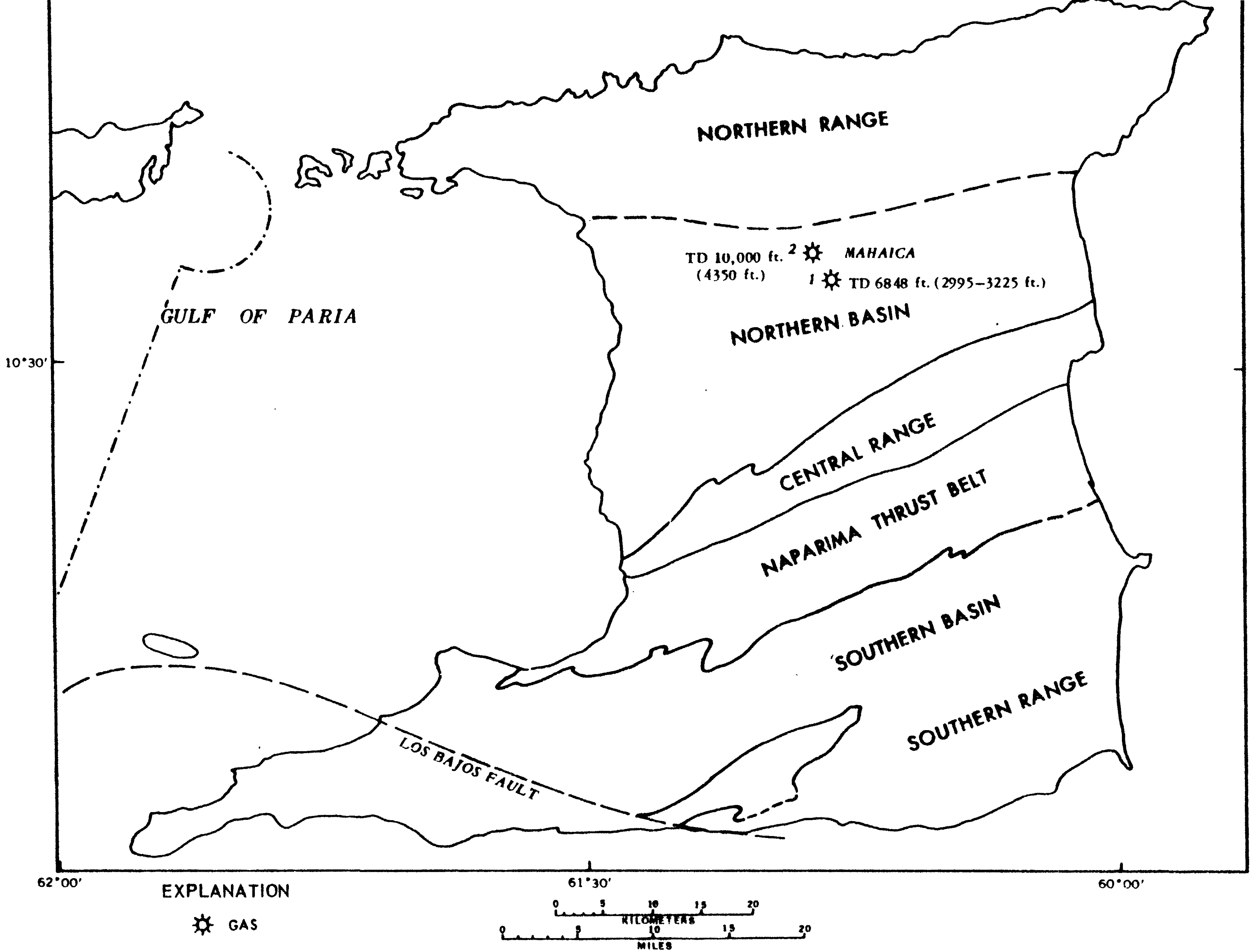
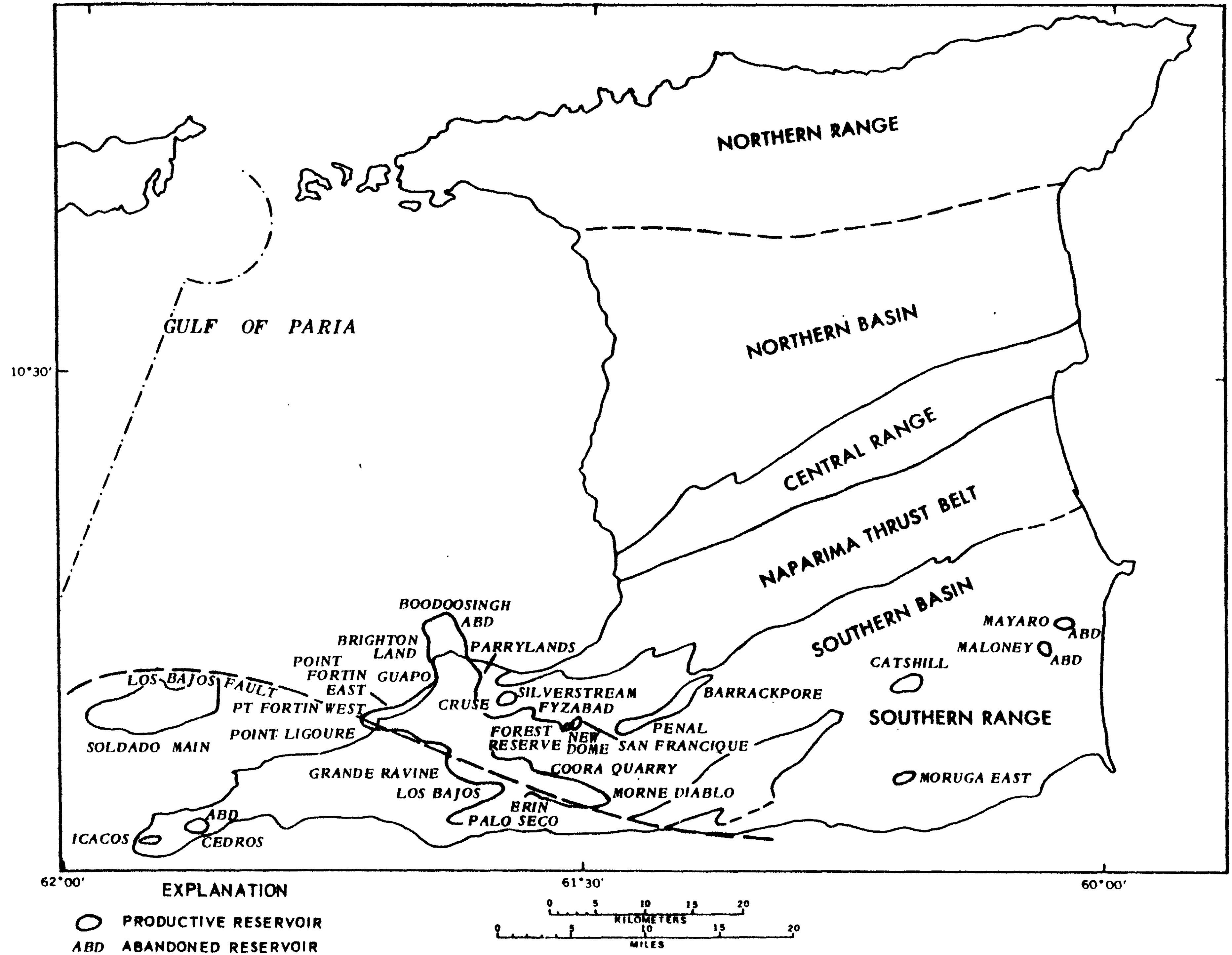



Figure 23

**FIELDS OR POOLS IN SPRINGVALE SANDSTONE RESERVOIR**




EXPLANATION

- PRODUCTIVE RESERVOIR
- ABD ABANDONED RESERVOIR

Figure 24

**FIELDS OR POOLS IN FOREST AND CRUSE RESERVOIRS**

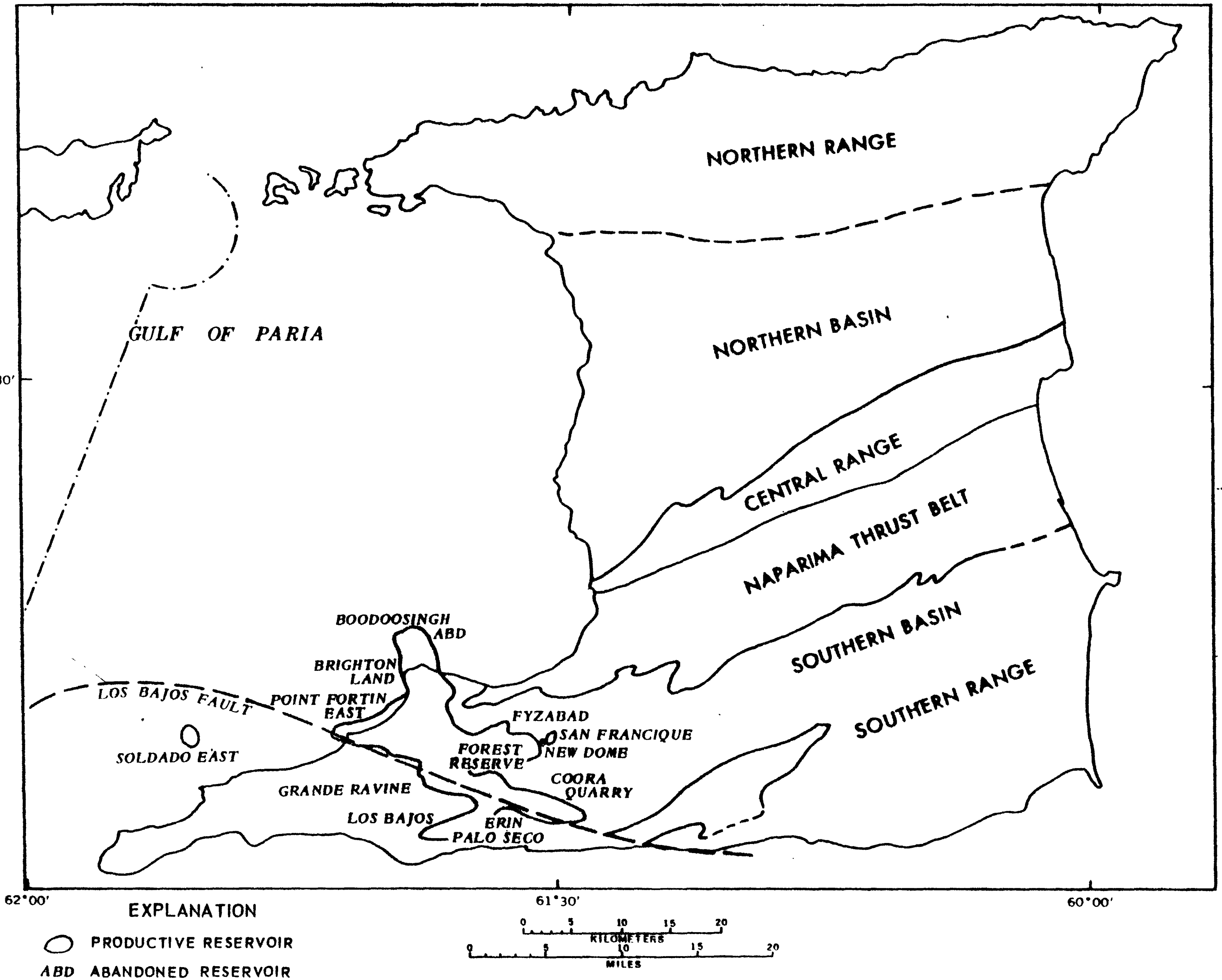
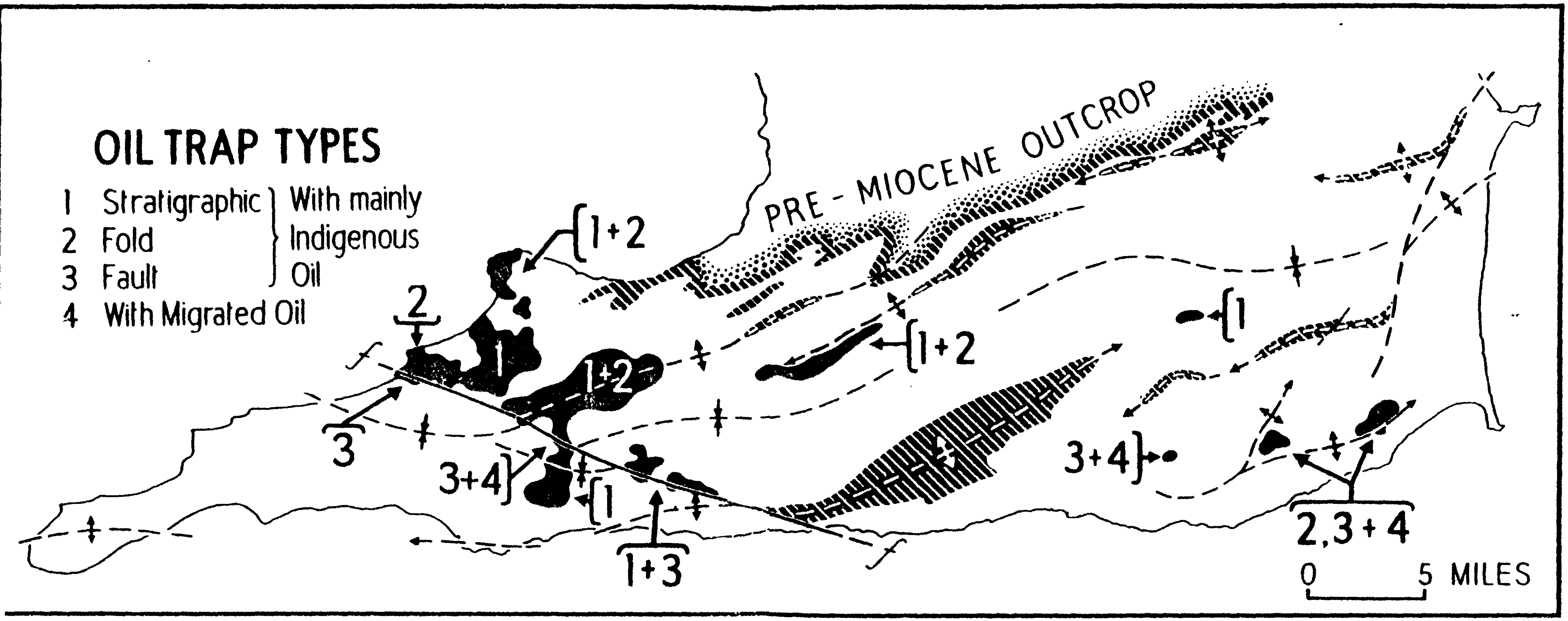



Figure 25

**FIELDS OR POOLS IN MORNE L'ENFER SANDSTONE RESERVOIR**




igure 26

Source: Barr, and others, 1958

Type and distribution of oil accumulation in Trinidad

Cipero Formations are reservoirs in the following fields in the Southern Basin:

| | |
|---|---|
| Parrylands | Tabaquite |
| Brighton-Land | Johnson Road (shut in) |
| Brighton-Marine | Guapo |

The Miocene shales and clays of the Brasso Formation of the Northern Basin and Central Range contain isolated reef limestones on local uplift. No indications of hydrocarbons have been reported either from these reef limestones or sandstones.

Miocene

The Herrera sandstone facies of the Upper Cipero Miocene Formation is an important hydrocarbon producing reservoir. Prolific production from Herrera sandstone occurs particularly in the Penal and Barrackpore Fields. However in the Moruga West Field, the time equivalent facies of the Herrera sandstone are shale. The younger Herrera sandstones found in the south represent the final stages of a shallowing sea and, consequently, are siltier and thinner than the older Herrera sandstones to the north. Herrera sandstones have not proved to contain commercial quantities of trapped hydrocarbons south of the Los Bajos fault.

Herrera sandstone deposition is restricted to the Siperia syncline and ranges areally in thickness from a few feet to over 1,000 feet within a few miles. Chances of large hydrocarbon accumulations occurring in this unit are small because of the irregular occurrence of secondary calcite cementation, which all too often critically reduces reservoir sandstone porosity. Herrera sandstone distribution within the Siparia syncline is restricted to an area between the Mandingo-Penal oil field anticline in the north to the Rock dome anticline in the south.

The overlying Upper Miocene 24 Lengua claystone and calcareous siltstones are void of any sandstones, and therefore this formation has no prospects for hydrocarbons.

Pliocene

In the Northern Basin, the Pliocene Manzanilla sandstone reservoirs are the principal objectives for hydrocarbon possibilities. In addition, the overlying Springvale sandstone reservoirs are producing in the Soldado-North Field, and gas has been produced intermittently from the Mahacia Field.

Sand thickness is greatest at the end of each of the three major sedimentary Pliocene cycles. In these intervals most of the oil accumulations have occurred. Onshore in the Pliocene below the Forest clays, isopach maps show great variations in thicknesses of sandstone thinning northward and a depocenter along the axis of the syncline. The combination of a northward wedging out of sandstones and anticlinal folding has resulted in the entrapment of oil accumulations in the Forest Reserve producing area (figure 27). These same conditions have also resulted in oil entrapment along the southward rising synclinal flank.

Cruse Cycle

Oil is produced from Cruse in southwest Trinidad in three principal areas (Barr and others, 1958):

1. Forest-Reserve-Point Fortin
2. Los Bajos fault zone area
3. Palo Seco area

In the Forest Reserve-Point Fortin area, oil accumulation occurs in combination traps, such as sandstone wedge-outs located on the crest of anticlines as in the Point Fortin and Forest areas. The Los Bajos fault area is an example of hydrocarbon accumulation in Cruse sandstone where

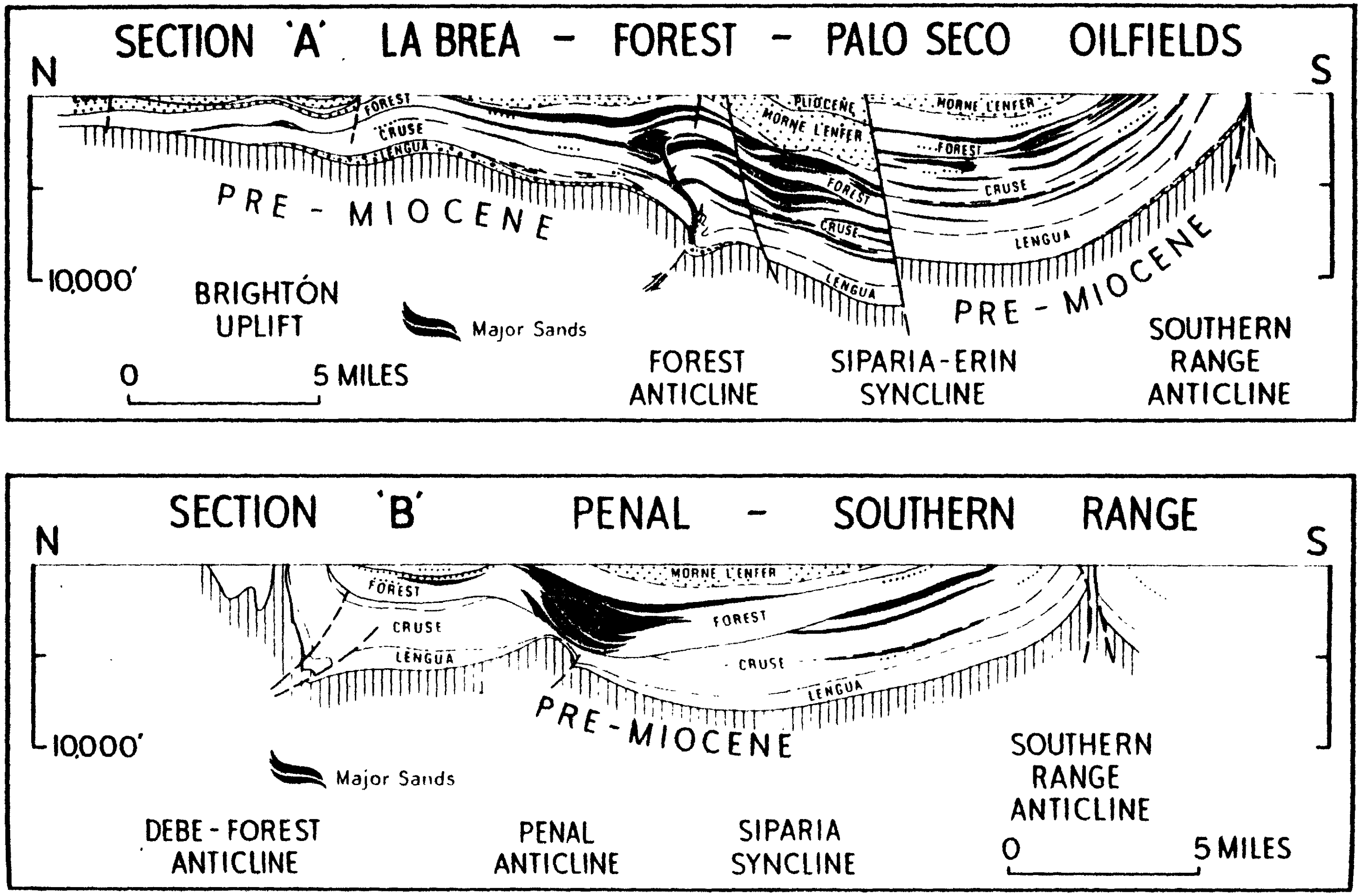



Figure 27 North-south cross sections showing structure and form of southern Trinidad basin. *A* extends from La Brea to Palo Seco oil field; *B* extends through Penal field to the south coast. See fig. 5 for locations of oil fields and structural features.

Source: Barr, and others, 1958

closure is controlled by trend and faulting. Even though the source of Cruse hydrocarbons is indigenous, fault migration together with fault entrapment are significant influences. South of the Los Bajos fault in the Palo Seco producing area, the hydrocarbon accumulations occur in lenticular shaped sandstone bodies.

Forest Cycle

Similar to the underlying Cruse oil reservoirs, the significant Forest oil accumulations are in the southwest, whereas the maximum sand concentrations are in the southeast in the Guayaguayare-Moruga area. Sandstone trends enlongated in a west-southwestward direction are evident in the Forest and Point Fortin producing areas. Although oil in the Penal area is in stratigraphic traps, entrapment of oil in the Forest Reserve producing area is for the most part structurally controlled.

Morne L'Enfer Cycle

Usually the Morne L'Enfer sandstones do not contain hydrocarbon reservoirs. However, the Morne L'Enfer sandstones do contain oil in proximity to the Los Bajos fault. This oil has most likely migrated upward from the underlying Cruse and Forest Formations. The 10° A.P.I. crude is found in the basal Morne L'Enfer section in the La Brea area which may represent a fossil seep.

Moruga Group

The Gros Morne sand and St. Hilaire siltstone members of the Moruga Group are the principal hydrocarbon reservoirs in the offshore area east and southeast of Trinidad. Currently, over 80 percent of the oil and gas production in Trinidad and Tobago is coming from this area. Also, this offshore area has accounted for close to 30 percent of Trinidad's cumulative production.

The Gros Morne Formation, up to 4,500 feet thick, is massive and made up of shales, siltstones and sandstone. The St. Hilaire, which includes interbedded sandstones and shales, is indicative of deposition in a distributary mouth bar. The A.P.I. gravity of the oil ranges from 24° to 29° A.P.I., whereas the reservoir porosities range from 24 to 30 percent and permeabilities average 250 millidarcies.

## Areas of Hydrocarbon Production

The following oil and gas descriptions are representative of different producing areas in Trinidad and Tobago.

Exploration and development in the onshore operations have been difficult because of structural complications resulting from overthrusting and underthrusting that have been compounded by lenticular sandstones and faulting. In addition, many structures are involved with diapirism. Drilling problems include hydration and swelling of surface-active claystone in the shales and the abnormally high pressures. The high number of wells in Trinidad can be attributed to the close spacing of wells, which has been necessary due to the rapid lateral changes from sand to impervious siltstone or shale (Ablewhite and Higgins, 1965).

### Offshore-South and East Trinidad

The following fields in the aggregate have cumulative production close to 300 million b/o from the Moruga Group (Personal Communication, DOE, Dallas):

| Field | Producing Formation |
|---|---|
| Galeota | St. Hilaire<br>Gros Morne |
| Teak | Gros Morne |
| Samaan | Gros Morne |
| Poui | Gros Morne |

Teak Oil and Gas Field

This field is located 25 miles off the southeast coast of Trinidad. Development drilling in the area of this field located on a broad asymmetrical anticline shows that the feature is traversed by numerous antithetic and synthetic normal faults. A typical well in the Teak field penetrates from four to five faults. One fault system has a 4,000-foot throw; another fault has a 400-foot throw. The larger fault system probably acts as a barrier which traps migrating oil, whereas another fault system traps migrating gas. Faulting in the area occurred recently and may in part be due to wrench faulting as well as to deposition. The trapping mechanism in this offshore area, unlike that found in onshore producing areas, divides the producing reservoirs into many separate pools. The 17 producing sandstone reservoirs are from 20 to 500 feet thick and at depths of between 4,000 to 14,000 feet. Sandstone thickness decreases with depth. These faults conspicuously alter reservoir parameters; for example, between fault blocks a variation in edgewater is recognized, also reservoir pressures and gas-oil ratios. At Teak, deeper shales are believed to be the source of the hydrocarbons which migrated upward via deep-seated conduits.

Galeota Field

This field is located on an anticlinal trend that extends from the onshore Beach field in the southwest through the Galeota Field and then east-northeast through the Samaan Fields. This anticlinal trend developed during the Late Oligocene-early Miocene times (Gabriel, 1979). The producing reservoirs are the St. Hilaire siltstones and Gros Morne sandstones of the Moruga, which in this case are time equivalent to the Middle and Upper Cruse Formations. Galeota East No. 2 well flowed 1,040 b/d of crude oil from a 60-foot pay zone below 3,580 feet and tested a total of 22.74 mm cf/d of gas, plus small quantities of condensate, from three lower reservoirs (Quarterly Economic Review, 1st Quarter, 1979). The deepest well in the field was drilled to a subsea depth of 10,200 feet and produces from depths ranging from 450 to 4,500 feet. Another offshore well in this area, Ibis No. 3, tested at rates between 1,522 and 2,020 b/d of 38° A.P.I. crude oil, with gas rates between 4.7 and 5.9 mm cf/d of gas.

Smaller structures, some of which appear on seismic records in the Galeota area, have not been drilled. The areas southeast of the area west of Galeota have further development potential, as does the area east of the Teak Field.

General Comments on this Offshore Area

The major structure alignments in this area are northwest-southeast, which contrasts with the east northeast-west southwest structure trends (figure 22). In an eastward direction offshore, subsea outcrops of sedimentary rocks become progressively younger so that the furthermost sandstones are Pleistocene. Even though the Pleistocene rocks are 12,000 to 15,000 feet thick, these rocks contain a lesser amount of sandstones than formations to the west. These Pleistocene sandstones are gas bearing as evidenced by the Dolphin and Queens Beach gas Fields. The Poui and Teak Fields produce both oil and gas on seismic records. There is no expression of an eastward offshore extension of the Los Bajos fault in the Pliocene and younger formations. However, Miocene strata below the depth of seismic penetration may be offset by an offshore extension of the Los Bajos fault. No development activity of any significance has taken place in the offshore area south of the possible extension of the Los Bajos fault. In all probability Tertiary deposits become more continental southward as the Guayana shield is approached.

In the offshore area east and north of Trinidad, Miocene sediments were deposited unconformably on Cretaceous rocks as evidenced by the data in the NB-2 well. In this area the Cretaceous formations appear to have been subject to low-grade metamorphism (Kugler, 1953; Suter, 1960). This offshore area is an extension of the Northern Basin.

Offshore Area Adjacent to Tobago and Trinidad
Margarita-Tobago Platform

This province extends from Trinidad and Tobago waters westward into Venezuelan waters and is known as the Margarita-Tobago platform or the Tobago trough. Several structural closures favorable for hydrocarbon accumulation are located on the northern flank of the trough. Sedimentary rocks include clastic rocks deposited in prograding shelf and shallow marine environments. On seismic records a series of reef-like anomalies appear along the basin hinge for a distance of about 60 miles. In the deepest part of the basin data suggests that the sedimentary rocks are about 20,000 feet thick. Keller and others (1972) suggest two primary sources for the deposits in this trough, one from the proto-Orinoco River to the south and another from the southwest along the northern Venezuelan margin.

Twelve wells have been drilled in the Trinidad and Tobago portion of this offshore basin. The following results have been obtained from the drill hole data: The LL-9 well was drilled to a total subsea depth of 7,059 feet on an anticline subsurface expression. The deepest offshore well has been drilled to a subsea depth of 14,550 feet. The LL-9 well tested Tertiary (probably Eocene) gas reservoir at about 37.5 million cf/d of natural gas, which depleted rapidly during testing.

The Tobago trough is part of the Antillean arc-trench system, which is marked by a sharp gravity anamoly at the eastern margin of the Caribbean plate. At this location, sedimentary rocks have been highly disturbed by the convergence of the Atlantic and Caribbean plates. This compression, which caused the complex deformation of the strata together with probable high heat flux from a trench regime, is interpreted by Walper (1980, p.906) as unfavorable factors for significant hydrocarbon potential. Notwithstanding these unfavorable considerations, a significant gas discovery, Pateo No. 1 well, tested 24.5 mm cf/d of gas. This well is located north of the Paria peninsula in the Venezuela portion of the Tobago trough. The Pateo well may be located on an extension of the structure, KK4 and LL-9-1, containing the gas fields discovered offshore from Trinidad (Quarterly Economic Review, 2nd 1980).

In the Venezuelan portion of this Margarita-Tobago Trough, Lagoven, a Venezuelan oil company, says that four of six wells have tested natural gas in volumes assessed as potentially commercial. Lagoven's resource estimate ranges up to 20 Tcf. On the basis of these results and resource estimates, Petroven, another Venezuelan oil company, is resuming operation in the Venezuela portion of this offshore Trough.

Southeast Onshore Trinidad

Fields in this area have been producing from the Pliocene Gros Morne and Miocene Herrera sandstone. These reservoirs are lenticular shaped sandstone bodies in faulted anticlines. Future oil and gas prospects in this area are limited due to the fact that those sandstones encountered by recent onshore drilling have been found to be water bearing. The Gros Morne reservoirs become increasingly gas prone going north and east. Considering that the Roseau well, north of the Navette Field, tested gas from only 17 feet of the Lower and Middle Gros Morne Formation, it can be reasonably assumed that the Gros Morne sandstones shale out northward and westward from the Navette Field.

Representative oil fields in this area and field parameters* include:

| | | | |
|---|---|---|---|
| Beach | Lizard | Goudron | Navette |
| Moruga North | Innis | Moruga West | Balata East |

| Net Pay Thickness | Producing Formation | Porosity Permeability | Deepest Depth Drilled |
|---|---|---|---|
| | Moruga North, Innis, Trinity Fields | | |
| Av. 160' | Herrera | 14-34% (av. 22%) | -7,893' |
| | Beach Field | | |
| Av. 275' | Gros Morne | | -9,023' |
| | Goudron Field | | |
| Av. 150' | Goudron SS | av. 25% (90-700md) | -6,500' |
| Av. 150' | Gros Morne | 24% (10-520 md) | |
| | Navette Field | | |
| Av. 250' | Gros Morne | (av. 520 md 24% (2-700 md) (av. 70 md) | -6,772' |

* Field porosities average 24 percent; permeabilities range from 2 to 700 md. (av. 70 md), and sands wedge to the north of the fields (reservoir limited to the south by edges water)

South of the Los Bajos Fault

Oil traps in this area are essentially stratigraphic, but those nearby the Los Bajos fault may have been an influencing mechanism. Future oil development appears to be limited south of this fault because the regional oil/water contact in these sandstones is relatively close to this fault, that is except for the producing area. The Herrera sandstone south of the fault is silty and lacks reservoir porosity and permeability conducive for oil and gas accumulation. Representative oil fields in this area and related data include (Jones, 1965):

| Net Pay Thickness | Producing Formation | Depth to Reservoir | Deepest Subsea Depth Drilled |
|---|---|---|---|
| | Grande Ravine Field | | |
| Av. 440' | Morne L'Enfer | 1,200' to 6,000' | 12,718' |
| Av. 145' | Forest | 3,000' to 7,500' | |
| Av. 90' | Cruse | | |
| | Palo Seco-Los Bajos-Erin Fields | | |
| | Morne L'Enfer Forest & Cruse | 15' to 7,500' | 11,557 |

Areas adjacent to and north of the Los Bajos Fault

The Los Bajos fault has been an important factor that has influenced oil accumulations and has resulted in the major onshore producing area in Trinidad and Tobago. The significant producing areas in this vicinity include the: Forest Reserve-Fyzabad Apex Area, the Point Fortin East Area, and the Guapo Field.

Forest Reserve Field (figure 6)

Deepest well drilled to a subsea depth of 13,082 feet into Lower Miocene Upper Cipero sandstones.

Producing reservoirs and minimum subsea depths to these reservoirs (Same for Fyzabad) Morne L'Enfer, 50 feet; Forest, 150 feet; and Cruse, 1,500 feet.

Range of producing intervals: 50' to 8,300'
Approximate number of wells drilled: 2,600
Reservoir characteristics: Cruse sands 30 percent porosity
permeabilities 600 to 8,300 md range
formation waters: average 21 percent
crude oil A.P.I. gravities: 11° to 50°

Fyzabad Apex Field

Deepest well drilled to a subsea depth 16,169' into Eocene Navet formation. Producing reservoir characteristics: similar to those in the Forest Field; total number of wells about 700. Both producing areas are the result of anticlinal control of lenticular shaped sandstone bodies.

Point Fortin Field

The hydrocarbon entrapment in this area is the result of lenticular shaped sandstone bodies and deltaic sandstones that are controlled by the Point anticline, a series of thrusts and normal faults, and most important the right lateral strike-slip Los Bajos fault. Whether or not a particular sand reservoir is hydrocarbon bearing depends on its structural position, especially the position of the sandstone reservoir relative to the Los Bajos fault.

Approximately 25 million b/o remain to be recovered from this field; this recovery can be increased by enhanced recovery techniques such as water flooding and thermal methods in field areas south of the Los Bajos fault, and possibly north of the fault in deeper pre-Cruse sandstones. Characteristics of the producing formations in this area include:

| Net Pay Thickness | Producing Formation | Deepest Subsea Depth Drilled |
|---|---|---|
| over 250' | Morne L'Enfer<br>Forest<br>Cruse | 11,042' |

Guapo Field

Over 97 percent of hydrocarbon production from the Guapo field has come from the Pliocene Cruse sandstones. The crude oil averages 14° A.P.I.; reservoir sandstone porosity averages 33 percent; and permeabilities average 450 millidarcies. Oil was entrapped in lenticular shaped sandstone bodies that lie along a fault pattern which developed perpendicular to the anticlinal axis. Future production of the Guapo Field will require use of enhanced recovery techniques to increase production of the heavy oil in the Upper Cruse sandstones. Characteristics of the producing formations in this field include:

| Net Pay Thickness | Producing Formation | Depth to Reservoir | Deepest Subsea Depth Drilled |
|---|---|---|---|
| Av. 250' for all reservoirs | Forest & Cruse Nariva | 200' to 4,000' | 10,625 |

Brighton Marine and Brighton Land Fields

Whereas the Pliocene Morne L'Enfer Formation sandstones (maximum thickness of 1,500 feet) and Forest/Cruse sandstones produce onshore, Oligocene-Miocene Nariva sandstones produce both onshore and offshore. Whereas the typical Forest and Cruse sands are well sorted and fine grained, the Nariva quartzose sandstones have a wider range of grain size from coarse to fine grained. The Nariva Formation has a gross thickness of about 5,000 feet. Hydrocarbon prospects in the Nariva sandstones are controlled by the 10 to 22 percent siltstone and claystone fractions. These silt and clay fractions result in a range of permeabilities from 20 to 1,750 millidarcies; correspondingly, Nariva sandtone porosities range from 19 to 29 percent. Other Nariva sandstone reservoirs reflect similar reservoir parameters. Oil production is from lenticular shaped sandstone bodies controlled by a thrust faulted anticline that trends northeast from the Soldado Field in the Gulf of Paria.

## Other Producing Areas North of the Los Bajos Fault
## The Barrackpore Anticline
## Penal, Siparia, Los Naranjos & Mandingo Group of Fields

Oil production in this area has come from lenticular shaped sandstone reservoirs in highly compressed elongated anticlines located on the north flank of the Siparia syncline. These anticlines become more complex at depth where thrusting and recumbent synclines are recognized. Producing reservoirs are the Forest and Herrera sandstones; Cruse sandstones were not deposited in this area but were deposited to the south and east. Future hydrocarbon prospects are limited to the north and east of these areas because of a thinning of the Pliocene sedimentary rocks.

Drilling has been continuous as deeper reservoirs have been discovered down to a subsea depth of 10,000 feet. The complex and strong pre-Lengua folding with concomitant faulting and thrusting precludes the localization of hydrocarbons in any significant quantities below Miocene Herrera-Lengua formations.

New Herrera sandstone reservoirs continued to be discovered from 1911 through 1958 as the structural interpretation of the subsurface became more fully understood. Now, Herrera sandstones have limited future hydrocarbon potential as all Herrera sandstone production has come from reservoirs on structures that are located along the rim of Herrera sandstone deposition (see figure 10), and most of these structures have probably been discovered.

Those wells that have drilled into the pre-Upper Cipero formations have encountered claystones and marls for the most part which are not suitable reservoirs. The Eocene marls have yielded poor results when tested even though the cores have been strongly impregnated with oil. Condensate has been produced from a 50-foot sandstone at the base of the Karamat claystone in the Siparia Field (Kugler, 1953).

Although the Cruse Formation attains a maximum thickness of 4,000 feet in the Barrackpore area, it is only 600 feet near the crest of the anticline. The overlying Forest Formation with a maximum thickness of 3,000 feet has an increasing sandstone porosity from Barrackpore westward to the Penal Field Reservoir parameters in this producing area include:

| Net Pay Thickness | Producing Formation | Depth to Subsea Reservoirs | Deepest Subsea Depth Drilled |
|---|---|---|---|
| Av. 250' | Forest | 500 to 3,500' | 10,500' and 11,067' (Oligocene Cipero) |
| | Herrera | | |
| 300-400' | (Overthrust) | | |
| 1,300' | (Intermediate) | 3,000' to 10,000' | |
| 1,000' | (Underthrust) | | |

Porosities in the Herrera sandstone reservoir range from 10 to 30 (average 25) percent and decrease with depth; permeabilities range from 150 to 500 millidarcies. Whereas the A.P.I. gravities of Herrera crudes range from 19° to 45°, the sulphur content ranges between 0.14 to 0.81 percent.

Northern (Caroni) Basin

The Northern (Caroni) Basin has been explored both by seismic mapping and exploratory drilling, particularly from 1953 to 1957. The exploratory well Mahaica No. 1 tested gas from Pliocene Springvale sandstones in the subsea interval 2,995 to 3,225 feet. The well had been suspended at a total depth of 6,841 feet. Mahaica No. 2 was drilled subsequently to a total depth of 10,000 feet and tested gas at the subsea depth of 4,350 feet, presumably from a new reservoir (World Oil, August 15, 1956, p. 218-222). During 1956, six additional exploratory wells were drilled in this Northern Basin; all were abandoned. Isolated Miocene Pliocene Manzanilla sandstone reservoirs were penetrated subsequently in the Gulf of Paria portion of the Northern Basin at the Cova Marine and at Domoil S. Fields. The South Domoil No. 1 well tested 1,000 b/d of 45°-47° A.P.I. oil from flow through perforations at subsea depths of 9,340 to 9,370 feet, after having been drilled to a total depth of 11,337 feet. South Domoil No. 2 well was drilled to a total subsea depth of 9,957 feet. All other drilling for Manzanilla sandstones has not been successful.

Most of the Northern (Caroni) Basin has limited oil potential because the Tertiary sedimentary rocks were not deeply buried. The temperatures to which the rocks were subjected, therefore, were too low to have generated hydrocarbons in any appreciable amounts (Hunt, 1979). Also, the depth of burial of the sedimentary rocks in the Northern Basin was much less than the burial depths to the south in the Southern Basin and Range. As the Northern Basin deposits originated for the most part from the north, i.e., North Range and Coastal Range of Venezuela, the amount of sedimentation was correspondingly less in the Northern Basin Central Range areas than it was to the south. The underlying Cretaceous formations have been metamorphosed to varying degrees.

In addition, a great discontinuity and lenticularity exist in sandstone deposition together with stratigraphic unconformities which diminish the prospects for finding hydrocarbons in any appreciable quantities (Galaviss and Louder, 1971).

The average A.P.I. gravity for produced oil is 30°. The average sandstone reservoir is 200 feet thick and produces from subsea depths of 1,500 feet along the anticline crest to over 6,500 feet subsea along the flanks. One well drilled to 14,222 feet into the Upper Cretaceous black shale Gautier Formation. In addition to the 3,500 feet of the Cretaceous Naparima Hill and Gautier Formations penetrated, the well drilled through 3,000 feet of Brasso-Cipero and Nariva Formations. None of these formations contained the necessary porosity and permeability to become hydrocarbon reservoirs.

North Soldado Field (Figure 28)

This field, located north of the Los Bajos fault in the Gulf of Paria, is in the Northern Basin. Production is from the Pliocene Manzanilla sandstone Formation. Although the gross thickness of the Manzanilla Formation in this field ranges from 80 to 1,700 feet, it is known to thin rapidly to the north and west of this field. Average porosity is 30 percent, and the crude oil gravities range from 8° A.P.I. to condensate, averaging 19° A.P.I. Although the Manzanilla sandstones are the main reservoirs, the overlying Springvale sandstones are important reserves in the western part of the field. Structurally this field is in a wedge-shaped graben which was formed contemporaneously as the reservoir sands were deposited. Figure 28 compares the stratigraphic section of the North Soldado Field with the main and east Soldado Fields south of the Los Bajos fault and in the Southern Basin.

Soldado Field-Main

This field, immediately south of the Los Bajos fault, covers over 5,500 acres. This field has been developed on the south flank of the Soldado Anticline that trends west-southwest for 10 miles. The Los Bajos fault abruptly cuts off this anticline in the northeast. The Cruse sandstones are the principal reservoirs; the overlying Forest sandstones have provided only minor production. Although the average reservoir porosity is 27 percent, the shale and silt fractions that constitute 20 percent of the reservoir reduce reservoir permeabilities to a range from 5 to 75 millidarcies.

## SOLDADO FIELDS
## GENERALIZED GEOLOGIC SUCCESSION

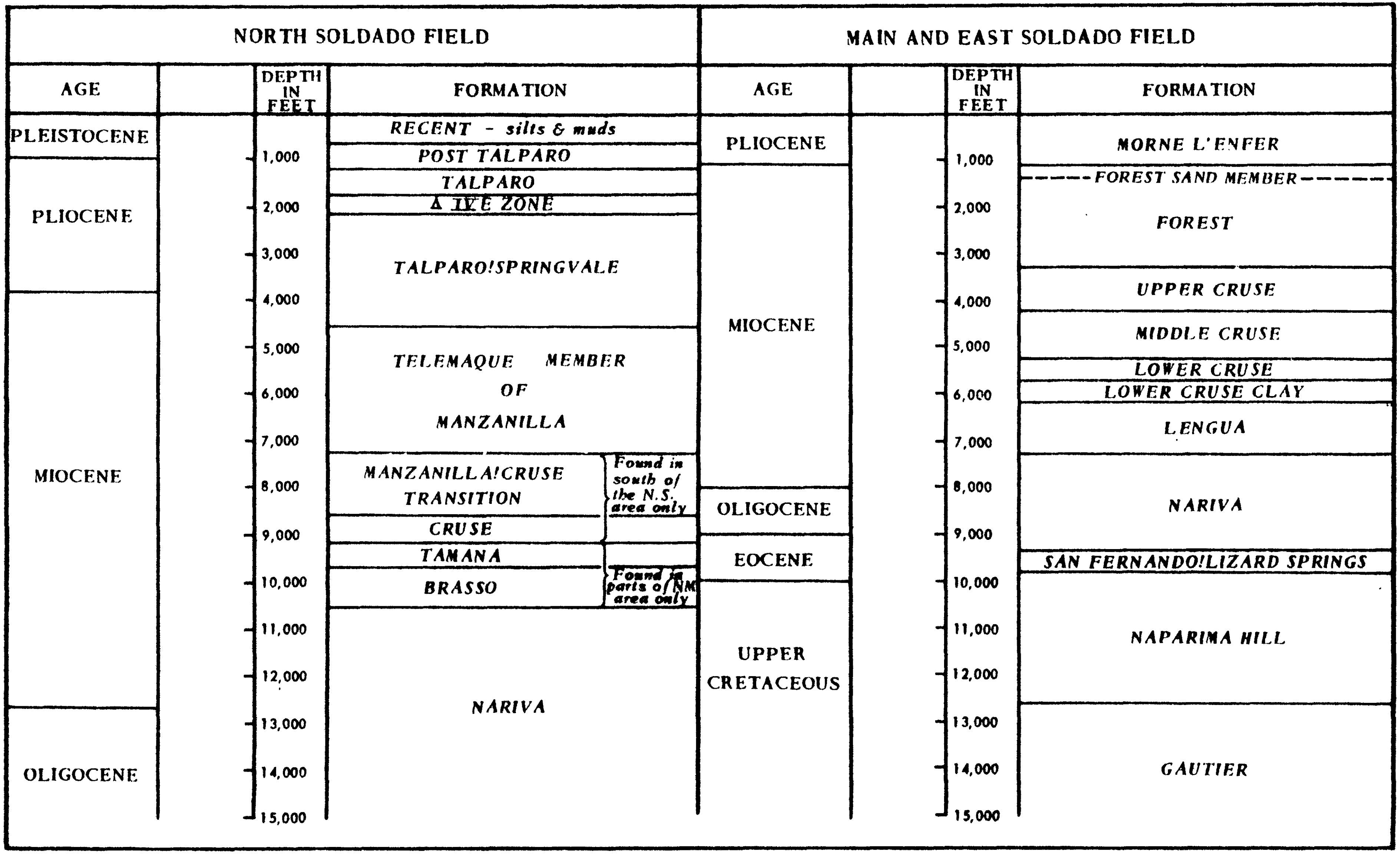



Figure 28

Source: Kugler, (1953), and Radovsky and Igbal, (1979) Observations - Summary

1. Future oil and gas discoveries can be expected in the offshore areas surrounding Trinidad and Tobago.
2. Over 80 percent of current production now comes from these offshore areas.
3. Onshore petroleum production, which began in 1914, has passed its peak and is declining.
4. Almost all of the petroleum production in Trinidad and Tobago has come from Miocene and younger formations. Most of this production has come from sands in the Cruse and Forest or age equivalent rocks.
5. Possible pre-Miocene reservoirs have limited or no prospects because of extreme depths of burial and metamorphism. Porosities and sand content of these rocks are low.
6. The Los Bajos fault, with a maximum of 6.5 miles horizontal displacement, is the most significant onshore regional structure that influenced the accumulation of petroleum in Trinidad.
7. Although many regional stratigraphic similarities exist between eastern Venezuela and the Trinidad and Tobago area, the latter remained a mobile belt longer. Therefore, the mode of oil and gas entrapment was structurally more complex in Trinidad.
8. Mud diapirs and mud volcanoes are associated with many onshore and offshore structures in Trinidad and Tobago. These features do not extend into Venezuela, with the exception of the Pedernales area.
9. Most of the Northern (Caroni) Basin and Central Range have only limited hydrocarbon potential. This potential is limited to small amounts of gas; i.e., Mahaica. The sedimentary rocks are buried at shallow depth, and

therefore hydrocarbons would be limited to biogenically generated methane gas.

10. The Margarita-Tobago area has at least 20,000 feet of sedimentary rock. Thick sedimentary rock cover extends westward into the waters north of Venezuela where sizeable amounts of gas have been discovered. Discoveries have been made in the area north of Trinidad in Eocene sands.

Appendix 1. - Deep wells in Trinidad and Tobago

| Field | Geological Province | Maximum Depth Drilled | Structure | Bottom Hole Formation | Depth to Producing Formation | Producing Formation |
|---|---|---|---|---|---|---|
| **MARGARITA-TOBAGO TROUGH** | | | | | | |
| 1. KK-4 Well | Norther Trinidad Atlantic Shelf | 14550' | Anticline | Tertiary | | |
| 2. LL9-1 | Norht Trinidad Atlantic Shelf West, W-N of Tobago | 7059' | Anticline | Tertiary | Dry Hole | Tertiary |
| **NORTHERN BASIN** | | | | | | |
| 3. Coura Marine Bovallius | Northern; Gulf of Paria | -12192 | Anticline | Lower Cipere Oligocene | -2500' to -4500' | Manzanillr SS Miocene |
| 4. Domoil South | Northern Basin Gulf of Paria | 11387' | Faulted Anticline | Cuche Lower Cretaceous | -8,700' to 9,600' gas condensate | Manzanilla SS Miocene |
| 5. Marine North | Northern Gulf of Paria | below 15,000' | Structure | | -3,0000to -15,000' productive range | Manzanilla SS, Miocene |
| **CENTRAL RANGE** | | | | | | |
| 6. Balata-Central | Central Basin | 9426' | Anticline | Upper Cipero Lower Miocene | -2500 to -4500' | Herreral sandstone abr. P. Ciper |
| 7. Point Fortin West Central | Central Basin | 11042' | Faulted Anticline lenticular sands | Upper Cretaceous | -1,500 to -1,500' | gas show, offsetting commerical gas well FF4 well |
| 8. Balata-East Bovallius | Central Basin | 6193' | Anticline | Lower Cipere Oligocene | -2500' to -4500' | Producing fm, Forest and Cruse |
| 9. Marine North | Northern Basin Gulf of Paria | below -15000' | Structural | Middle Cipero SS Oligocene | Forest -200' Cipero: -2500' | Forest (Wilson SS mbr). L. Mioce |
| **SOUTHERN BASIN** | | | | | | |
| 10. Barrackpore-Wilson | Southern | -11,067' | faulted plus trust Anticline; lenticular sands | | -2887' to 3200' | Upper Cruse: Upper Miocene |
| 11. Icacos | Southern; extreme Western tip of island | -7515 | Strucutre Stratigraphic | Upper Cipero | 500 to 4500' | Herrera SS of U. Cipero lwr Miocene |
| 12. Moruga North-Inniss-Trinity | Southern south central part of Island | -7833 | thrusted, faulted anticline | U. Cipero Miocene | 3500 to 6000' | Herrera Mbr.-U. Cipero Lower Miocene |
| 13. Mandingo-Las Naranjes | Southern | -7833 | complex folded faulted anticline | Cretaceous Gautier Formation | -500 to 2100' | Morne L'Enfer Forest & Cruse |
| 14. Brighton-Land and Marine | Southern | -10865 | Anticline lenticular sandstone | Upper Cretaceous | 100 to 7000' most production -3500 Forest/Cruse | Morne L'Enfer Forest & Cruse |
| 15. Cooua-Quarry | Southern-along the Los Bajos Fault | -13471 | faulted controlled lenticular sands | | | |

Source: Petroconsultants: Geneva, Switzerland, 1980

| Field | Geological Province | Maxumum Depth Drilled (ft.) | Structure | Bottom Hole Formation | Depth to Producing Formation | Producing Formation |
|---|---|---|---|---|---|---|
| 16. Grand Ravine | Southern-along the Los Bajos fault | -12718 | lenticular sands on faulted syclinal limb | Karamat Miocene) | 1200 to 6000 U.M. -3000 to 7500' -4500 to 10500' | L. Morne L'enfer M. Miocene Fores M. Mi. |
| 17. Los Bajos Fyzabad | Southern-immediately adjacent N & SLos Bajos Ft. | -12413 | faulted anticline lenticular sands | Upper Cipero Miocene | -500 to 6800' | Morne L'Enfer Forest & Cruse |
| 18. Palo Seco-Los Bajos-Erin | Southern-immediately adjacent to Los Bajos fault | -11557 | lenticular sands of anticlinal flank | Karamat SS Miocene | 15 to 7500' | Morne L'Enfer Forest & Cruse |
| 19. Forest Reserve | Southern-immediately adjacent to Los Bajos Fault | -13082 | Anticlines stratigraphic mud folwa unconformities | Upper Cipero Miocene | -50 to -8300' | Morne L'Enfer Forest & Cruse |
| 20. Fyzabad (Apex) | Southern | -16169 | Anticlines-lenticular sands | Navet sandstone Eocene | -50 to -8500' multiple pays | Morne L'Enfer Forest & Cruse |
| 21. Soldado East | Southern Basin Gulf of Paria Offshore | -7074 | Faulted anticline | | | Morne L'Enfer Pliocene U. Miocene |
| 22. Parrylands | Southern Basin | -10626 | Anticline with lenticular sands | Soldado (Paleocene) | -1,000 to 5,000' multiple reservoirs | U.M. Miocene Forest/Cruse L. Miocene Nariva |
| 23. Guapo | Southern Basin; part onshore; part offshore | -6000 | lenticular sands synclintal structure | Navet (Eocene) | -2,000 to -4,800' multiple reservoirs | forest U. Miocene Cruse M. Miocene Nariva L. Miocene |
| 24. Moruga East | Southern Basin | -11448 | very lenticular sand on structural high | Gautier Cretaceous | -50 to -9,300 multiple reservoirs | Forest/Cruse U. Miocene |
| 25. Soldado Main | Southern Basin Gulf of Paria | -14622 | faulted anticline | Gautier Cretaceous | -750 to -6,500' 4 major pays in Cruse | U. Miocene Forest & UM Cruse |
| 26. Fyzabad | Southern Basin | -9960 | Anticline w/ lenticular pays | Cipera Miocene Oligocene | multiple pays -150 to 3,300' | Upper Miocene Forest/Cruse |
| 27. Morne Diablo-Quninam | Southern Basin | -13471 | lenticular sands on faulted anticline | U. Cretaceous | -200 to 3,900' multiply pays | Forest & Cruse U.& M. Miocene |
| 28. Catshill | Southern Basin | -9109 | stratigraphic minor structural | Upper Cipero Miocene | -1,400' to 2,800' multiple pays | Forest & Cruse Upper Miocene |
| 29. Penal | Southern Basin | -10500 | Diapiric anticline normal and thrust faulting | Navet (Eocene) | -500 to 3,500' -2,500 to -10,500' | Forest, U. Miocene Herrera mbr. U. Cipero (lwr Miocene) |
| 30. Oropuche | Southern Basin | -9077 | Anticline w/lenticular sands | Navet (Eocene) | -650 to 4,400' multiple pays | Retrench sands of Upper Cipero |
| 31. Tabaquite | Southern Basin | -6519 | Fault trap w/ lenticular sands | Lower Cipero | -200 to 2,000' Multiple pays | Nariva-lwr Miocene U. Oligocene |
| 32. Forest Reserve | Southern Basin | -13082 | Anticline w/ mudflow lenticular sands | Upper Cipero Miocene | -50 to 8,300' multiple pays | Morne L'Enfer Forest & Cruse |

| ield | Geological Province | Maxumum Depth Drilled | Structure | Bottom Hole Formation | Depth to Producing Formation | Producing Formation |
|---|---|---|---|---|---|---|
| | SOUTHERN RANGE | | | | | |
| . GBM | Southern Range Offshore Trinidad | -10,000 | Anticline | L. Gros Morne Miocene | | L. Gros Morne SS Miocene |
| . Beach | Southern Range | -9023 | Faulted diaptroid anticline | | -450' to 4,5--' miltiple pays | St. Hilaire-Gros Morne Miocene |
| . Galeota eastward exten. Guayaguayare-Beach anticl/ | /Southern Range /Offshore Trinidad | -10,200 | Anticline | Naparima Hill Cretaceous | -250 to -4,500' with 7 pay zones | Gros Morne Upper Miocene |
| . Navette | Southern Range | -6772 | faulted closure, updip wedge-out on anticlinal flank | Karamat SS Miocene | -600 to -2,600' 3 reservoirs | Gros Morne Middle Miocene |
| . Moruga West Rock Dome | Southern Range | -14018 | Anticline thrusted and faulted | Gautier Cretaceous | -700 to 4,000' 9 pay L. Miocene | Herrera SS member Karamat -U. Cipero |
| . Point Ligoure | Southern Basin | -9,000 | S. flank rt-lateral fault lenticular | Lower Cruse Pliocene | -15,00 to 7500' multiple reservoirs | Forest U. Miocene Cruse M. Miocene |
| . Goudron | Southern-East part of Island | -6,500 | stratigraphic, fault faulted. | Lower Cipero Oligocene | -150 to 1,600' UM -1,400 to 3,900; M.M. | Gourdron (Moruga Grp.) Gros Morne/L. Cruse |
| | OFFSHORE-EAST TRINIDAD | | | | | |
| . Galeota East | Southeast Trinidad | 10214' | Faulted Anticline | Upper Tertiary Sandstone | oil, gas condensate | 4 productive intervals -3532 to 5408' |
| . Galeota, South | Southeast Trinidad | 15536' | Anticline | Cipero, Oligocene | -12,000' | Cruse |
| . Manzanilla East | East Trinidad Atlantic Shelf | 10086' | Anticline | Miocene | | Miocene |
| . Kiskadee Atlantic Shelf | Southeast Trinidad | 16119' | Anticline | Miocene | Gas well 3 zones one zone -15,362-82' | Miocene; Gros Morne 138 b/o; 16,214 ucfd |
| . Teak | Southeast Trinidad Atlantic Shelf | | Anticline | Miocene | oil, gas condensate | Multiple pays -6690'-15,5900 |
| . Samaan Atlantic Shelf | Southeast Trinidad | 12181' | Anticline | Gros Morne Pliocene | | oil gas-multiple pays at 1-5900 |
| . Queens Beach East | Southeast Trinidad Atlantic Shelf | 16030' | Anticline | Miocene | oil, gas condensate | disc well-MMcfd |
| . Oilbird | Southeast Trinidad Atlantic Shelf | greater than 13001' | Anticline | Pliocene-Cruse fms | -13,000' gas condensate | Assumed by comparison w/Teak, S.E. Galeota Fields. |

## Appendix 2

### Trinidad & Tobago: Oil and Gas Fields by Basins

| Fields (discovery date) | Producing Depth (ft) | A.P.I. Gravity |
|---|---|---|
| **East Trinidad Atlantic Shelf & Tobago Trough** | | |
| Barracuda 1 (1976) | | gas |
| Dolphin (1977) | | |
| GBM (1972) | | |
| Galeota, S.E. (1972) | 1,091-6,310 | con, gas 31.5° |
| Ibis 1 | 8200 | gas, 38° |
| Kiskadee (1976) | 15,362-382 | gas, oil |
| KK4 (1974) | | gas |
| LL-9-1 (1976) | total depth 7,059 | gas |
| Manzanilla, E. (1973) | | gas |
| Oilbird 1 (1977) | av. 4,000 | con, gas |
| Pelican 3 (1977) | tested 11,650-12,410 | gas |
| Poui (1972) | | 30.6° |
| Queen's Beach E. (1970) | | con, gas, oil |
| Samaan (1971) | av. 5,900 | gas, 36.8° |
| Teak (1968) | 6,690-15,791 | con, gas, 30° |
| **Northern Basin (including portion of Gulf of Paria)** | | |
| Couva Marine (1963) | 7,492 | gas, 38.6° |
| Domoil, s. (1959) | 8470-9400 | 55° |
| Mahaica (1955) Shut-in | 2,995-4,350 | gas |
| Marine, N. (1959) | 3,000-10,007 | gas, 16-34° |
| Manica (1980) | 5,500 | |
| Soldado, N. (1955) | 3,500 | 9-38° |
| **Southern Range** | | |
| Balata Central (1952-54) | av 2500 | 29-31° |
| Balata, E. Bavallus (1952-1954) | 2500-9,426 | 29-35° |
| Beach (1902) | 250-4,500 | 15-40° |
| Cruse (1913) | 500-4,500 | gas 13-29° |
| Galeota (1963) | 450'-4,500 | 24-32° |
| Goudron (1927) | 1,500-3,900 | gas, 28-48° |
| Morugu, W. rock dome (1952-62) | 700-8,604 | gas, 22-43° |
| Navette (1959) | 600-3,600 | 37° |

| Fields con't.(southern basin) | Producing Depth (ft) | A.P.I. Gravity |
|---|---|---|
| Agostini (1925) Abd. 1928 | | |
| Aripero (1867) Abd. 1929 | | |
| Barrackpore-Wilson (1936) (1911-18) | 200-5,000 | con, gas 11-45° |
| Boodoosingh(1924) Abd. 1944 | | |
| Brighton Land (1908) | 700-7,500 | 16-38° |
| Brighton Marine (1908) | 1,800-8,500 | gas 30-36° |
| Catshill (1950-53) | 1,400-2,800 | gas 29-46° |
| Cedros (1912) Abandoned | | oil |
| Corra Quarry (1936) | 100-7,000 | gas 16-30° |
| Forest Reserve (1914) | 50-8,300 | gas 15-33° |
| Fyzabad (1918-20) | 150-3,300 | 15-36° |
| Fyzabad (Apex) (1920) | av. 2,500 | gas 14-35° |
| Grande Ravine | 1,200-10,500 | |
| Guapo (1912-22) | av 2,000 | 12-32° |
| Icacos (1965) | 2,887 | 25° |
| Johnson Road (1969) Shut-in | | |
| Lizard Spring(1928) Abd. 1939 | | |
| Los Bajos-Fyzabad (1918-26) | 460-12,718 | 16-33° |
| Oropouche (1944-54) | 2,000-9,077 | 35° |
| Palo Seco-Los Bajos (1926-29) | 15-12,718 | 16-33° |
| Parrylands (1913-18) | | |
| Penal (1936) | 1,300-1,067 | 11-35° |
| Point Fortin E. (1929) | av. 1,000 | 15-33° |
| Point Fortin W. Central (1904-16) | 1,000-8,072 | 15-45° |
| Point Ligoure (1908) | 1,000-8,072 | 15-45° |
| Roseau (1968) | 2,108 | |
| Silverstream | | |
| Siparia (1957) | | gas, con |
| Maloney (1946) Abd. 1949 | | |
| Mandingo-Los Naranjes(1953) Abd. | | |
| Mayaro (1937) Abd. 1949 | | |
| Morne Diablo-Quiman (1926-38) | 280-6,600 | 16-30° |
| Morugu E. (1953-56) | 9,693 | 11-40° |
| Morougu, N. Inniss Trinity (1956) | -500-5,127 | 33° |
| New Dome (1928) | | gas, 14-30° |
| San Francique (1922) | 300-2,600 | gas, 18-30° |
| Soldado, E. (1964) | | 12-20° |
| Soldado, Main (1954) | 1,000-6,500 | gas 11-34° |
| Tabaquite (1911) | 200-2,000 | 19-30° |

Source

The Oil and Gas Journal
Petroconsultants
Department of Energy-Dallas

## Appendix 3

### Comments on Tertiary stratigraphic correlations Trinidad and Venezuela

The 1979 stratigraphic time determination (figure 8) does not consider an analogy with the other part of the eastern Venezuela Basin of which Trinidad is an eastern extension. To consider the deltaic Cruse and younger Formations as Pliocene creates in the author's view an anomaly of no equivalent deltaic Pliocene Formations in eastern Venezuela. The 1979 stratigraphic time determination would place all predominantly Trinidadian deltaic formations as Pliocene, whereas in Venezuela the base of the deltaic Carapita Formation corresponds to the base of the Miocene. Previously, a correlatable sequence was possible between Trinidad and Venezuela. Attached is a correlation schedule of Trinidadian and eastern Venezuelan fields that previously too had been considered time-equivalent formation reservoirs. This analogy was intended to facilitate a reservoir assessment of undiscovered oil and gas.

## PETROLEUM CHARACTERISTICS

| Geologic Age | Trinidad | Venezuela |
| --- | --- | --- |
| Miocene | | |
| Lower | | Non-Petroliferous |
| Oligocene/Lwr Miocene | Herrera Sand Mbr-of Karamat Formation<br>Fields: Barrackpore Wilson 22-59°<br>Penal; Siparia<br>Balata; Balata East-Rovalllus<br>Balata Central; Moruga North- Innias-Trinity<br><br>Retrench Sand Mbr of Upper Cipero Fm<br>Oropuche<br><br>Nariva Sand Formation 19° to gas<br>Brighton Land; Brighton Marine<br>Guapo; Parrylands<br>Johnson Road; Tabaquite<br><br>Manzanilla Sand Foramtion 9-38-6°<br>Soldado North; Marine North<br>Couva Marine; Domoil South | Chaguaramas, Charapita, Tamanaco, Chucharo Formations<br>Main productive horizons-Central Guarico Fields 18° - 42° A.P.I.<br>Oficina and Freites Formations<br>Anaco Fields 33°-47°<br>Greater Oficina area 9°-57° (average 35°) A.P.I.<br>Temblador Field 15°-28° A.P.I.<br>Tucapita Field 17° A.P.I. oil<br>Meuecure Group-Buena Visa Fm, Carapitor fm<br>Locally productive i Northeast Quiriquire Field<br>Jusepin 22°-30° A.P.I. |
| Eocene | No production: that which had been previously reported as Eocene in early vessigny wells may be reworked sands in Lower Miocene | Mundo Nuevo Formation (very Upper Eocene only)<br>Quiriquire Field: productive gas reservoir, shows 11-29° A.P.I. oil |
| Eocene/Upper Paleocene | Oil saturation locally present | Oil saturation locally present |
| Lower Paleocene/<br>Upper Cretaceous | Lizard Spring Formation<br>Lizard Spring Field | Santa Anita Formation<br>Quirquire Field-14-25° A.P.I. oil saturation |
| Cretaceous Upper | Naparima Hill Formation<br>total 73,000 b/o production<br>locally shows of oil and gas | Oil Saturation locally present<br><br>Very lower part of Upper Cretaceous: La Cruz fm of Temblador Grp<br>Locally productive in Central Guarico Fields 13-35° A.P.I. oil |
| Middle | No shows of oil and gas due to low grade regional metamorphism<br>Gautier Formation | Temblador Group (Upper Middle Cretaceous)<br>Manresa Field: 16-18° A.P.I. oil<br>Temblador Field: heavier than water tar to 14° A.P.I. oil saturation |
| Pre-Middle Cretaceous | Lwr Cretaceous Cuche fm drilled into deeper formations unknown. | Either not reconignized or not deposited. |

| Geologic Age | Trinidad | Venezuela |
|---|---|---|
| Pliocene | Horne L'Enfer Formation - 11-50° A.P.I.<br>Fields: Brighton Land; Coora-Quarry<br>Forest Reserve; Fyzabad (Apex)<br>Grande Ravine; Los Bajos - Fyzabad<br>New Dome; Palo Seco-Los Bajos-Erin<br>Point Fortin East; San Francique<br>Soldado East | Upper Quiriquire Member heavy oil saturation & gas shows<br>Quiriquire Field |
| Miocene Upper | U. Forest & Upper Cruse Members 12°-41°<br>Major productive reservoir<br>Fields: Barrackpore Wilson; Brighton Land<br>Coora-Quarry; Cruse<br>Forest Reserve; Fyzabad (Apex)<br>Grande Ravine; Guapo<br>Icocos;Catshill<br>Parrylands; Los Bajos-Fyzabad<br>Moruga East; Morne Diablo-Quinam<br>New Dome; Palo Seco-Los Bajos-Erin<br>Penal ; Point Fortin East<br>Point Ligoure; Point Fortin-West Central<br>San Francique; Silverstream<br>Soldado Main<br>Springvale Fm: Mahaica gas field | Middle Quiriquire Member<br>Quiriquire Field: 15-21° API<br>Monosra Field: 17-18° API<br>Orocual Field: tar to 32° API (Average 13°) |
| Middle | Lower Forest - Middle & Lower Cruse, Gros Morne Mbrs<br>12°-40° A.P.I.<br>Coora-Quary; Forest Reserve<br>Fyzabad (Apex); Grande Ravine<br>Guapo;Catshill<br>Los Bajos; Fyzabad<br>Moruga East; Morne Diable-Quinam'<br>New Dome; Parrylands<br>Point Fortin-East; Palo Seco-Los Bajos-Erin<br>Point Ligoure; Point Fortin-West Central<br>San Francique; Silverstream<br>Soldado Main | La Pica Formation<br>Pedernales Field: 18°-31 API<br>Greater Jusepin Area: 22 -36° API<br>Quiriquire fm: (Theta, ETA, Zeta mbrs)<br>Quiriquire Field: 12-29° API |

## Appendix 4

### Comments on source of some Trinidadian crude oils

The origin, migration and entrapment of hydrocarbons in most oil bearing regions involve questions that are debatable; Trinidad is no exception. Answers to these questions are of more than academic interest, because they could lead to new oil and gas discoveries.

As over 99 percent of the hydrocarbon production in Trinidad and Tobago has come from Miocene and younger sediments, these comments are limited to the oils from these sediments. Although these percentages were reported up through 1964, this proportion has not changed appreciably through 1979 (Ablewhite and Higgins, 1965). However, the reader must remember that some portions of the sands producing off the east coast of Trinidad have not yet been correlated with certainty. In any event these offshore sandstone reservoirs are most probably post Miocene.

As the portion of Trinidad that is oil and gas producing is a continuation of the south flank of the Eastern Venezuela Basin, the environment of deposition is analogous to conditions in Venezuela. The 6,000 feet of Oligocene marls, claystones, and marly claystones were deposited in deep-water environment. Subsequent Miocene deposition was in waters of increasingly shallow depth. This probably reflects a gradual infilling of the basin. Local structures involving the Eocene, Oligocene and Lower Miocene rocks reflect periods of minor tectonic structural activity. However, the Mid-Pliocene Orogeny intensified the principle pre-existing trends.

Most of the production of onshore oil has been from the area of the Los Bajos fault where migration of hydrocarbons along the fault is believed to have localized oil deposits in anticlines.

Barr et al., (1951) found that when a ratio of various crude oil chemical properties were contoured on a structural map of the areas, the results indicated that the distribution of oil types has not been altered by structure, including faults.

The chemical composition of the various Tertiary reservoir oils are distinctive (Barr et al., 1951).

No evidence has been published that any oil found in Miocene-Pliocene reservoirs has been the result of migration from a deeper source, i.e., Cretaceous or Oligocene deposits. Therefore, it must be concluded that most if not all of the reservoir hydrocarbons, especially onshore, are indigenous to the formations in which they are found.

Summary of Production
(Barr et al., 1958)

| Formation Producing | Percent of Production |
|---|---|
| Morne L'Enfer | 2.9 |
| Manzanilla | 0.1 |
| Forest | 15.0 |
| Cruse | 38.7 |
| Forest/Cruse undifferentiated | 29.6 |
| Gros Morne | 2.8 |
| Shallow Herrera | 4.8 |
| Interned Limb & Deep Herrera | 2.6 |
| Nariva | 3.5 |
| Eocene | .1 |
| Cretaceous | |
| Total | 100 percent |

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