# Significance of Gravity Segregation in Heavy-Oil Distribution, Forest 'A' Reservoir, Parrylands Field, Trinidad, West Indies

H. Rambarran
*Trinidad and Tobago Oil Company Limited (Trintoc)*
*Trinidad, West Indies*

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**Parrylands is a multiple pay oil field with production from unconsolidated sand reservoirs of late Tertiary age in the Southern basin of Trinidad.**

**Stratigraphy and sedimentology of the formations penetrated indicate three cycles of delta progradation resulting in the deposition of the Cruse, Forest, and Morne L'Enfer formations. Primary production is obtained from the deeper Cruse Formation whereas the overlying Forest and Lower Morne L'Enfer formations contain heavy oil and tar sands.**

**The Forest 'A' Reservoir represents a delta fringe/barrier bar system containing approximately 100 million barrels of heavy oil in place. Within the Forest 'A' Reservoir, the oil occurs in north-northwest-trending barrier bars on the crest and flanks of the Lot 1 anticline. Geochemical evidence suggests that the oil was generated from a Cretaceous source and migrated along major faults into upper Tertiary reservoirs, where it occurs as a heavy degraded oil. Gravity segregation occurred resulting in 16–19°API crude in the crestal area of the anticline and 10–12°API crude on the lower flanks of the anticline. The higher API gravity crude is produced by primary methods while that of lower gravity can only be produced commercially by thermal methods.**

**This observed phenomenon of segregation within the same reservoir is significant in identifying primary production in areas of heavy oil. This can be done by carefully mapping and correlating structure, API gravity, and other characteristics of the crude.**

**The economic considerations of this technique in exploration and exploitation of heavy oil cannot be overstressed since a (favorable) cash flow can be generated prior to intensive capital investment for thermal enhanced oil recovery.**

## INTRODUCTION

Trinidad, the southeasternmost island in the West Indies, is located off the coast of Venezuela. Oil exploration began in 1866, but commercial production was not established until 1914. The search for hydrocarbons onshore in Trinidad is at a very mature stage because most of the productive fields were discovered before 1955.

Heavy oil occurs in sandstone reservoirs of late Tertiary age in the Southern basin of Trinidad, both onshore and offshore. Within Trintoc's leases, heavy oil occurs in two fields, with a total exploitable estimated oil in place of 127 mega cubic meters (800 million barrels; Bertrand et al., 1983). This paper illustrates an example of heavy-oil accumulation, in which relatively high-quality crude (17–19° API) occurs at the crestal area of the anticline and lower quality crude (10–12° API) occurs structurally downdip, and the significance of this hydrocarbon segregation in heavy-oil exploration and exploitation.

## REGIONAL GEOLOGY

Structurally, Trinidad lies at the eastern limit of a belt of extensive deformation along the northern border of South America. Southern Trinidad stratigraphically forms an eastern extension of the Orinoco basin (Fig. 1). The Parrylands field is one of the many fields within Trintoc's Point Fortin Field Complex (Fig. 2). It was discovered in 1913 by United British Oilfields of Trinidad (UBOT), the first well drilled producing from the Forest Formation.

The major structural features are:

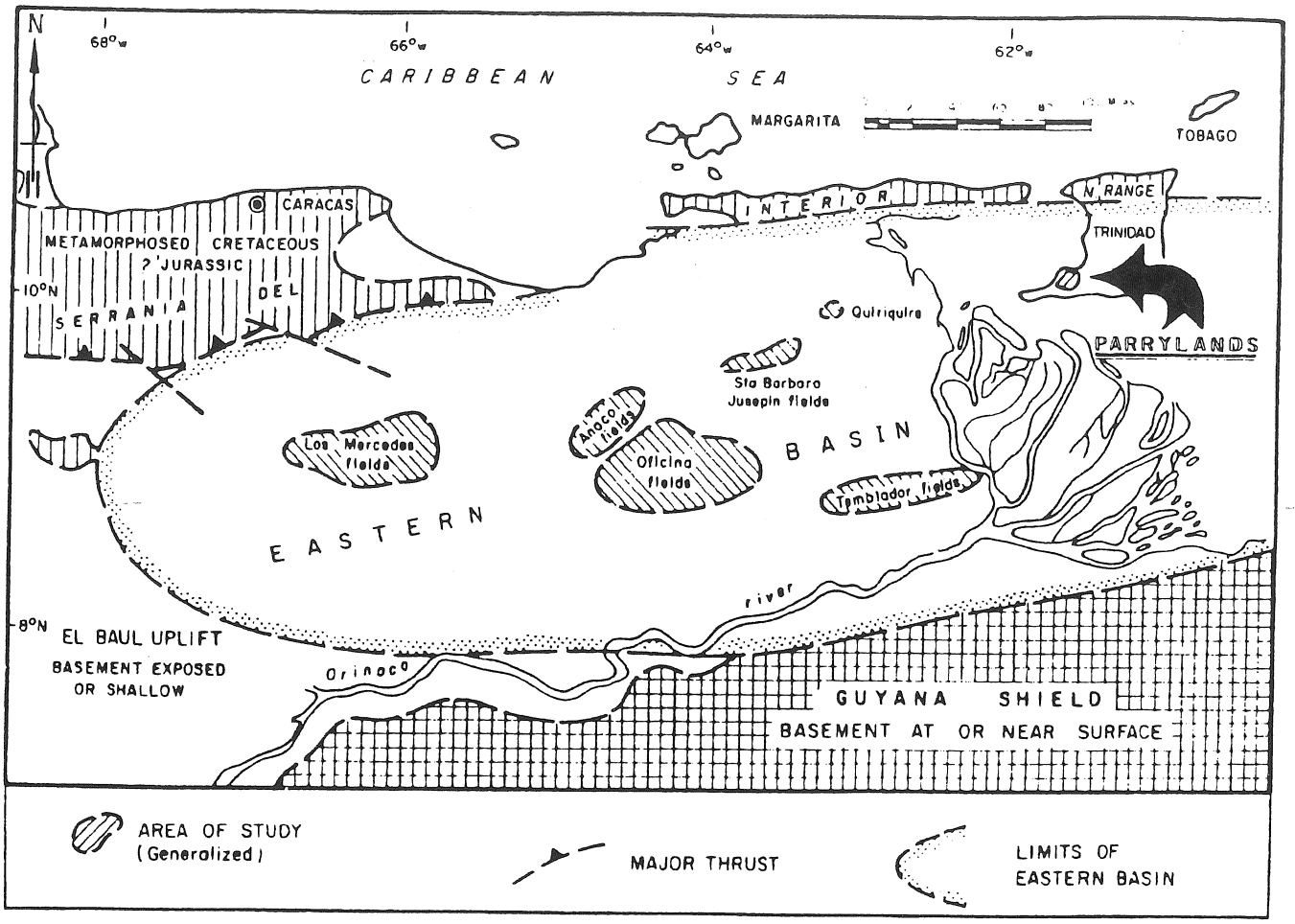


**Figure 1**—Location map of Parrylands field, Trinidad. Modified after Salvador and Stanforth, 1968.

1. The Los Bajos fault, which is a right lateral wrench fault, with displacement of late Miocene to Pliocene age sediments of 11 km (7 mi) (Wilson, 1940, 1965).
2. The Lot 1 anticline, with a pre-Cruse diapiric core, which is an asymmetrical fold that plunges to the southwest, with the northern limb being steeper. This structure is probably an extension of the Central Range Complex (Otaheite anticline).
3. The northeast-southwest-trending Parrylands syncline which lies to the south, and the northwest-southeast-trending syncline, to the west.

## STRATIGRAPHY

The formations penetrated range in age from Paleocene to Pliocene (Fig. 3). Well information and surface geology indicate a sequence of cyclic deposition resulting from a prograding delta. The Cruse, Forest, and Morne L'Enfer formations represent three cycles of deltaic infilling of the western part of the Southern basin, Trinidad, with the Cruse being the oldest and the Morne L'Enfer the youngest. These formations are separated by the Lower and Upper Forest Clay members, which reflect transgressive interludes in the overall regressive sequence (Fig. 4).

In Parrylands, the sandy horizons at the end of each cycle are the major reservoirs of interest and are usually oil bearing. Most of the "lighter less viscous" crude (20-30° API) is found in the Cruse Formation at depth. However, heavy crude (10-19° API) is found in the Forest and Morne L'Enfer formations.

The Forest Formation is divided into two major stratigraphic members, the Lower and Upper Forest. In the Parrylands area, the Lower Forest is almost always salt water bearing, whereas the Upper Forest (Forest 'A') contains heavy crude.

The Forest 'A' is a deltaic fringe/barrier bar system trending in a general north-northwest direction. Seven individual bars separated by shale-out are distinguished.

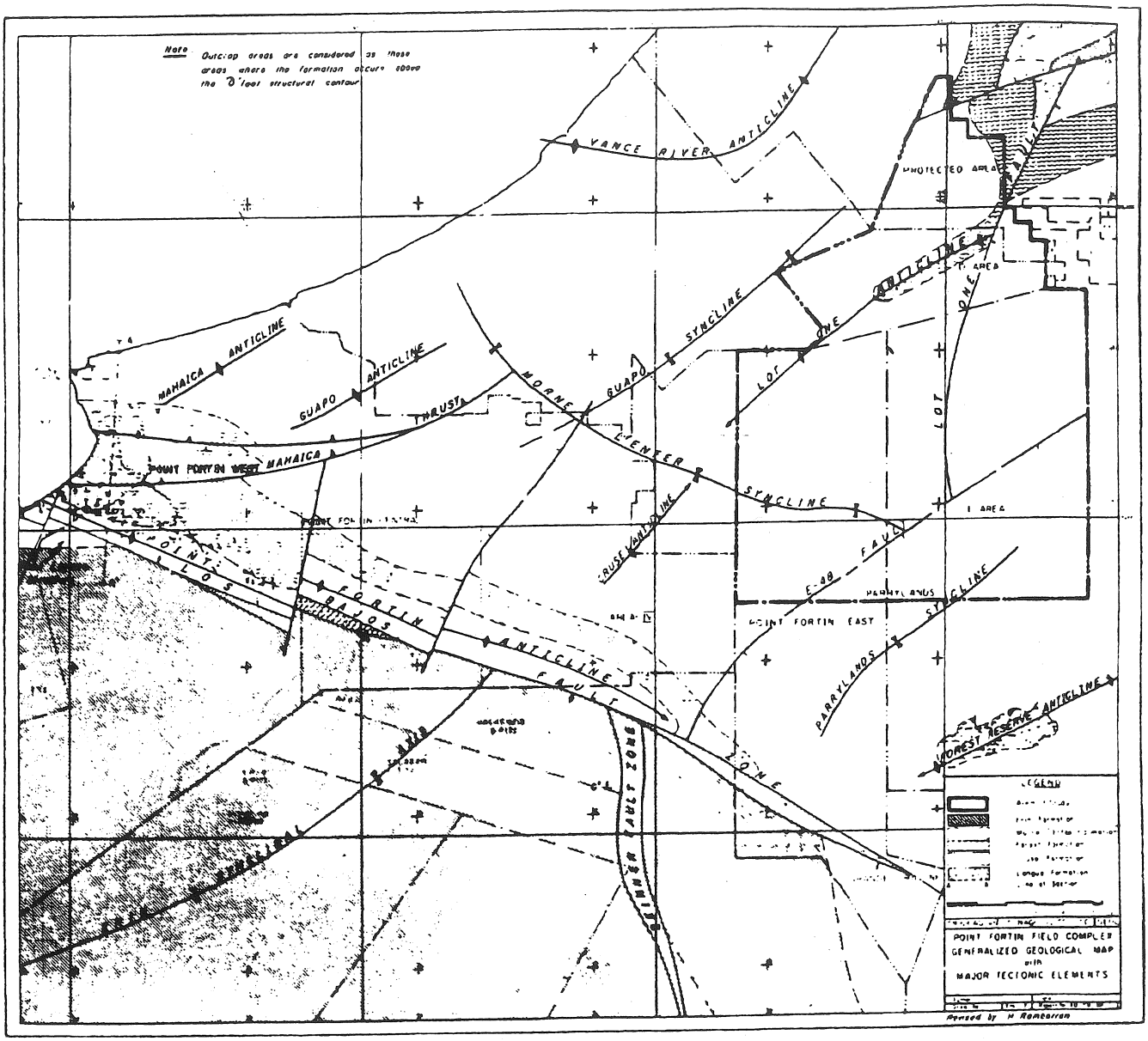


**Figure 2**—Generalized geological map of Point Fortin field complex, with major tectonic elements.

Log interpretation, full hole cores, and sand geometry show the Parrylands Forest 'A' sand reservoir to be comprised mainly of barrier bar deposits.

Overlying the Forest 'A' is the Upper Forest Clay, a regional transgressive shale, which marks the beginning of the Lower Morne L'Enfer cycle of deposition. The Lower Morne L'Enfer Formation is considered to be made up of delta-front sheet sands.

## STRUCTURE

The major surface as well as subsurface structural feature in the Parrylands field is the Lot 1 anticline, located to the north (Fig. 5). This structural high was present in pre-Forest time, as shown by a wedge of pre-Forest Formation over the Lot 1 high. The E-48 fault is a secondary normal fault emanating from the major Los Bajos fault.

## HYDROCARBON ACCUMULATION

Three major factors influence hydrocarbon accumulation: source rock, reservoir, and trap. Geochemical evidence, including total organic content and source rock maturity, suggests that oil was generated from Upper Cretaceous marls and shales and migrated along

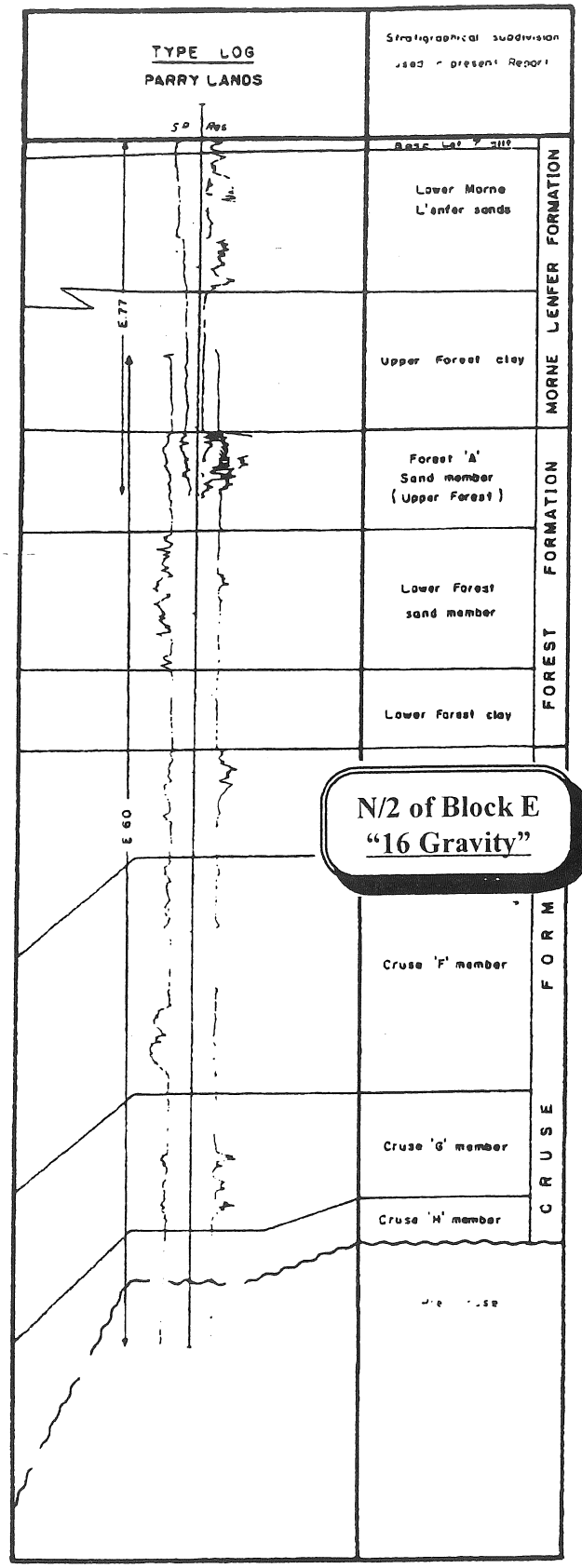


Figure 4—Type log, Parrylands area.

such major faults as the Los Bajos fault into Tertiary reservoirs (TRINMAR Geological Review Team, 1980; Fig. 6).

In 1983, further geochemical analyses of oil and Tertiary age rock samples from the Southern basin, Trinidad, were carried out to characterize and evaluate hydrocarbon source potential of the area. The results indicate only one oil family; the oils were geochemically similar (chromatographic and chemical results) but were subjected to different stages of maturation and biodegradation. The Tertiary shales are not considered as source rocks for the oils, because these sediments are not within the range of maturation (Braspetro, 1983).

The oil entrapment is influenced by both structure and stratigraphy. In these barrier bars, the accumulation of oil is usually affected by the lenticularity of the individual units of the system. The accumulation is controlled not only by shale out of the bars but also by position on the flanks of the Lot 1 anticline. The bars generally become water-bearing downdip into the Morne L'Enfer syncline, such as E-71 bar on the extreme east, and PL-222 bar on the west (Fig. 7).

Figure 8 is a cross section that illustrates a phenomenon observed in the Parrylands field. Heavy oil producible by conventional methods is obtained in the crestal area of the Lot 1 anticline. The E-87 barrier bar was the major objective during the early phase of development in this oil field; it was found that wells drilled on structurally high points contained oil of 15–19° gravity API which could be produced initially at high rates, sometimes greater than 500 bopd. These wells have produced to date approximately 6% of the oil in place in this barrier bar. Wells drilled structurally downdip contained oil of 10–12° gravity API, which can only be produced commercially by thermal methods. Hydrocarbon segregation by gravity drainage, in which light ends migrate updip, with the Upper Forest Clay providing an excellent seal, can explain this feature.

A similar situation may exist in the E-96 barrier bar (Fig. 9). To further evaluate this hypothesis, this bar will be tested for primary production at an updip location. Well E-84, drilled in a structurally downdip position, has already produced 43,000 barrels of 11° API crude, during and after a pilot steam injection project (Fig. 10).

Based on the foregoing, it appears that this segregation within the same reservoir can be significant in identifying potential primary production in areas of heavy oil. This can be done by carefully mapping and correlating structure, API gravity, and other characteristics of the crude. The economic considerations of this technique in exploration and exploitation of heavy oil cannot be overstressed because a favorable cash flow can be generated prior to intensive capital investment for thermal enhanced oil recovery.

Over the past 2 years, a pilot cyclic steam project on 30 acres containing 10–12° API crude in the Forest 'A'

**Adjacent to the S/2 of Block E!**

reservoir has been in progress. The results to date are as follows:

1. Oil/steam ratio averages 0.35, with instances of 0.9 for individual wells.
2. Present production is approximately 475 bopd (original prediction ±500 bopd) from capacity of 25 million Btu/hour of steam. This production is from the second cycle steam injection. The third cycle of injection has started, and it appears that the predicted high production trend will continue.

Because of these encouraging results, the project is now being expanded.

The calculated oil in place for the Forest 'A' reservoir in Parrylands is 100 million barrels and the estimated recoverable oil is 25 million barrels. Further geological mapping has shown that the Forest 'A' heavy-oil reservoir extends south of the Parrylands field and into the adjacent Point Fortin East field, thus significantly increasing the heavy oil reserves to be exploited.

## SUMMARY

Viscous heavy crude, commercially productive by steam injection techniques, is found in the Forest 'A' reservoir. However, less viscous mobile crude, producible by primary methods, occurs in the crestal area of the Lot 1 anticline. It is felt that hydrocarbon gravity segregation explains this occurrence. The concept of gravity segregation can be used to identify potential primary production in areas of heavy oil accumulation.

## ACKNOWLEDGMENTS

The author wishes to thank the Trinidad and Tobago Oil Company Limited (Trintoc) for allowing release of relevant information, which made this paper possible. The author also appreciates the contribution of many colleagues in Exploration and Production Division, Trintoc, and, in particular, Mr. W. G. Bertrand.

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**475 BOPD from a Cyclic Steam Injection Method into 6 wells on 30 acres using a 25 MMBTU Steam Generator with injection rates of approximately 1000 barrels per day.**

**NHE Steam Method will be Continuous into 6 wells using a Steam Generator with twice the heat capacity and injecting approximately 3000 barrels per day, thus anticipates producing 500 - 1000 BOPD.**

**Noted twice in this report, a fact which can not be over stressed, is that the Forest Sandstone will yield favorable oil production and economics without steaming!**

**This report also proves that steaming greatly enhances daily production and ultimate recovery!**

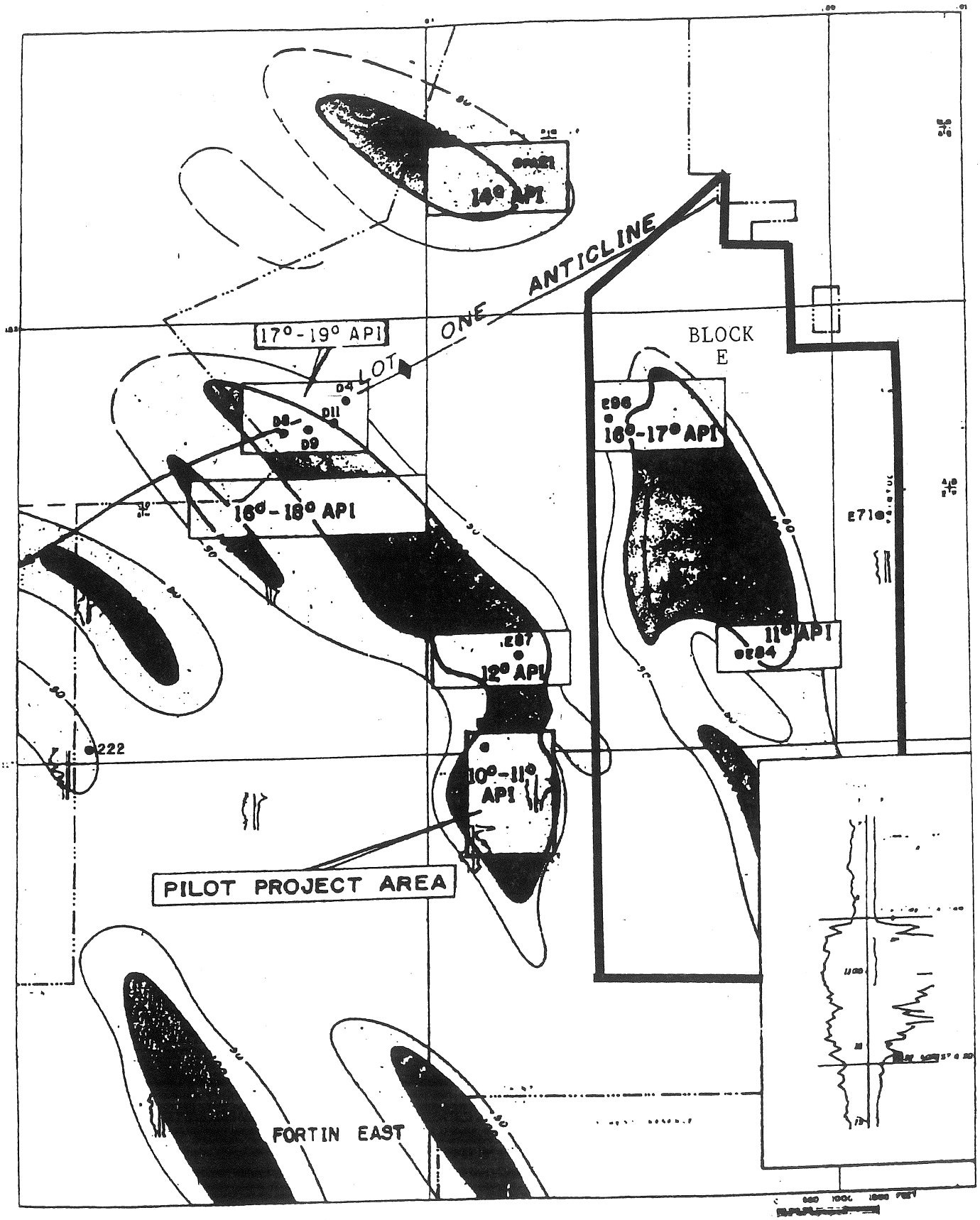


**Figure 9**—Thickness of Forest 'A' Formation showing oil gravity distribution.

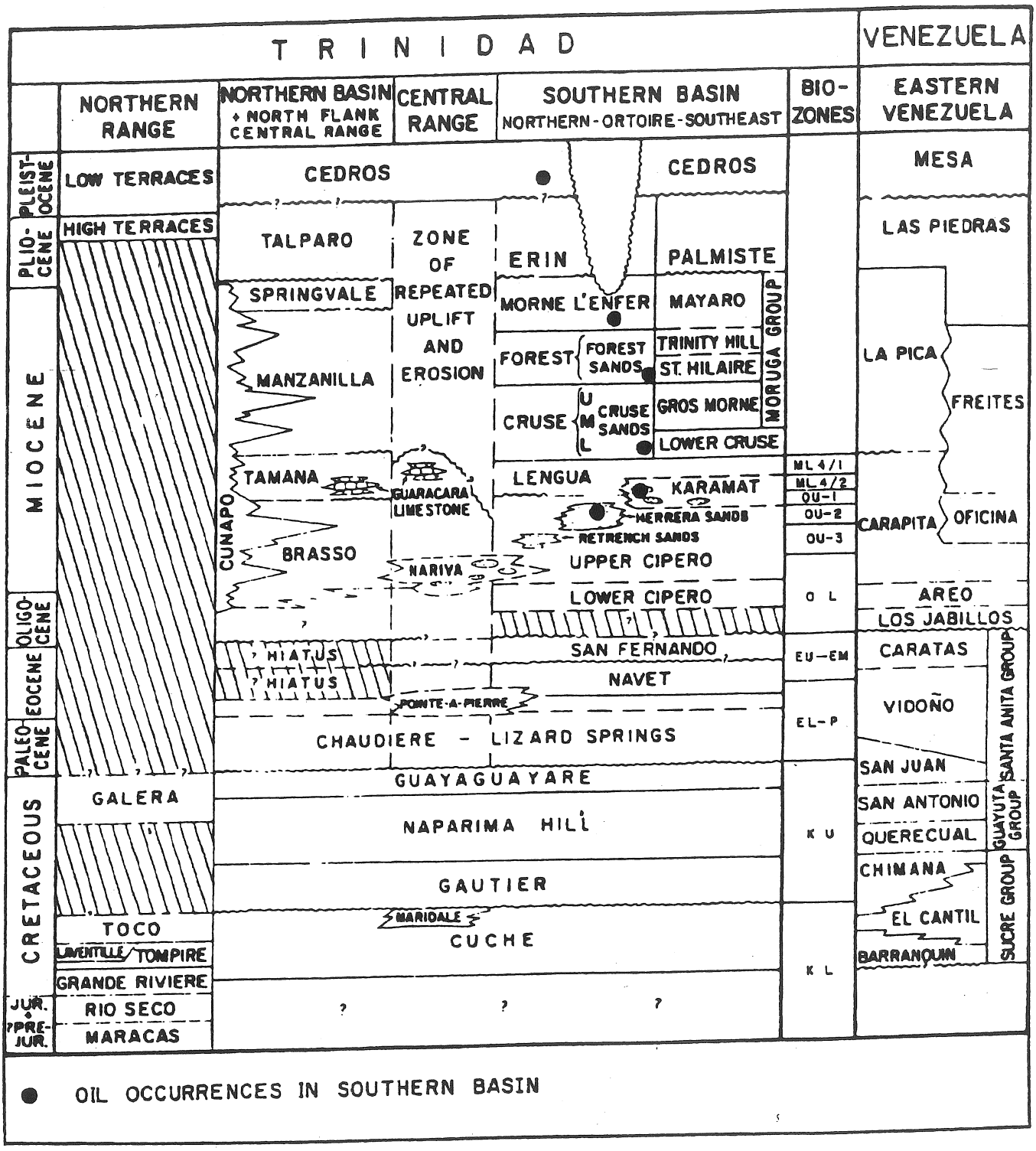


**Figure 3**—Stratigraphic chart of Trinidad.