EDITORIAL

LA EVOLUCION ESTRUCTURAL DE LA CUENCA ORIENTAL DE VENEZUELA

La publicación del tema principal del presente Boletín ha causado un dilema personal al editor.

La dirección del Boletín ha seguido la práctica de reproducir ocasionalmente artículos que traten o se refieran a la geología de Venezuela, aparecidos en publicaciones no facilmente asequibles a nuestros miembros. En este número se reproduce un artículo que reune las condiciones anteriores y cuyo autor es el Dr. Karl F. Dallmus, miembro honorario de la Asociación, y uno de los geológos de más largo ejercicio profesional en Venezuela. En mi condición de editor, me parece apropiado dar a conocer a nuestros lectores esta contribución a la geología del Oriente de Venezuela.

Por otra parte, como geológo en ejercicio interesado en el Este de Venezuela, tengo mis dudas sobre el mismo. El texto se basa sobre informes escritos hace ya muchos años y no ha sido puesto al día a la luz de las nuevas correlaciones estratigráficas, designación de edades y nomenclatura, que hoy día se aceptan casi unánimemente. Las conclusiones, en su aspecto regional, están basadas en lo que yo creo son datos erróneos, tales como isópacos incorrectos (Fig. 13) y en los abruptos límites, hacia el norte, indicados para varias formaciones (Figs. 16, 17). Las ilustraciones provienen de tres fuentes distintas (informes privados, el simposium "Habitat of Oil" de la AAPG (1958), y de el Primer Congreso Venezolano de Petróleo (1962), y no están integradas entre si ni con el texto.

Mi primera intención fue la de incluir una crítica al trabajo del Dr. Dallmus en este mismo número. Sin embargo, hacer esto en detalle hubiese requerido tantas páginas como el trabajo original, y hacerlo en forma abreviada sería inadecuado. En consulta con el Dr. Dallmus, quien se ha mostrado muy generoso en todo el asunto, el sugirió la idea de hacer de su trabajo el tema para una discusión en Mesa Redonda, y publicar la agenda en el Boletín Informativo. Esto parece ser una idea plausible. La literatura existente en forma predominante postula una orogenia compresiva como el factor de control en la evolución terciaria de la Cuenca Oriental de Venezuela, mientras que el Dr. Dallmus asevera que la formación de grabens y medio-grabens fue lo más importante. En relación con la sub-cuenca de Guárico, los trabajos de compilación han mostrado la tendencia a repetir interpretaciones que fueran originalmente publicadas hace una docena o más de años, aunque ya, en artículos de alcance local, se ha indicado la necesidad de efectuar revisiones a fondo sobre la materia. Al norte, la evolución de las montañas metamórficas estrechamente relacionada con la sub-cuenca de Guárico, se ha hecho mucho más clara por la publicación en el Boletín de Geología de las tesis de los estudiantes de la Universidad de Princeton. Avanzando aun más, nuevos conceptos sobre geosinclinales y comportamiento mecánico de la corteza terrestre se han dado a conocer recientemente en la literatura.

Todos estos datos hacen oportuno proponer la realización de una discusión en Mesa Redonda sobre la "Evolución Estructural de la Cuenca Oriental de Venezuela". La fecha será anunciada posteriormente, y mientras tanto se espera que los miembros interesados reunan sus datos y opiniones y los tengan listos para participar en el debate.

EDITORIAL

STRUCTURAL EVOLUTION OF THE EASTERN VENEZUELA BASIN

Publication of the principal item in this number has caused a personal dilemma for the editor.

It has been editorial policy of the Boletín Informativo from time to time to reprint articles on or pertaining to the geology of Venezuela, which have appeared in publications not readily accessible to a majority of our members. In this issue we reprint a paper which fulfills both these conditions and furthermore is by one of the senior geologists in Venezuela, an honorary member of the Asociación, Dr. Karl F. Dallmus. As the current editor, I consider it proper to make this serious contribution to the geology of Eastern Venezuela available to our readers.

On the other hand, as a practising geologist concerned with Eastern Venezuela, I have considerable misgivings. The text is based on reports written many years ago, and has not been brought up to date in terms of the stratigraphic correlations, age assignments and nomenclature now accepted almost unanimously. It bases regional conclusions on what I believe to be erroneous data such as incorrect isopachs (Fig. 13) and the abrupt northern limits indicated for several formations (Figs. 16, 17). The illustrations are drawn from three separate sources (private reports, the AAPG symposium "Habitat of Oil" (1958), and the First Venezuelan Petroleum Congress in 1962) and are not integrated with one another nor with the text.

My first reaction was to include a critique of Dr. Dallmus' paper in this same number. However, to do this in detail would require as many pages as the original paper, and to do it in thumbnail fashion would be inadequate. On consultation with Dr. Dallmus, who has been most amiable over the whole affair, he suggested making his paper the basis for a round-table discussion and publishing the agenda in the Boletín Informativo. This seems a sound idea. The existing literature dominantly postulates a compressive orogeny as the controlling factor in the Tertiary evolution of the Eastern Venezuela Basin, whereas Dr. Dallmus asserts that the formation of grabens and half-grabens was all-important. Regarding the Guárico Sub-basin, compilatory papers have tended to repeat interpretations first published a dozen or more years ago, although the need for far-reaching revisions has been shown in articles of local scope. The closely related evolution of the metamorphic mountains to the north has become much clearer as a result of Princeton University theses published in the Boletín de Geología. Farther afield, new concepts of geosynclines and crustal mechanics have been set forth in the recent literature.

All of these developments make it opportune to schedule a round-table discussion on "Structural evolution of the Eastern Venezuela Basin". The date will be announced later, and meanwhile it is hoped that interested members will marshal their facts and opinions ready for participation in the debate.

ACKNOWLEDGMENT

The following paper by our Honorary Member Dr. Karl F. Dallmus, entitled "The Geology and Oil Accumulations of the Eastern Venezuela Basins", first appeared in the "Symposium on Petroleum Geology of South America" published by the Tulsa Geological Society in 1963. It is reprinted here by kind permission of that Society. The text is unchanged. The figures are made from the same originals, but are mostly presented at larger size to improve their legibility.

The SYMPOSIUM ON PETROLEUM GEOLOGY OF SOUTH AMERICA (Tulsa Geological Society Digest, Vol. 31), as has already been mentioned in these pages (Vol.7,No.7), includes the following items :-

"The structural framework of the Caribbean region", by K. W. Barr (28p.)

"The geology and oil accumulations of the Eastern Venezuela basins", by K. F. Dallmus (26p.)

"The Maracaibo-Falcón Basin", translated by R. E. McMillen from the Spanish of G. A. Young et al.,1956 (17p.)

"General geology and oil possibilities of the Amazonas Basin in Brazil", by Luís G. Morales (31p.)

"Geology of the Colorado Basin", by J. P. H. Kaasschieter (11p.)

"Extent of the Carboniferous marine ingression in the Precordillera of San Juan-La Rioja", by Guillermo Furque (5p.)

"The Cambrian of northern Argentina", by Juan Carlos M. Turner (19p.)

"San Jorge Basin", by C. S. Deal & W. J. Cramer (abstract only, 1p.)

"Selected bibliography of South American geology", by Howard Ross Cramer (27p.)

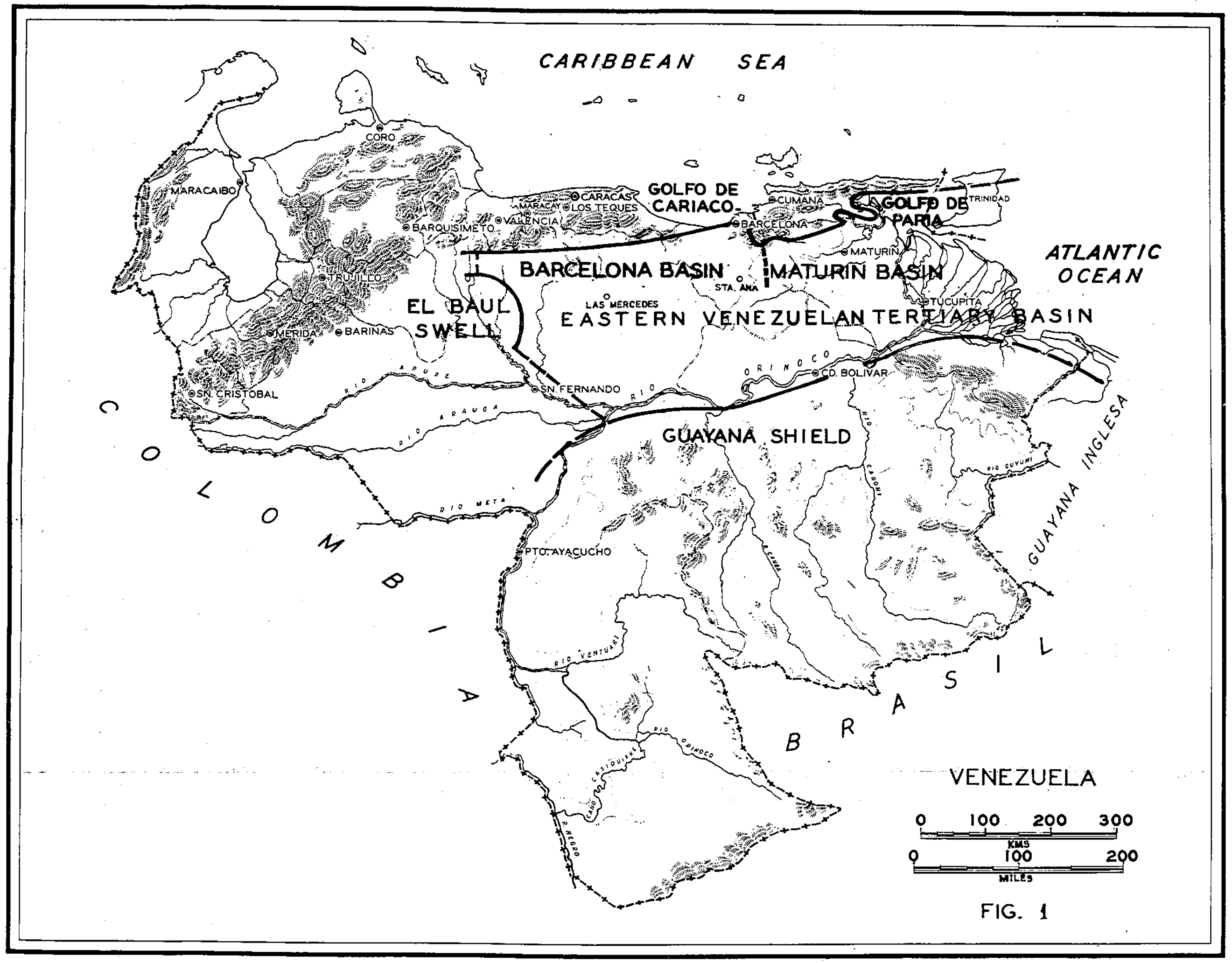

FIG. 1

THE GEOLOGY AND OIL ACCUMULATIONS OF THE EASTERN VENEZUELA BASINS

by K. F. Dallmus[1]

ABSTRACT

The sedimentary basin of eastern Venezuela is divided into two compound structural basins, the Barcelona basin on the west and the Maturín basin on the east, separated by the Urica arch.

Analyzing the regional structure by the means of approximate true shape cross-sections and paleo-geographic maps it can be seen that in the Barcelona basin a secondary Oligocene dynamic basin, a half graben, is superimposed on a primary Cretaceous basin. In the Maturín basin a late Tertiary and recent primary basin is superimposed on an Oligo-Miocene secondary basin, a half graben, and this in turn is superimposed on a Cretaceous primary basin.

The inter-relationship of time, lithologic facies and geographic location is analyzed by means of cross-sections in which time is substituted for the thickness of section. This device is essentially a time-space graph independent of thickness and facies development of the rocks.

No primary accumulations of importance of petroleum have been found in the Cretaceous of eastern Venezuela. The bulk of the oil occurs on the southern rim of the Oligocene half grabens and the northern rim of the late Tertiary primary basin.

Local anticlinal folding is of secondary importance in the accumulation of oil in eastern Venezuela. On the hinge belts the accumulation is controlled, either by normal faulting or stratigraphy or a combination of the two.

With respect to lithologic facies most of the oil occurs where the marine shale facies interfinger with sands on the hinge belts of the basins.

Accumulations of very heavy oil are found both above and below major unconformities, high up on the shelves, both on the north and the south sides of the Maturín basin, and on the south side of the Barcelona basin.

Referred to the original basins there is an increase of A.P.I. and paraffinicity with an increase of depth.

The great bulk of commercial oil is found on the hinge belt of the structural basins contemporaneous with the sedimentary cycle in which the oil originated, and in which the accumulations are reservoired.

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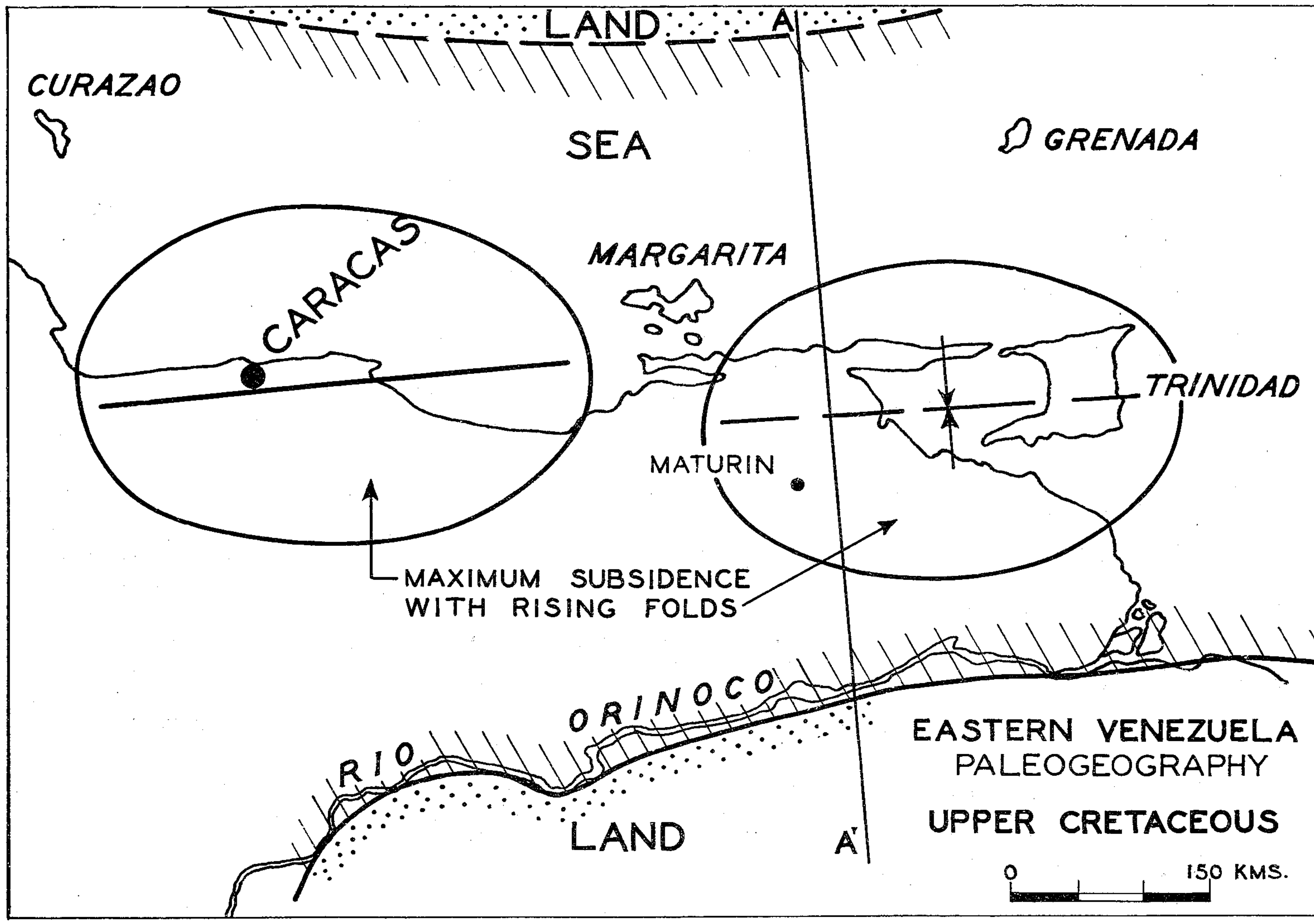
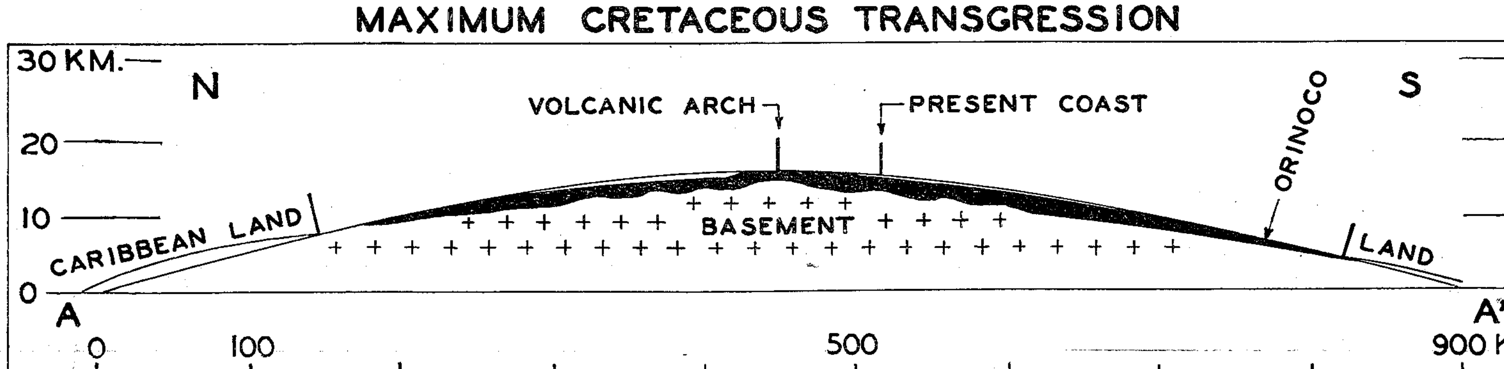
[1] The author is associated with H.W. Thoms, Consulting Geologist in Caracas, Venezuela, to whom he is indebted for editing the manuscript. The original paper was written while the author was still in the employ of Creole Petroleum Corporation, in 1957, and grateful acknowledgement is made to the Company for permission to use the original text and illustrations from their files in preparing the present paper.

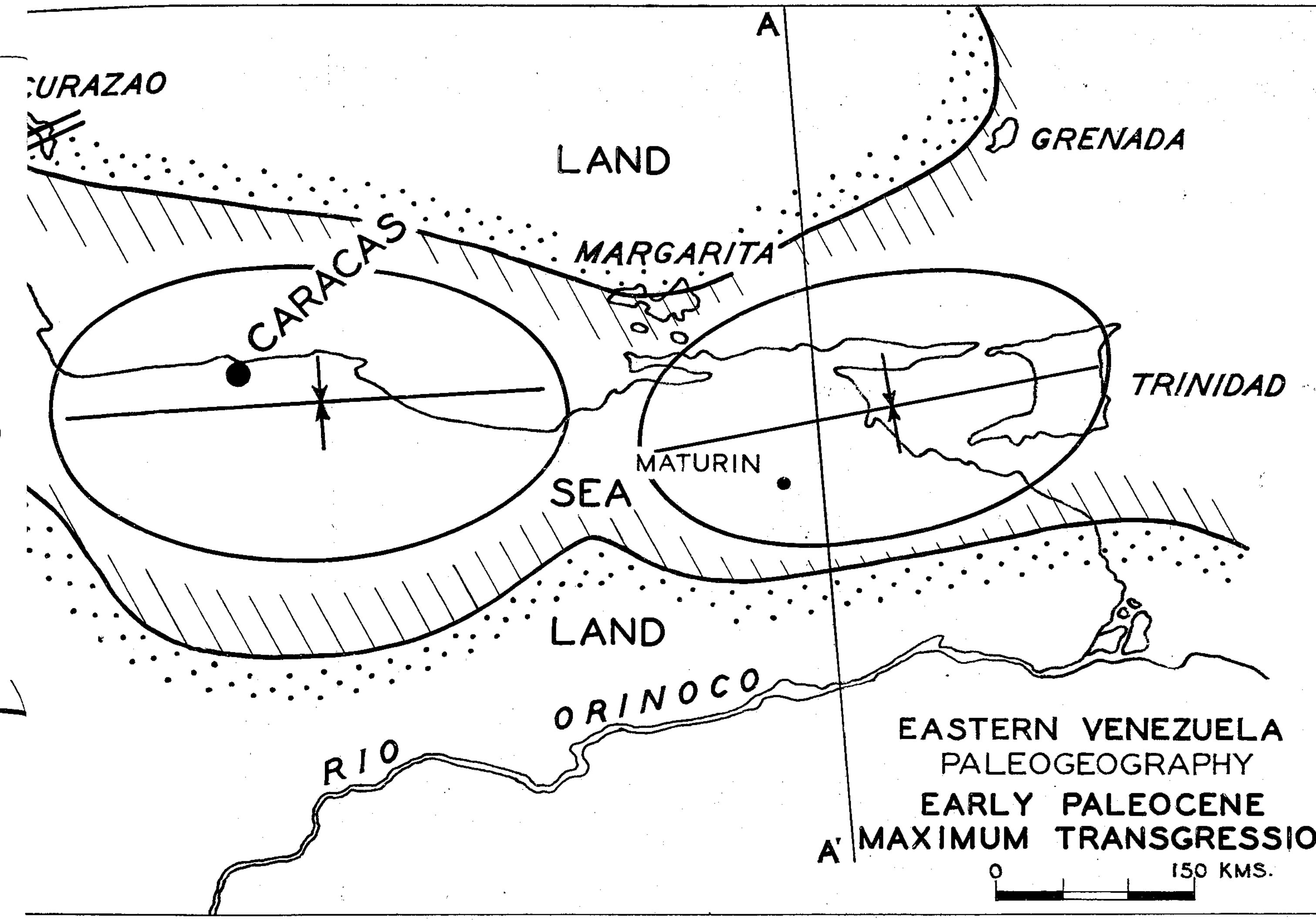


MAXIMUM CRETACEOUS TRANSGRESSION

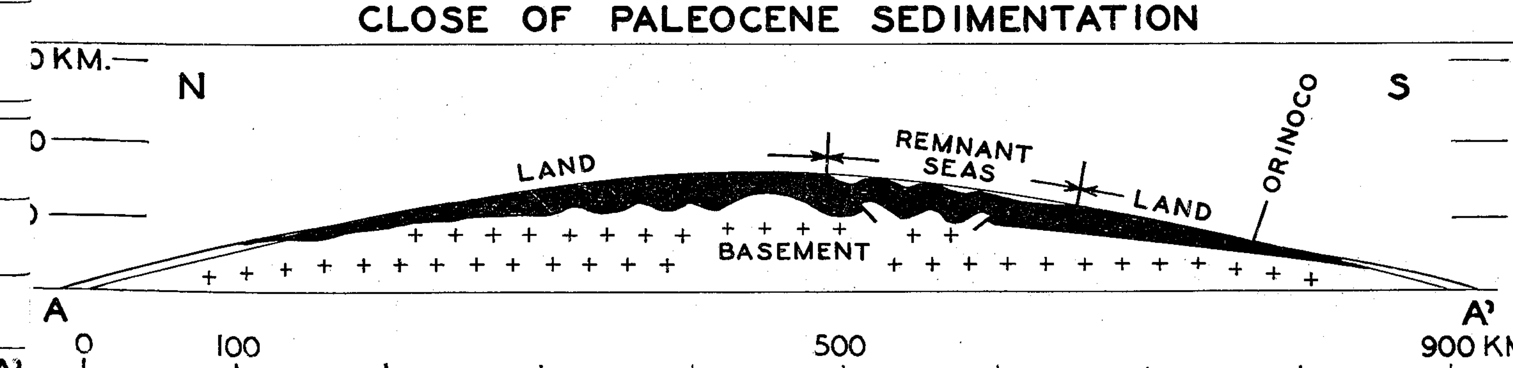


GENERALIZED HISTORICAL CROSS SECTION OF THE MATURIN BASIN

FIG-2

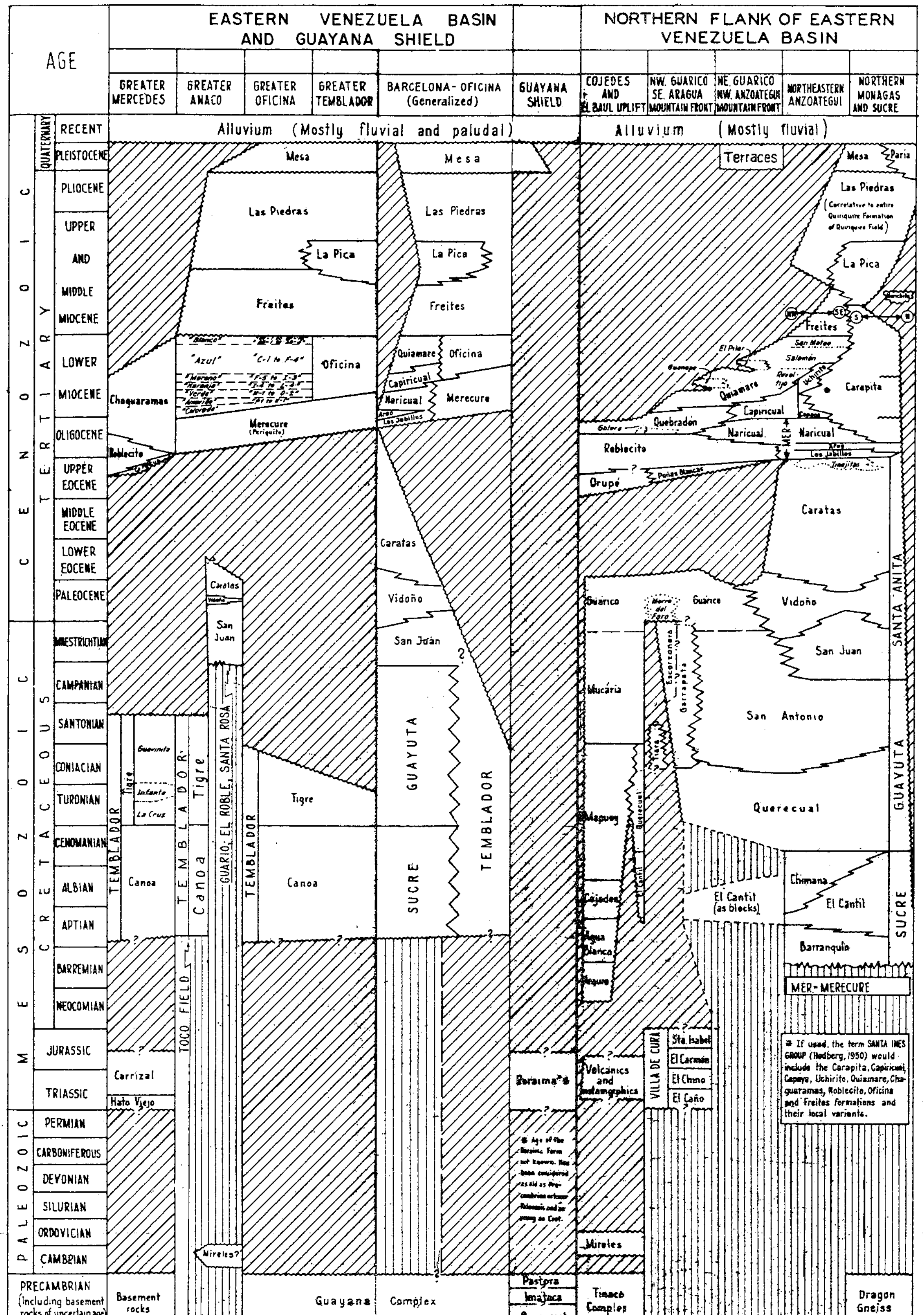


CLOSE OF PALEOCENE SEDIMENTATION



GENERALIZED HISTORICAL CROSS SECTION OF THE MATURIN BASIN

FIG-3



CORRELATION CHART OF EASTERN VENEZUELA
FIRST VENEZUELAN PETROLEUM CONGRESS
MARCH - 1962

TABLE 1

INTRODUCTION

The oil producing Barcelona and Maturín basins of eastern Venezuela lie between the coastal mountain ranges on the north and the highlands of the Guayana shield south of the Orinoco River (Fig. 1). The topography gradually rises from the low flat grassy plains immediately north of the Orinoco to the brush and forest covered foothills of the interior mountains. The maximum elevation in the foothills is about 2,000 feet.

The topography and drainage systems roughly reflect the underlying crustal framework. A large part of the Barcelona structural basin is occupied by drainage systems which drain northward into the Gulf of Barcelona. The Maturín basin drains eastward into the Gulf of Paria and the Atlantic Ocean. A topographic high extending southward from the eastern interior range reflects the structural saddle between the two basins. Although the Orinoco River flows along the southern edge of both basins, it actually receives very little drainage from the north. It owes its present position at the southern edge of the sedimentary area to a very late Cenozoic tilt to the south and east of this part of the continent.

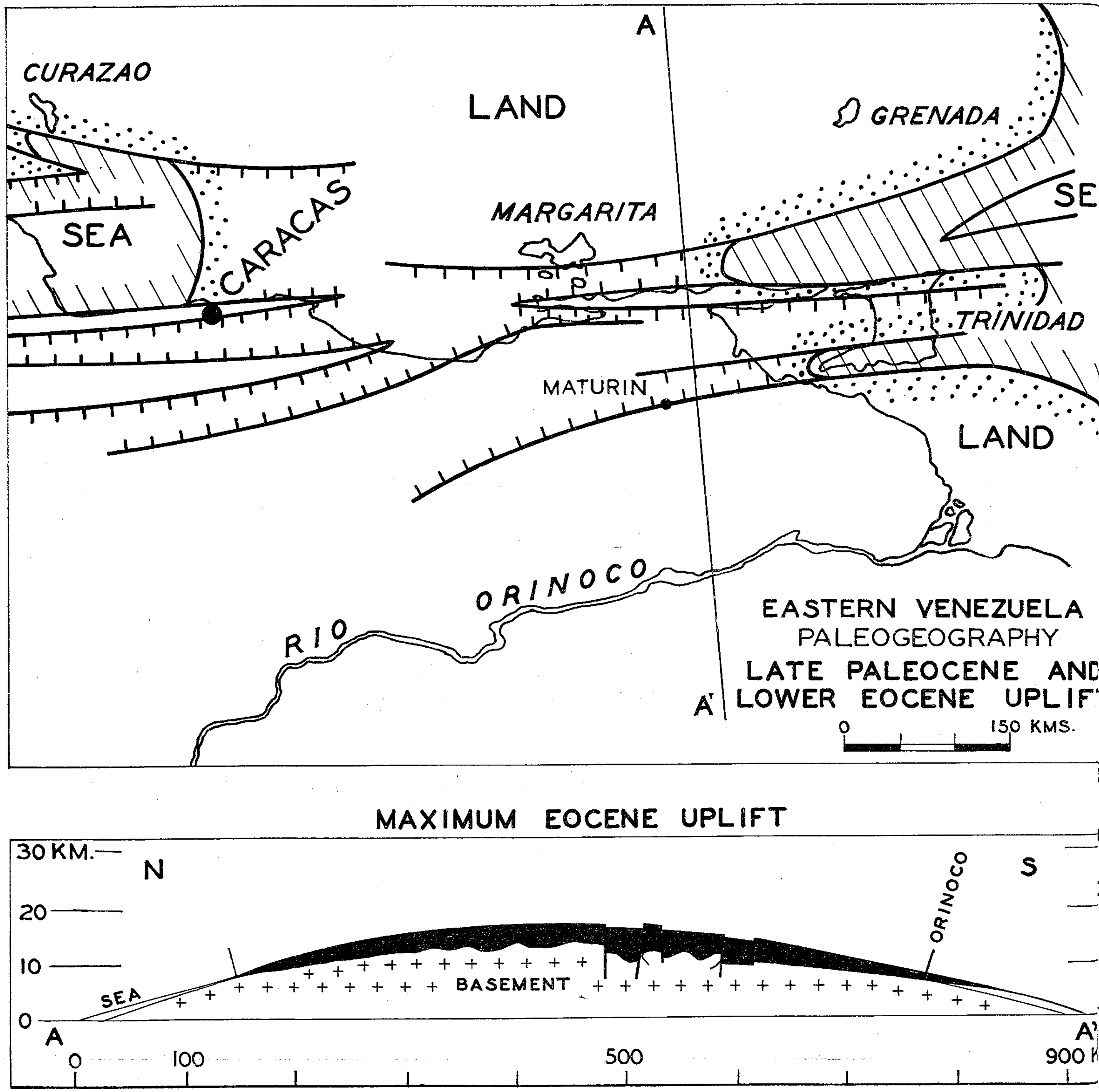
STRUCTURAL HISTORY AND MAJOR STRUCTURAL COMPONENTS

Since the sedimentary area of eastern Venezuela is divided into two compound structural basins, a brief review of the structural history is necessary to understand the development of the oil producing basins. Throughout eastern Venezuela the rocks of the sedimentary cycle which began in late Jurassic or early Cretaceous time, rest unconformably on older rocks. A sequence of six paleogeographic maps, and six generalized cross sections of the Maturín basin attempt to portray the main structural events from the Cretaceous to the present.

A new technique is employed in the cross sections in that the sea level base line curvature over the distance of the section is exaggerated at the same scale as the thickness of the section. The section is 8° long (890 kms.) and the median height at the center is 15.5 kms. This method shows the major structural elements in their approximate true shape despite the vertical exaggeration. However, at the scale of the maps and sections, namely 1:5,000,000, no attempt has been made to depict exact or structural detail. No attempt has been made to show erosion of the horsts which developed during post-Paleocene uplift of the folded sediments.

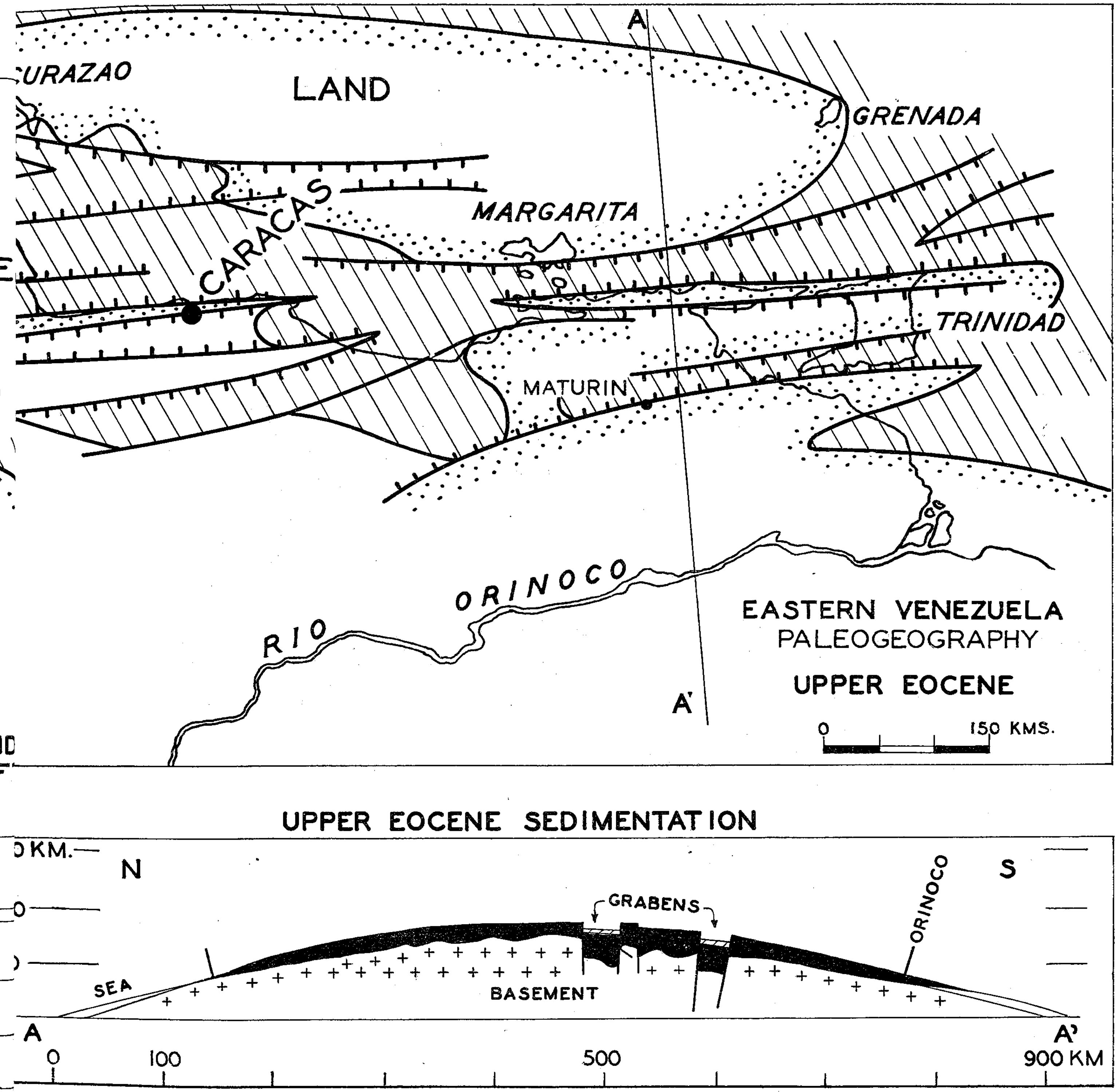
During the Cretaceous, a seaway extended through northern Venezuela between the rising Guayana shield and a land mass to the north in the site of the present Caribbean Sea. At the beginning, the seaway appears to have been confined to the area south of the islands off the north coast. As the subsidence continued, the seaway widened until in the Upper Cretaceous, the southern shore line must have lain south of the Orinoco River (Fig. 2). Two centers of maximum subsidence of the primary basins are shown by the oval outlines on the map. North of these maxima there is evidence of much vulcanism on the islands. This vulcanism may be related to a volcanic arch separating the southern primary basins from other primary basins to the north as shown in the cross section (Fig. 2). The northern shore line may have been considerably to the north of its shown position.

Although the seaway attained its maximum width in the Upper Cretaceous, the subsidence continued into the Paleocene and probably lower Eocene. As the basin filled up, the seaway became narrower (Fig. 3), until at the end only remnant seas remained (Cross Section Fig. 3). Contemporaneous with the subsidence, folding and some thrusting took place where the greatest thicknesses of sediments were deposited in the deepest part of the basins.



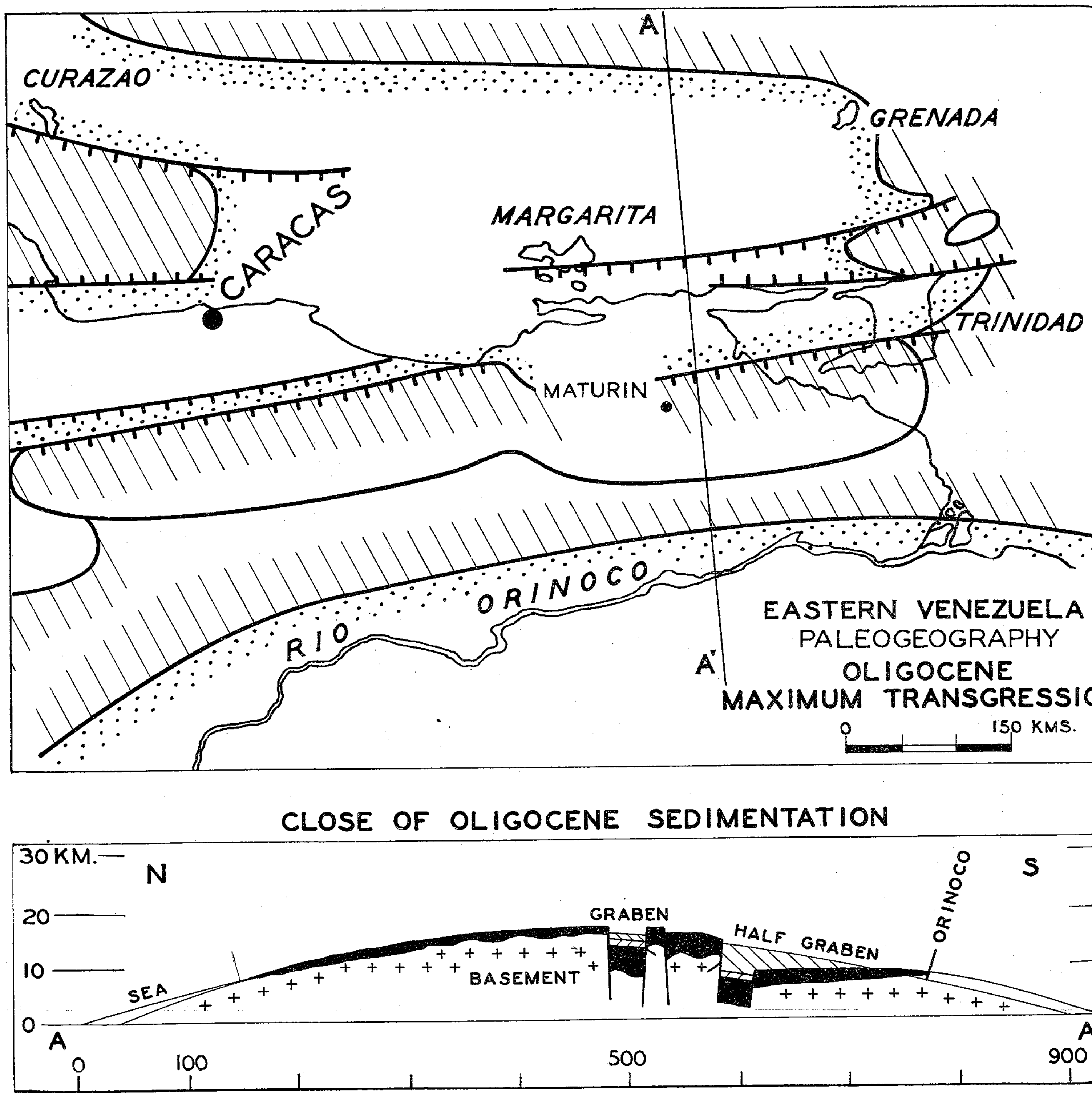
GENERALIZED HISTORICAL CROSS SECTION OF THE MATURIN BASIN

FIG-4



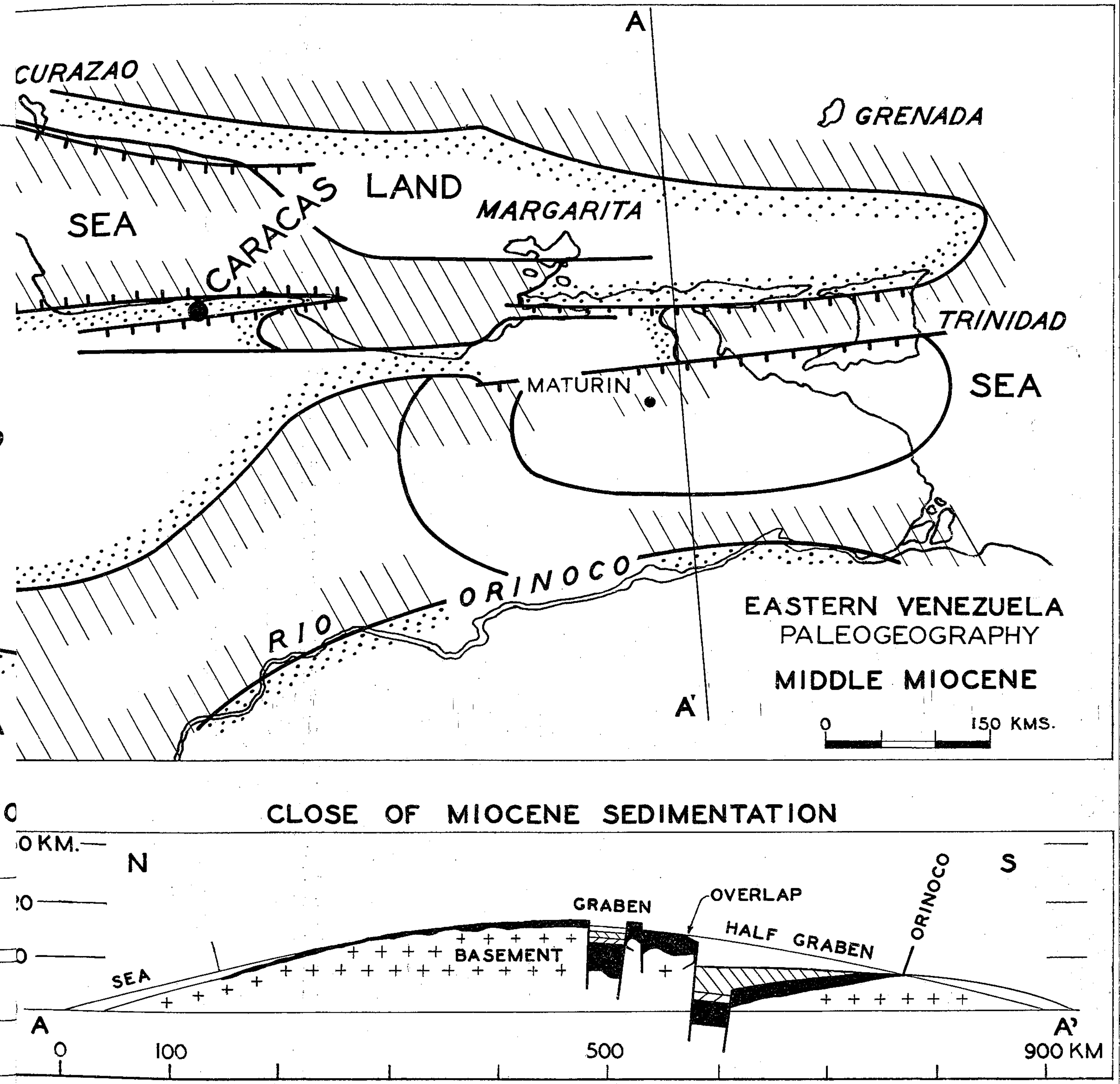
GENERALIZED HISTORICAL CROSS SECTION OF THE MATURIN BASIN

FIG-5



GENERALIZED HISTORICAL CROSS SECTION OF THE MATURIN BASIN

FIG-6



GENERALIZED HISTORICAL CROSS SECTION OF THE MATURIN BASIN

FIG-7

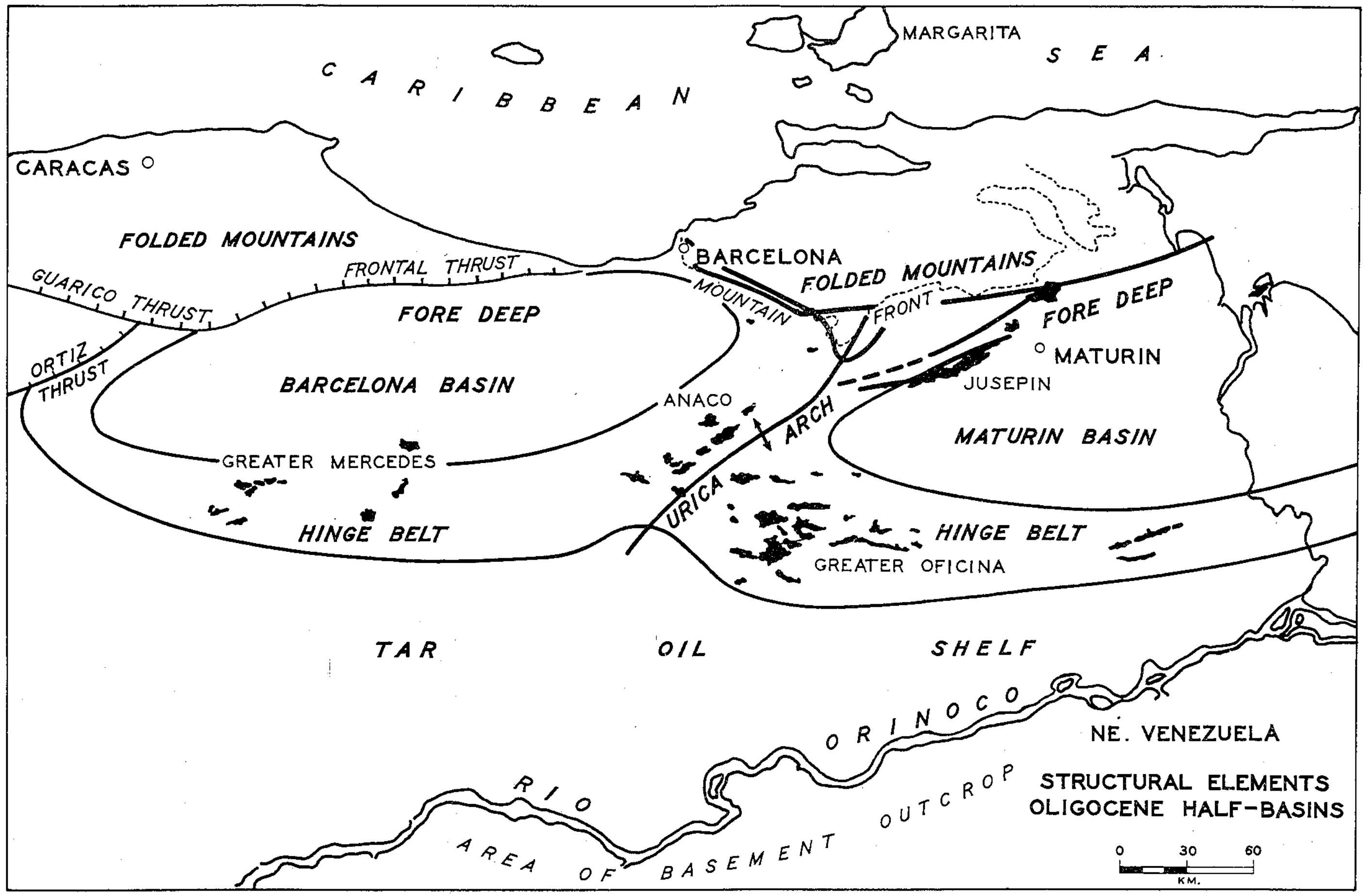


FIG. 8

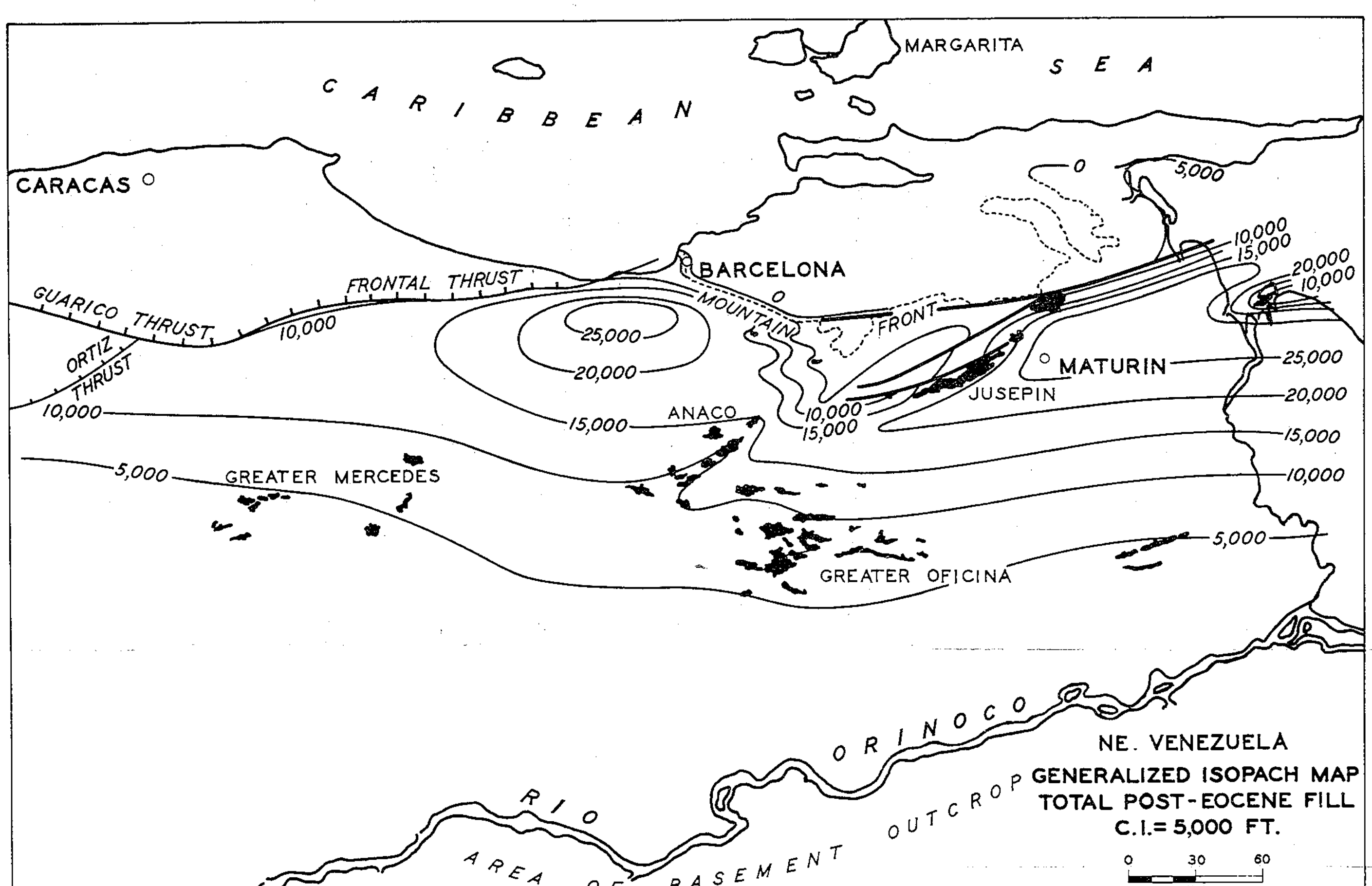


FIG. 9

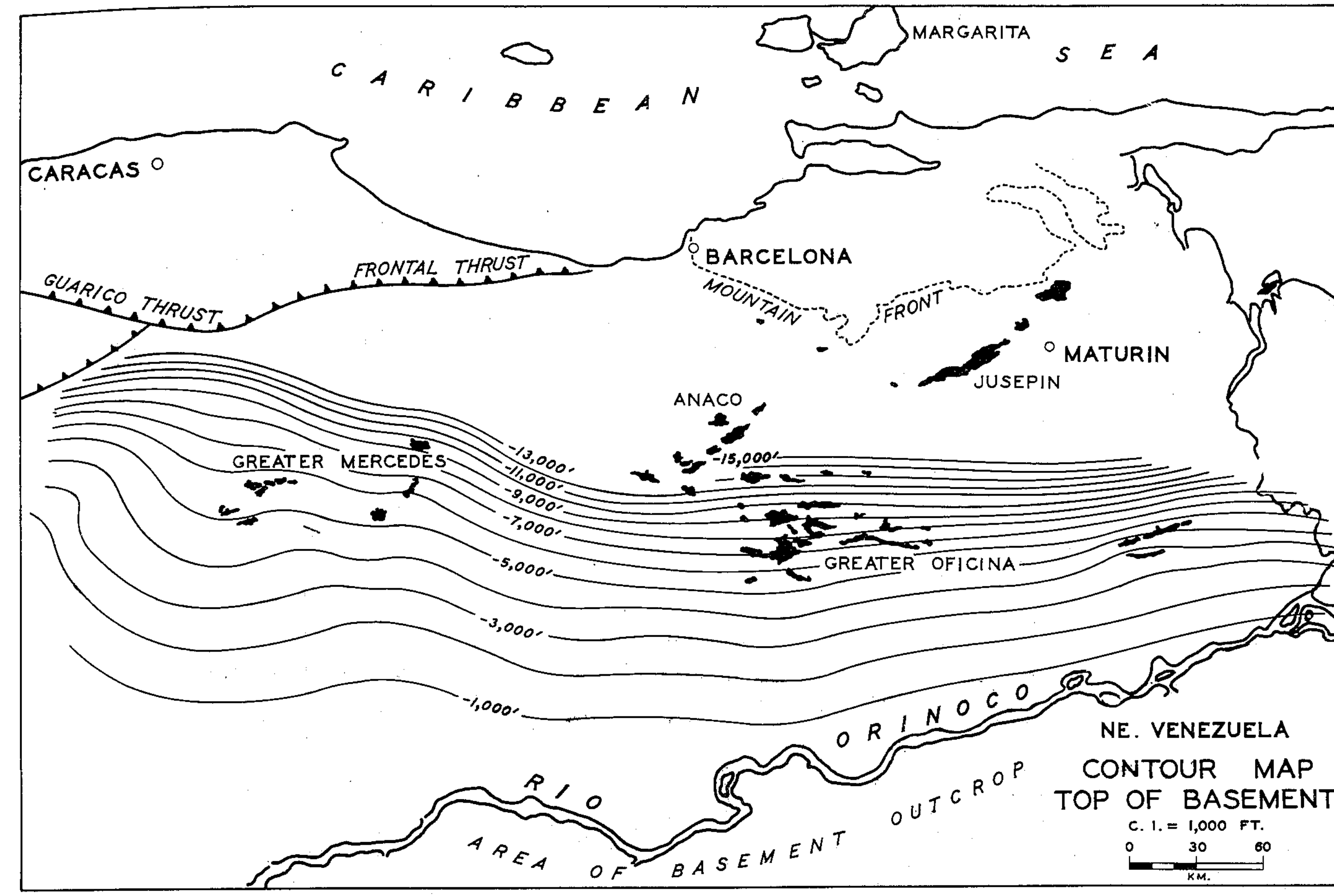


FIG. 10

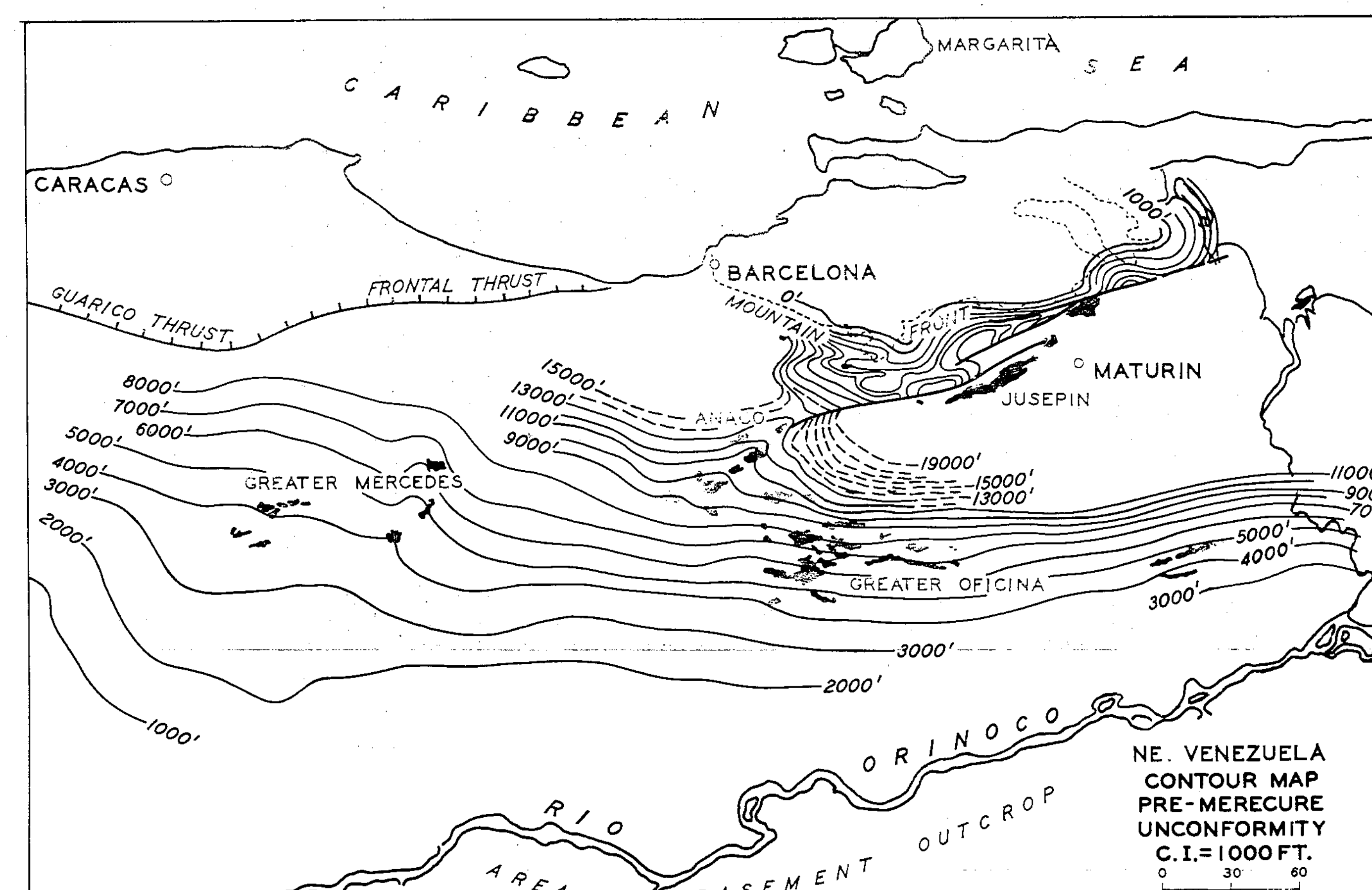


FIG. 11

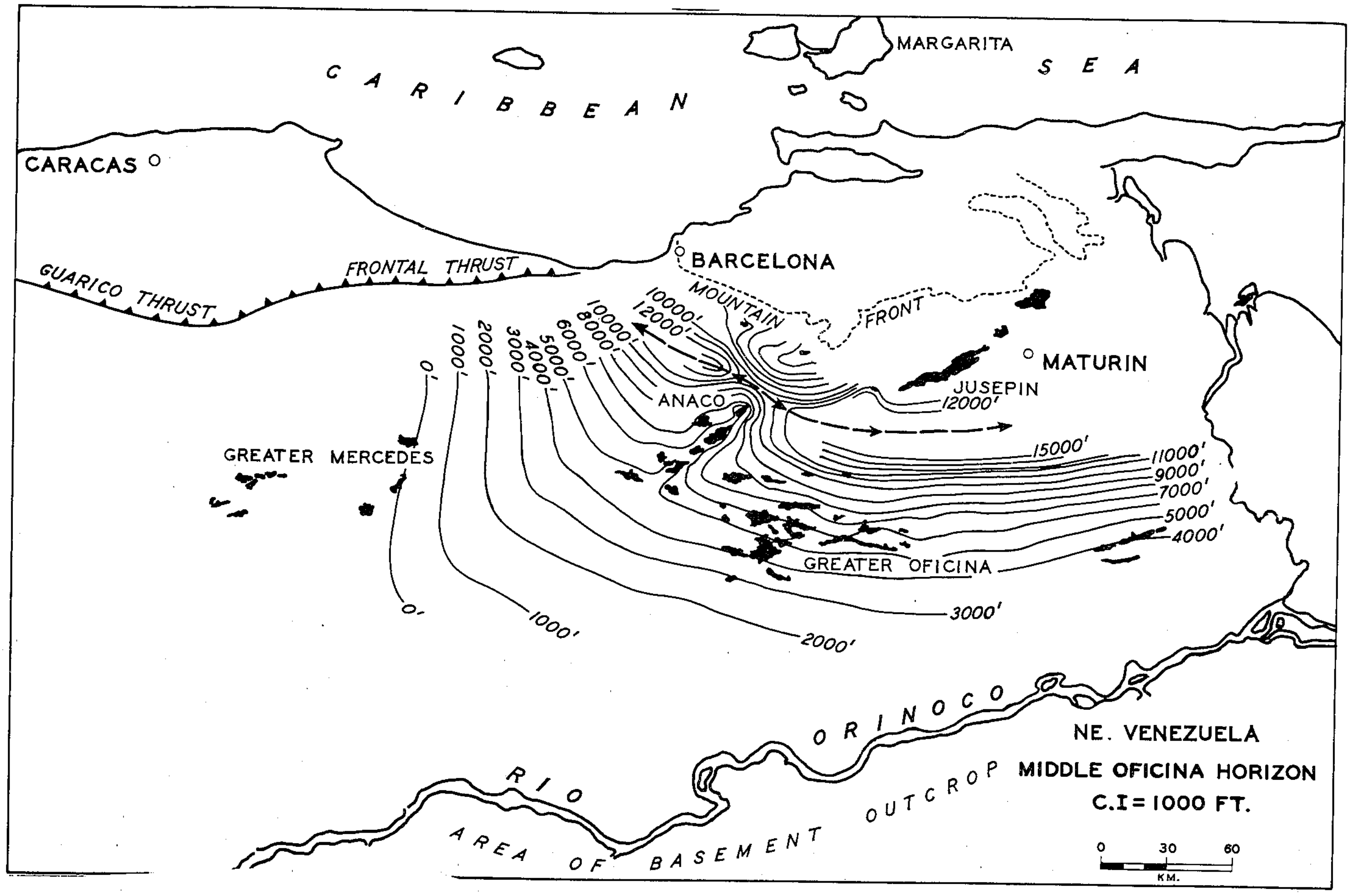


FIG. 12

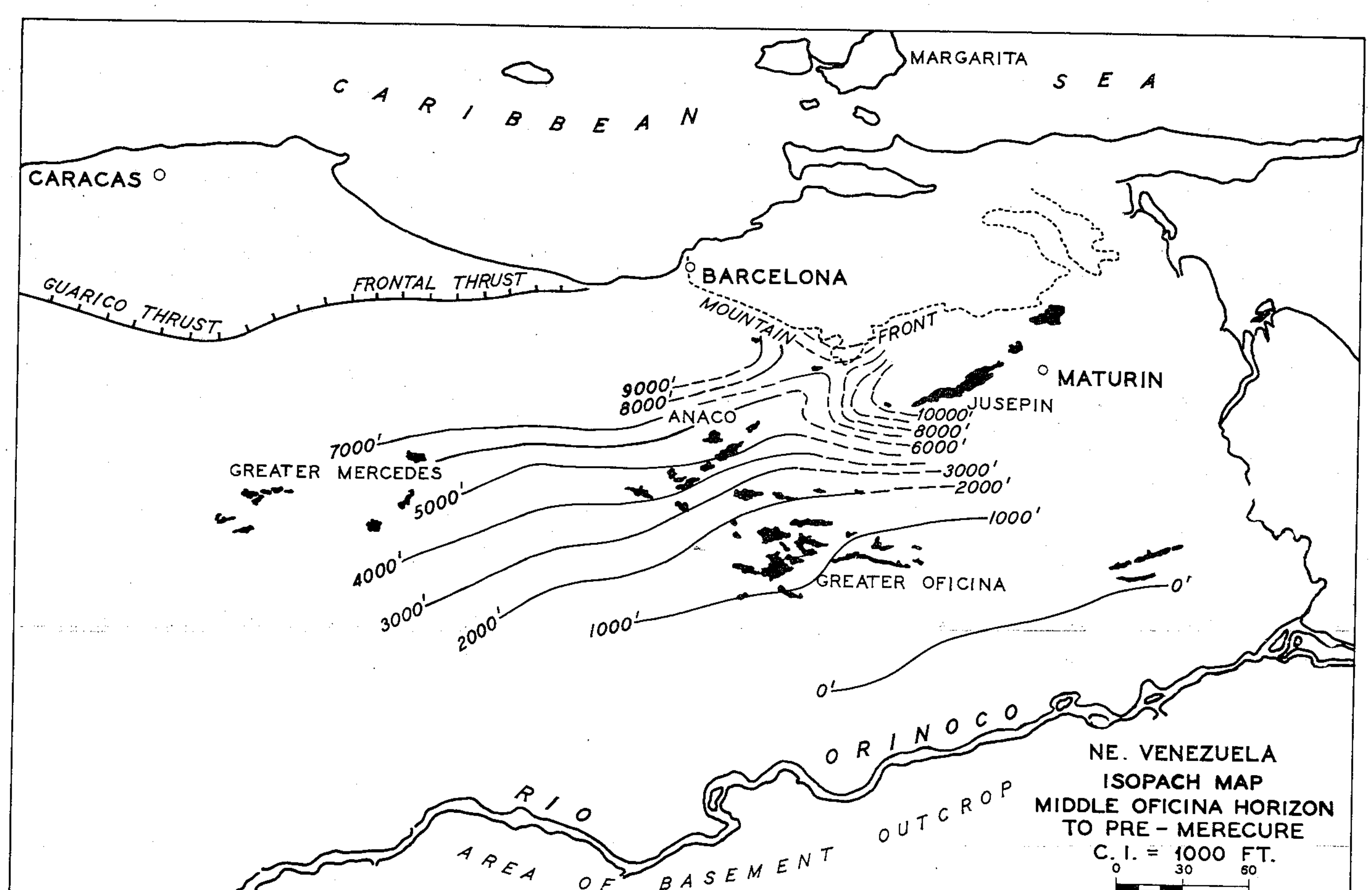


FIG. 13

Beginning in the late Paleocene an epeirogenic uplift raised all the northeastern Venezuela and the southern Caribbean area above sea level (Fig. 4). This even clearly shows up in the stratigraphic table where a very marked hiatus appears in all sections except in the grabens along the mountain front in the Maturín basin (Table 1). As a result, the Cretaceous and Paleocene were very widely eroded. To the north, the former Caribbean land mass sank beneath the sea. Contemporaneous with the overall uplift of the former sedimentary basins large scale normal faulting, parallel to the long axis of the uplift, down dropped long narrow blocks within and on the edges of the folded belts. Vigorous igneous activity and vulcanism occurred along the arch between the basins.

As the overall uplift progressed, some of the long narrow grabens dropped below sea level and Eocene marine sediments were deposited. An eustatic change also apparently took place at this time because a thin Eocene section overlaps some of the eroded edges of the fault scarps for a short distance (Fig. 5).

With the beginning of the Oligocene, the area south of the master normal fault system along the front of the highly folded belt started to subside and the Oligocene half basins were formed. It is this subsidence which brought the present oil producing basins into existence. Although there was a continuous sedimentary trough from western Guárico eastward, there were two sites of maximum subsidence, one in northern Guárico and Anzoátegui and the other in Monagas (Fig. 6).

Sedimentation continued uninterrupted into the Miocene in the deeper parts of the basin, but the borders were affected by eustatic changes and local structural movement and here minor unconformities are found. Beginning in the late Oligocene, an overall tilt of the continent as a whole was superimposed on the more local movements. By the end of the Miocene, marine sedimentation was confined to the eastern part of the area. As the tilting continued, the younger progressively overlapped the older Tertiaries and lapped up on to the eroded pre-Eocene surface (Fig. 7).

Oligocene Half-Basins: The structural elements of the Oligocene half-basins are shown on Figure 8. The Barcelona basin on the west is separated from the Maturín basin by the Urica arch. The generalized isopach map of the total post-Eocene fill (Fig. 9) shows the present day thickness of sediments. Since there has been considerable Tertiary erosion in the Barcelona basin, the original area of maximum deposition probably lay to the west of its position on the map.

Barcelona Basin: This basin is a typical half-basin bounded on the north by a master fault system of large vertical throw. Although this system is mapped as one continuous thrust fault, actually there are a number of separate high-angle faults which may or may not show reverse throw at the surface. The greatest thickness of sediments is immediately in front of the fault. Although some of the very oldest Oligocene may occur locally for a short distance north of the fault system, the greater part of the section was never deposited on the upthrown side of the fault system. On the western plunging end of the eastern interior ranges the Oligocene section thickens very rapidly to the west, probably caused by a large fault downthrown on the side to the west. Here also the section contains many conglomeratic beds which point to the close proximity of high land.

The configuration of the Cretaceous basin floor is shown by the structural contour map on the top of the basement (Fig. 10). The map on the post-Cretaceous pre-Merecure erosion surface (Fig. 11) is very similar to the basement map in that it shows the effect of the overall tilt to the east. The strike of the contours originally must have been nearly east-west, or even a little south of west, in contrast to the present northwesterly strike.

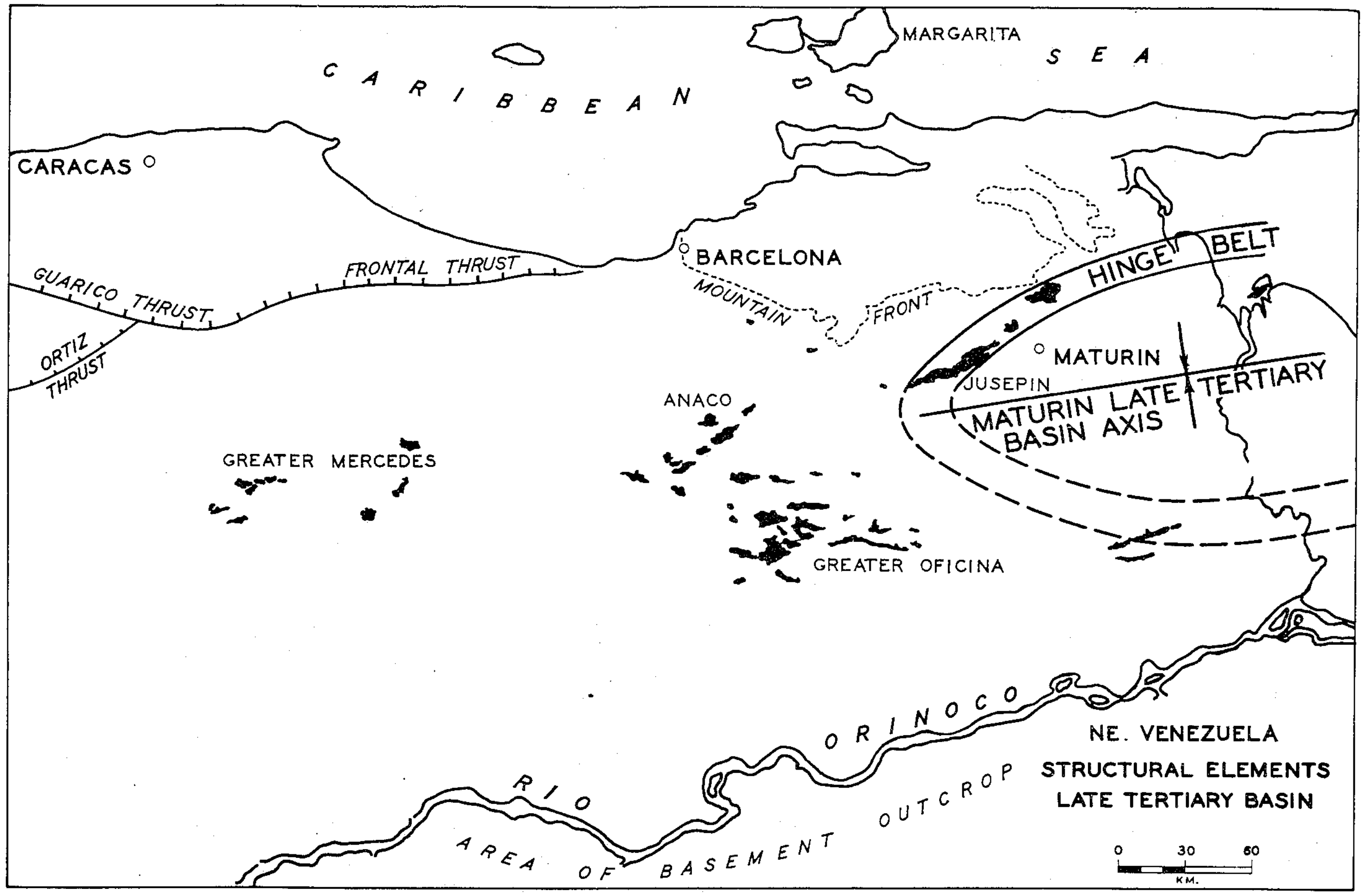


FIG. 14

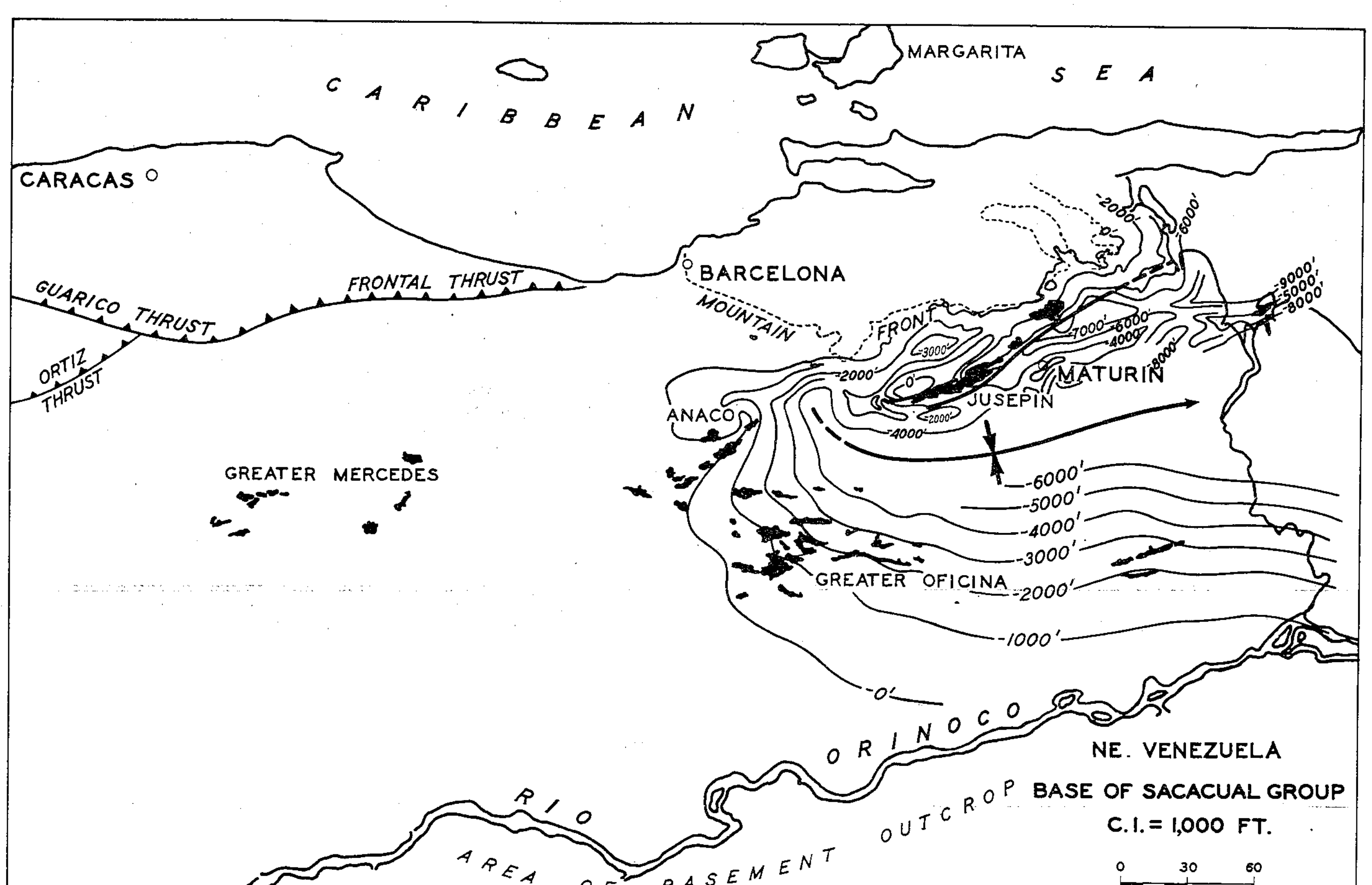


FIG. 15

The correlation chart published by the First Venezuelan Petroleum Congress, March 1962, shows the present accepted correlation and nomenclature (Table 1). The validity of the maps published in the Habitat of Oil (AAPG) has not been affected materially by the revision of the nomenclature, and the maps are reproduced here for easy reference. The correlation horizon chosen by H.H. Renz in the Middle Oficina (Fig. 12) shows the correlation between the two basins. The isopach map of the Middle Oficina to pre-Merecure has been altered to fit the present concept (Fig. 13).

The axis of the basin inside the hinge belt (Fig. 8) is about 300 kilometers long, and the maximum width of the deep part of the basin is about 80 kilometers. A hinge belt of rim, where the rate of change of dip on the pre-Oligocene floor is at a maximum, is well developed on the south side. The hinge, or rim, is discernible in the greatest change of rate of thickening where the oil fields occur. The hinge belt is from 35 to 50 kilometers wide. A shelf area from 100 to 150 kilometers wide with a thin cover of sediments extends from the hinge belt outward to the Guayana shield, whose pre-Cretaceous rocks start to outcrop along the Orinoco River.

On the north the basin is bounded by the master fault system previously mentioned, and north of this the folded mountains of Cretaceous and Paleocene rocks are exposed. The mountains plunge to the east where the fault zone intersects the coast; the Oligocene sediments extend to the coast in the Barcelona gap.

On the east, the basin is separated from the Maturín basin by a low structural saddle, the Urica arch.

Maturín Basin: This Oligocene half-basin (Fig. 8) is similar in structure to the Barcelona basin except that the northern fault system is apparently much wider. This may be, in part, due to the fact that much less is known about the subsurface in the western basin, because very few wells have been drilled there. Immediately east of the Urica arch, at least three large vertical throw faults are known which step down to the south, but only the northernmost fault can be observed at the surface in the western part of the area. Although the faulting continued into the Miocene, the subsurface structure is obscured in the basin by the overlap of the young Tertiary caused by the overall tilt to the east. Because of the great thickness of these younger sediments, very little is known about the thickness and areal disposition of the Oligocene sediments in the deep part of the basin.

The hinge belt and shelf areas, however, are better known than in the Barcelona basin (Figs. 8 and 9). In the west end of the basin where the hinge belt merges with the Urica arch, the hinge belt is about 70 kilometers wide. To the east it narrows down rapidly to less than 30 kilometers. The location of the eastern end of the basin is not known, but the depositional strike of the contours of the isopach map (Fig. 13) indicates that a structural saddle similar to the Urica arch must exist not too far east of the island of Trinidad (Fig. 6). The shelf of the Maturín basin narrows down rapidly eastward from the Urica arch and at Tucupita is less than 40 kilometers wide.

The Maturín basin differs from the Barcelona basin in that a late Tertiary basin (Figs. 14 and 15) is superimposed in the older Oligocene half-basin. Contemporaneous with the continental tilt a new center of subsidence developed well to the south of the deepest part of the underlying half-basin. This late Tertiary basin developed a very sharp hinge belt on the north. On the west and south, the hinge belt falls inside of, or is superimposed on, the older Oligocene rim.

On the northern side, a rather wide shelf area is locally developed on the eroded edges of Cretaceous and older Tertiary formations, but on the south the sedimentary sequence in the Tertiary is almost continuous, and the two shelf areas are more or less superimposed. The exact thickness of the younger fill in the center of the basin is not known, but it is definitely more than 10,000 feet.

The historical cross sections clearly indicate that the conventional concept of geosynclines is based on an erroneous notion of the shape of the bottoms of basins. The term syncline implies a concave surface, and a geosyncline should necessarily have a concave bottom. From the width of the outcrop and thickness of the Cretaceous and Paleocene sediments, the sections clearly show that the original surface of deposition has not approached the chord between the limits of subsidence. Subsequent folding caused by the shortening has formed synclines and anticlines, but a concave basin never existed (Figs. 2 and 3).

The downbend on the flank of primary basins where the subsiding surface has been nearly peneplained seldom exceeds 6°, even where the subsiding area is of the dimensions of the Atlantic Ocean. The hinge belt, i.e. the part of the curve with the maximum curvature, is always measurable in tens of kilometers. Since the thickness of sediments cannot exceed the vertical distance between sea level and the subsiding floor the rate of thickening of a continuous sequence of sediments cannot exceed the angle of the total bend on the rim of the basin. Rates of thickening in excess of this amount can, therefore, only be explained by two causes. The first of these is irregular bottom topography, which generally does not exceed a few thousand feet. The second, and more important, cause is large-scale normal faulting. The extremely rapid increase of thickness of the Oligocene and younger sediments along the southern mountain front in eastern Venezuela, of the order of ten thousand feet or more, can only be explained in this manner.

These large-throw faults involve the basement, and dense rocks (density 2.7 or more) abut laterally against unconsolidated sediments. The compressive strength of granite is approximately 20,000 pounds per square inch at surface conditions. The base of a column of granite 20,000 feet high will, therefore, cede under its own weight. Although the sediments afford some lateral support there is a critical depth at which the rocks on the upthrown side will start to bulge toward the downthrown side and compress and displace the sediments on that side. The column is lowered and the top of the column will tend to override the downthrown side; thus, transforming original normal faults into steep-angle reverse faults. If the dip on the upthrown side is toward the fault, large scale slumping will cause a very complex structure on the downthrown side.

The structural complexities along the north side of the Maturín and Barcelona basins can be explained in this manner without invoking either large scale thrusts or transcurrent faults.

A further complication occurs in the eastern part of the Maturín basin where a late Tertiary basin is superimposed on the Oligocene half-basin. The northern rim of the basin cuts diagonally across the southern limit of the older half-basin and across topography with 4,000 to 5,000 feet of relief. The anomalous thicknesses (Fig. 15) make it difficult to determine where the rim actually lies.

In summary, the Barcelona basin, an Oligocene half-basin, is superimposed on a Cretaceous primary basin. A third stage has been added in the Maturín basin where a late Tertiary primary basin is superimposed on an Oligocene half-basin and this, in turn, is superimposed on a Cretaceous primary basin.

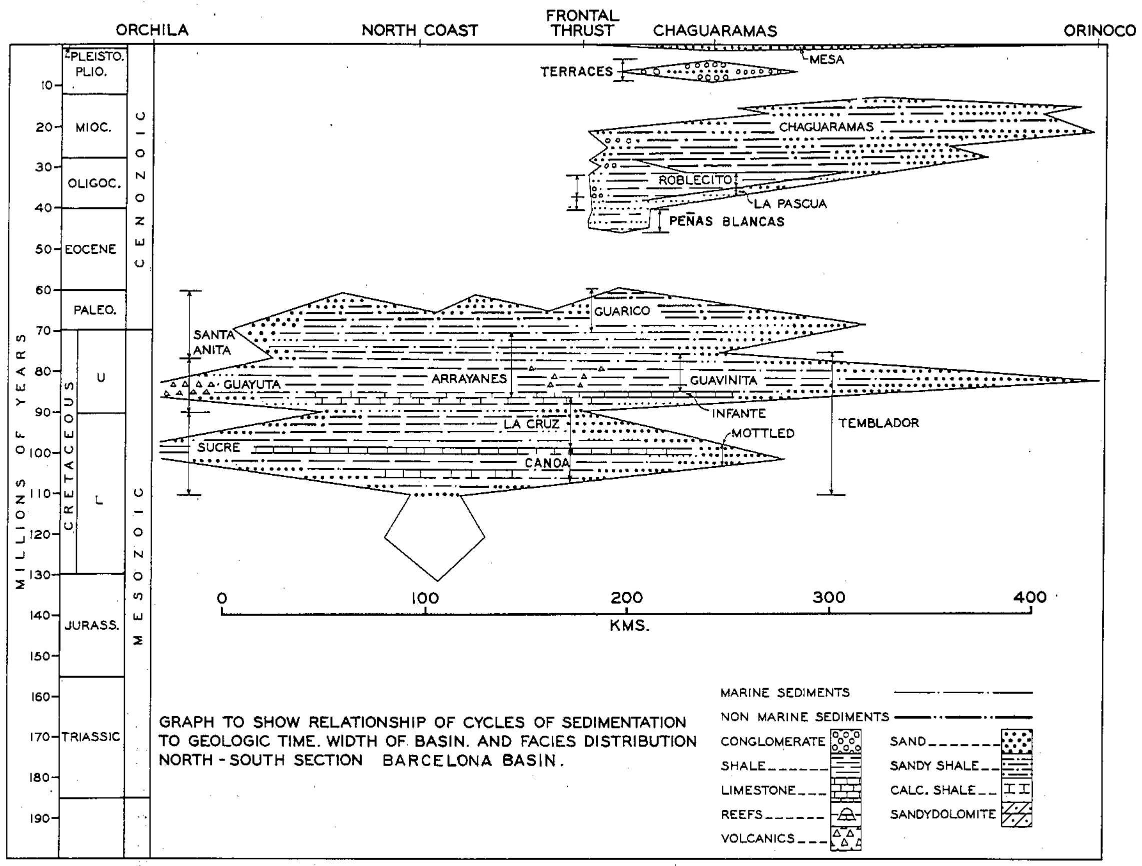


FIG. 16

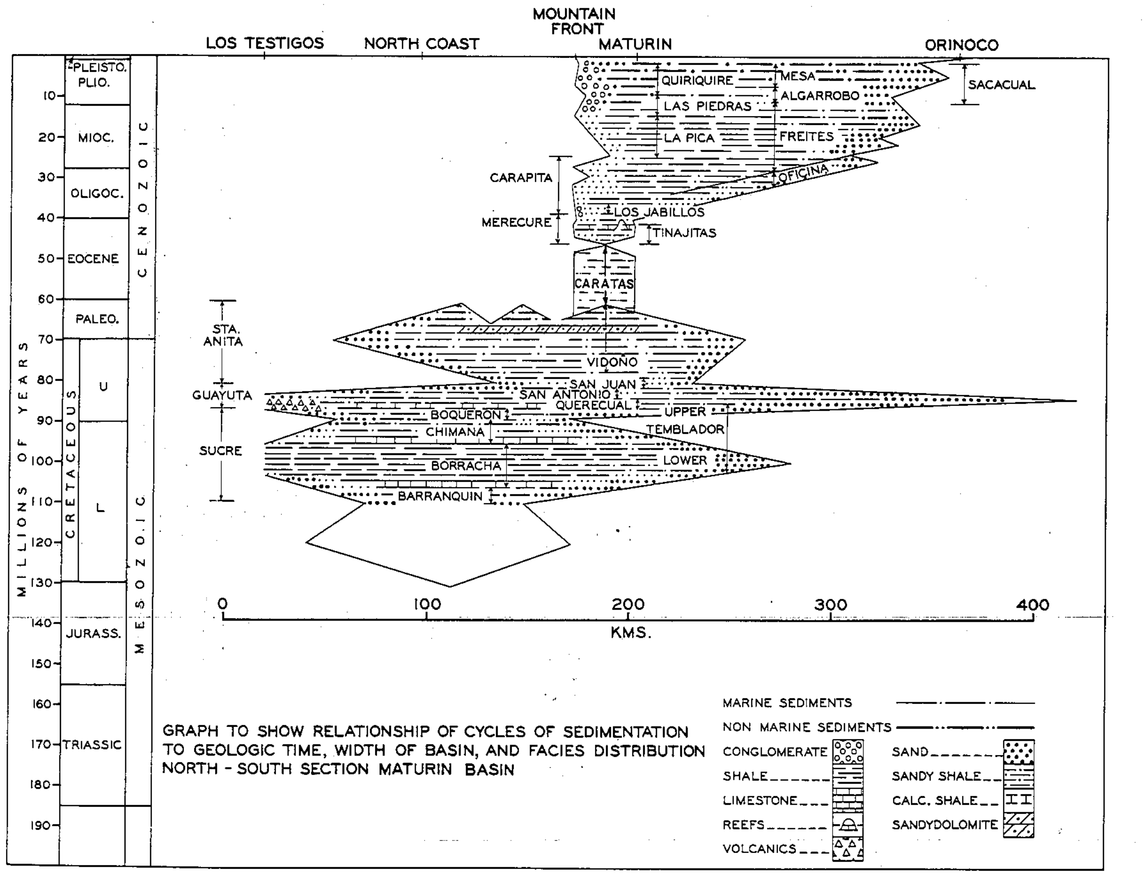
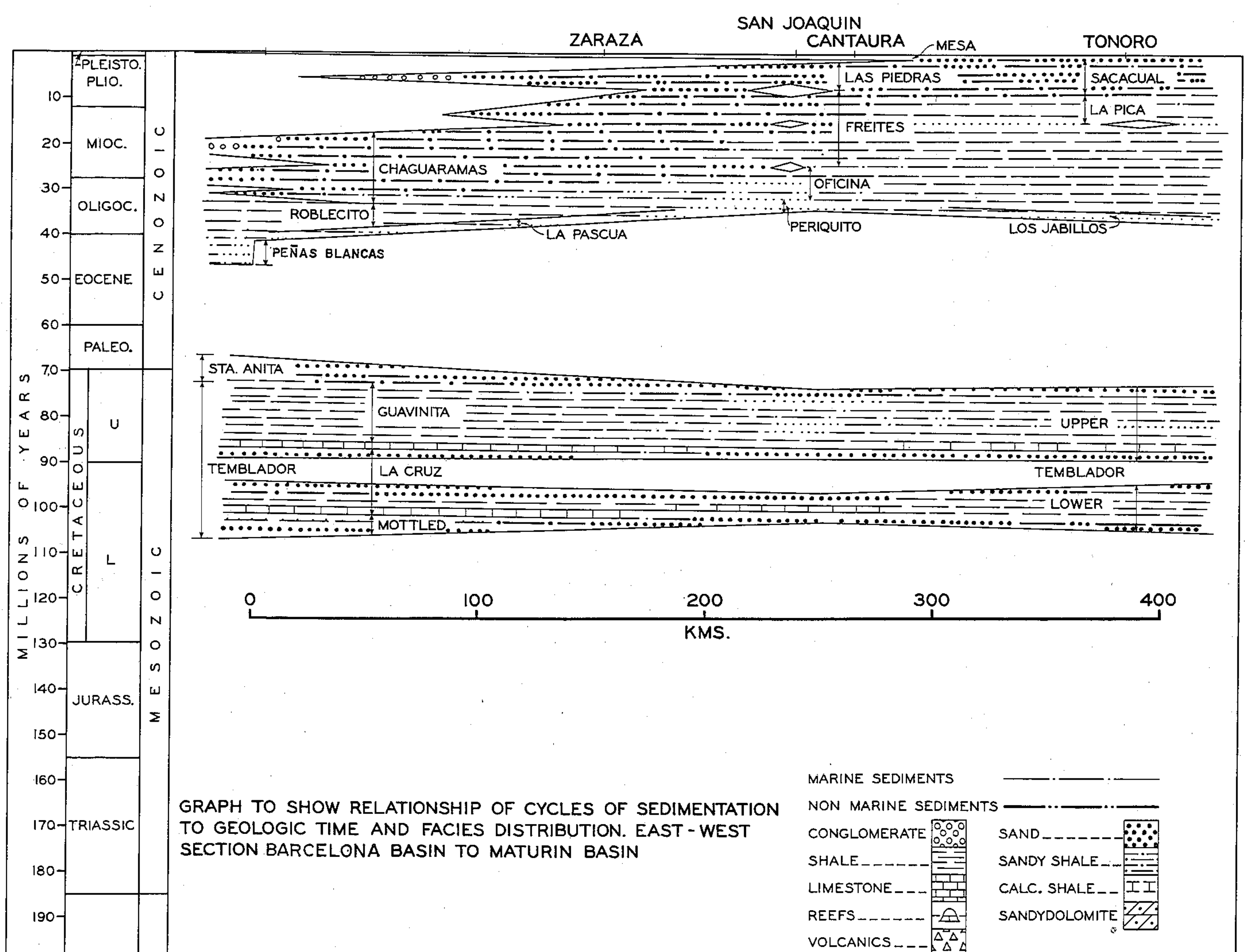


FIG. 17



GRAPH TO SHOW RELATIONSHIP OF CYCLES OF SEDIMENTATION TO GEOLOGIC TIME AND FACIES DISTRIBUTION. EAST - WEST SECTION BARCELONA BASIN TO MATURIN BASIN

FIG. 18

STRATIGRAPHY

The stratigraphic section present and the correlation between formations in the Barcelona and Maturín basins are summarized in Table 1.

In all areas where pre-Cretaceous rocks have been observed directly, these lie unconformably below the Cretaceous and it is suspected that this condition also exists in the mountainous areas on the north. The problem of recognition of the ages of the various formations in the coastal mountains is complicated by strong regional metamorphism. However, sufficient fossil evidence has been found to indicate that the great bulk of the metamorphics is composed of Cretaceous rocks.

It is difficult to obtain a comprehensive grasp of the inter-relationship of time, lithologic facies and geographic location from conventional facies maps and cross sections based on formational contacts. An alternate solution of the problems is to make cross sections and to substitute length of time for the thickness of section and to indicate the lithology by symbols on the resulting cross sections (Figs. 16, 17, 18). This device is essentially a time-space graph independent of the thickness and facies development of the rocks. The area inside the closed figures represents the length of time during which sedimentation took place within the indicated horizontal limits. The area outside the closed figures indicates the length of time and the horizontal distribution of the areas undergoing erosion. The overall shape of the closed figure also shows the shape of the basin involved. This method of presentation also clearly indicates the relative importance of the unconformities, local or regional. To make the graph represent the actual rocks present after erosion, it is only necessary to draw a profile through the points representing the youngest rocks of each main cycle actually present along the cross sections.

Barcelona Basin: In the Barcelona basin the Cretaceous rocks belong to one main cycle of sedimentation starting with shallow water, mainly coarse-grained clastic deposits at the bottom. These grade upward into deeper water calcareous and fine-grained clastics, and finally, upward into the shallow-water sediments of the final fill-up during the Paleocene. The major part of the Paleocene fill-up was subsequently removed by erosion, but enough is left in the mountainous area to indicate the general character of the rocks. There may have been disconformities on the shelves of the basin, as indicated on Figure 16.

The Cretaceous formations were laid down in a symmetric basin. The positions of the hinge belts are indicated on Figure 16 by the presence of volcanic rocks, on the south immediately north of the present mountain front and on the north, in the islands of the Caribbean. The distance between the two belts is about 200 kilometers (124 miles).

The distribution of the Cenozoic sediments is erratic both in time and location, as shown by Figure 16. The shape of the sites of sedimentation is also radically altered. All of the deposition took place in grabens or half-grabens or basins, except the very youngest Cenozoic sediments which, in large part, consist of true continental deposits, terraces and outwash alluvial fans.

The oil bearing section, the Oligocene through Miocene rocks, constitutes one main cycle laid down in a half-graben. On the north the section is composed almost entirely of very coarse clastics, conglomerates, gravels and sands. The Oligocene part of the section rapidly grades southward into an almost pure shale section known as the Roblecito Formation (Fig. 16). This shale wedges out southward between the basal La Pascua sands and the overlying sandy Chaguaramas Formation. On the east-west section (Fig. 18) the Roblecito shale is seen to intertongue with the Merecure formations of the Greater Anaco area. In the same manner, the non-marine sediments of the Chaguaramas Formation are seen to pass eastward into the marine Oficina. Also the La Pascua Formation of the Mercedes area, although older than the Periquito Formation of the Anaco area, is seen to constitute the basal sand section of the same cycle. The conventional cross sections based on thickness of lithologic units, such as Figures 19 and 20, although they give the structural detail, do not give any idea of the time equivalency of the lithologic units because of the difference in rate of deposition between the coarse- and fine-grained sediments.

Erosion has removed a considerable portion of the thick coarse clastics along the northern and western edges of the basin. As a result, the total post-Eocene fill shown on Figure 9 is in error, and the actual location of the site of maximum deposition was probably considerably west of its position shown on the map.

Maturín Basin: The stratigraphy of the Cretaceous section in the Maturín basin is very similar to that in the Barcelona basin (Fig. 17). In general, the rocks are much less metamorphosed and the original lithologies are better preserved over a greater area, and as a result, it has been possible to divide the section into more formational units. The volcanic rocks on the islands to the north indicate the position of the northern hinge belt but, because of erosion, there is no evidence to indicate the position of the southern hinge belt.

The Cenozoic section of the Maturín basin differs from that of the Barcelona basin as two main cycles of sedimentation are present. The lower one corresponds to the Oligocene-Miocene cycle of the Barcelona basin, but the upper one, Miocene to Recent, is absent in the Barcelona basin except for non-marine sediments.

The distribution of the lithologic facies of the sediments of the Oligo-Miocene cycle is similar to that of the Barcelona basin but the marine facies extends much higher in the section, in fact, in the central part of the basin, the marine section extends well up into the upper cycle. The lower cycle was laid down in a half-graben and the sediments along the northern edge show characteristic rapid grading into shale which occurs in such depositional environments.

Although marine sedimentation continues from the Oligocene to the Recent in the Maturín basin, the upper cycle, beginning with the La Pica Formation in the north, is separated from the lower cycle by a pronounced angular unconformity on the north side of the basin. Because of the continued eastward tilt of the continent, the upper cycle shows a rather well developed shelf area on the north, and here coarse clastics abound in the section. However, on the south there is no pronounced break between the cycles, and the formations show a progressive overlap to the south.

The conventional cross section of the Maturín basin (Fig. 21) gives the structural details of the basin, but again it is difficult to visualize the time equivalency of the rocks shown in the section. It is only by a combination of the two types of cross sections that the true picture emerges.

Correlation between Basins: Although the sediments of eastern Venezuela were laid down in two separate areas of maximum subsidence, they were laid down in one continuous depositional basin. During the Cretaceous, the seaway extended far beyond the eastern and western limits of Venezuela. A continuous source area bordered the seaway and, as a result, the sequence of formations and their facies

development is very similar throughout the whole area. The Temblador Group is developed in a similar manner in the south side of both basins and across the Urica arch. Although it is impossible to make bed-for-bed correlations there is little doubt that the group contains parts of the same time equivalents in both basins. The most characteristic feature is the section of mottled kaolinitic sands and sandy clays found everywhere at the base. Since the basal sands of the Oligocene section may also contain mottled beds, it is sometimes difficult to locate the contact where the Oligocene directly overlies the mottled Temblador.

In the Oligocene-Miocene cycle the correlation from the Barcelona basin to the Maturín basin was in doubt for a long time. Attempts based on lithological correlations failed to give a reasonable east-west cross section through the basins. However, (Fig. 18) the time space presentation produced a logical answer long before the present correlation was worked out and accepted.

Since the section does not show thickness in feet, the apparent anomalies caused by large differences of thickness of lithological units - by difference of rate of thickening of the lithological units - and by differences in depositional dips, disappear.

In the section, the upward creep of the marine facies from Middle Oligocene in the west to well up into the Pliocene in the east clearly indicates the overall continental tilt to the east. Also, the presence of the Urica arch and its effect on sedimentation are clearly indicated by the much greater erosional span in this area than either to the east or west and by the greater sand development higher in the Tertiary section.

OIL AND GAS IN THE EASTERN VENEZUELA BASINS

Surface Oil and Gas Indications: Surface manifestations of oil and gas are comparatively scarce in the eastern Venezuela basins. The greatest number of oil and gas seeps is found on the northern flank of the late Tertiary Maturín basin. The seeps along the mountain front are associated with the unconformity at the base of the late Tertiary section. Those farther south are always associated with mud volcanoes.

Only one live oil seep is known on the northern flank of the Barcelona basin. The only gas seeps found on the south flank of both the Barcelona and Maturín basins are three seeps in southern Guárico.

LOCATION OF OIL WITH RESPECT TO BASIN POSITION

Cretaceous Basins: In eastern Venezuela, very little commercial oil has been found in Cretaceous formations. In all cases, where oil does occur in these rocks, it is always found very close to the unconformity which separates the Cretaceous from the Tertiary. Considerable quantities of heavy tar oil are found in the southern tar belt from Guárico to the Delta. A small amount of commercial oil occurs in the Temblador in the Mercedes area.

In the northeast, some oil occurs in the Sucre and Guayuta groups on the shelf area north of the late Tertiary basin rim (Fig. 14). In one area, very heavy oil of undesirable refining characteristics occurs in secondary porosity developed in Cretaceous limestones immediately below the unconformity. In another area, very heavy oil is found in fractured Guayuta shale.

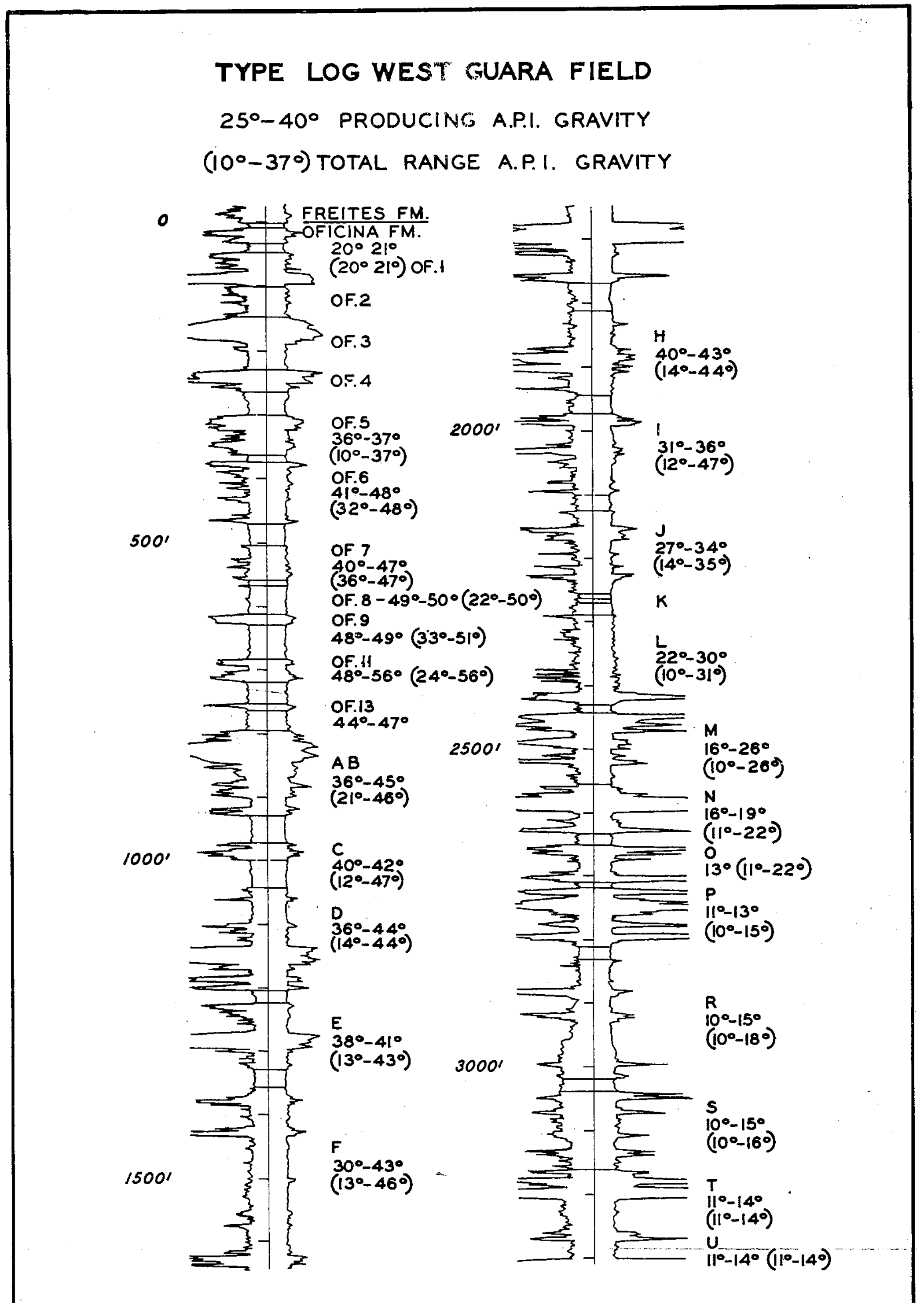

TYPE LOG WEST GUARA FIELD
25°–40° PRODUCING A.P.I. GRAVITY
(10°–37°) TOTAL RANGE A.P.I. GRAVITY
0
500'
1000'
1500'
2000'
2500'
3000'
FREITES FM.
OFICINA FM.
20° 21°
(20° 21°) OF.1
OF.2
OF.3
OF.4
OF.5
36°-37°
(10°-37°)
OF.6
41°-48°
(32°-48°)
OF 7
40°-47°
(36°-47°)
OF.8 - 49°-50° (22°-50°)
OF.9
48°-49° (33°-51°)
OF.11
48°-56° (24°-56°)
OF.13
44°-47°
AB
36°-45°
(21°-46°)
C
40°-42°
(12°-47°)
D
36°-44°
(14°-44°)
E
38°-41°
(13°-43°)
F
30°-43°
(13°-46°)
H
40°-43°
(14°-44°)
I
31°-36°
(12°-47°)
J
27°-34°
(14°-35°)
K
L
22°-30°
(10°-31°)
M
16°-26°
(10°-26°)
N
16°-19°
(11°-22°)
O
13° (11°-22°)
P
11°-13°
(10°-15°)
R
10°-15°
(10°-18°)
S
10°-15°
(10°-16°)
T
11°-14°
(11°-14°)
U
11°-14° (11°-14°)

FIG. 22

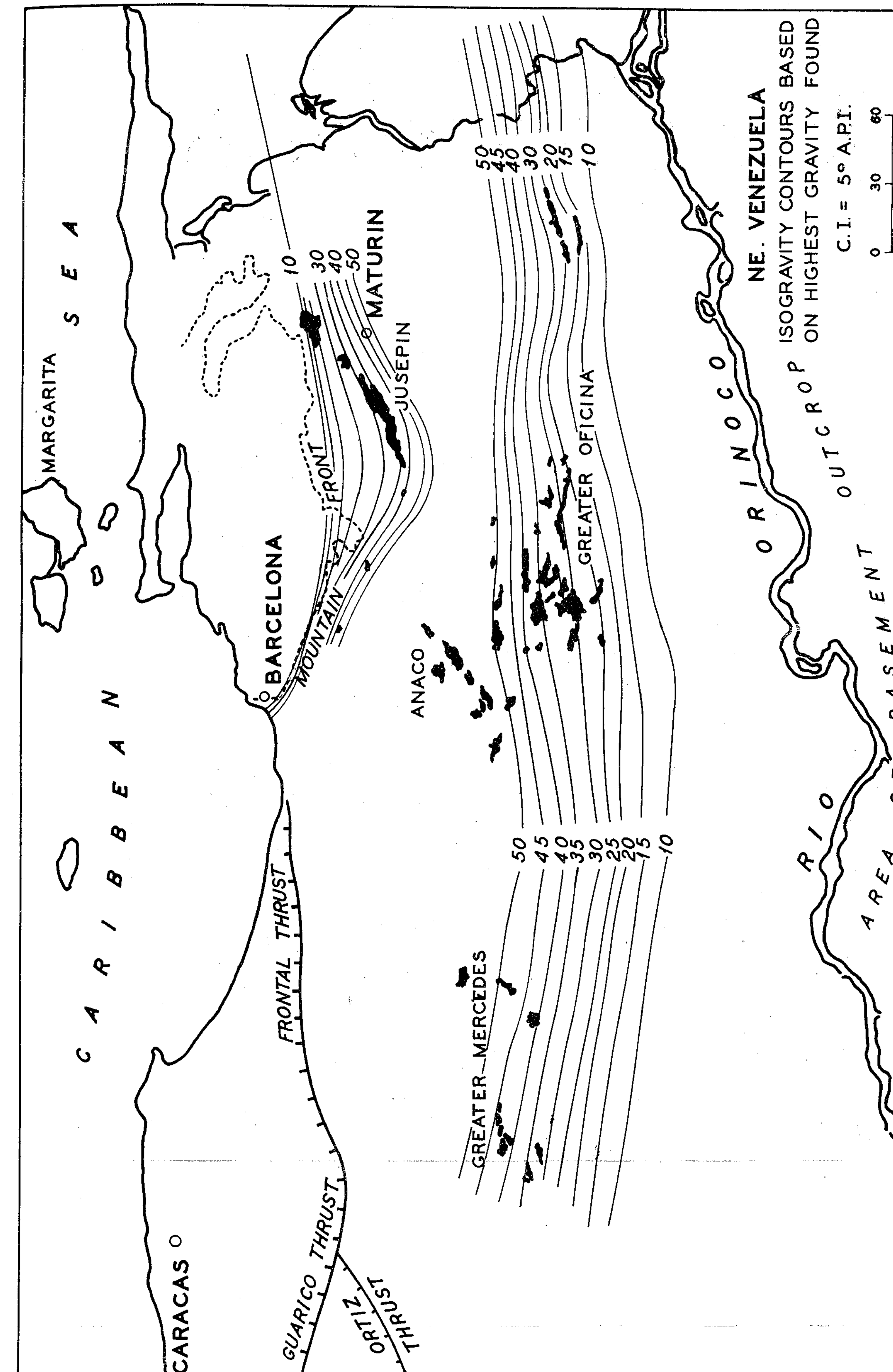
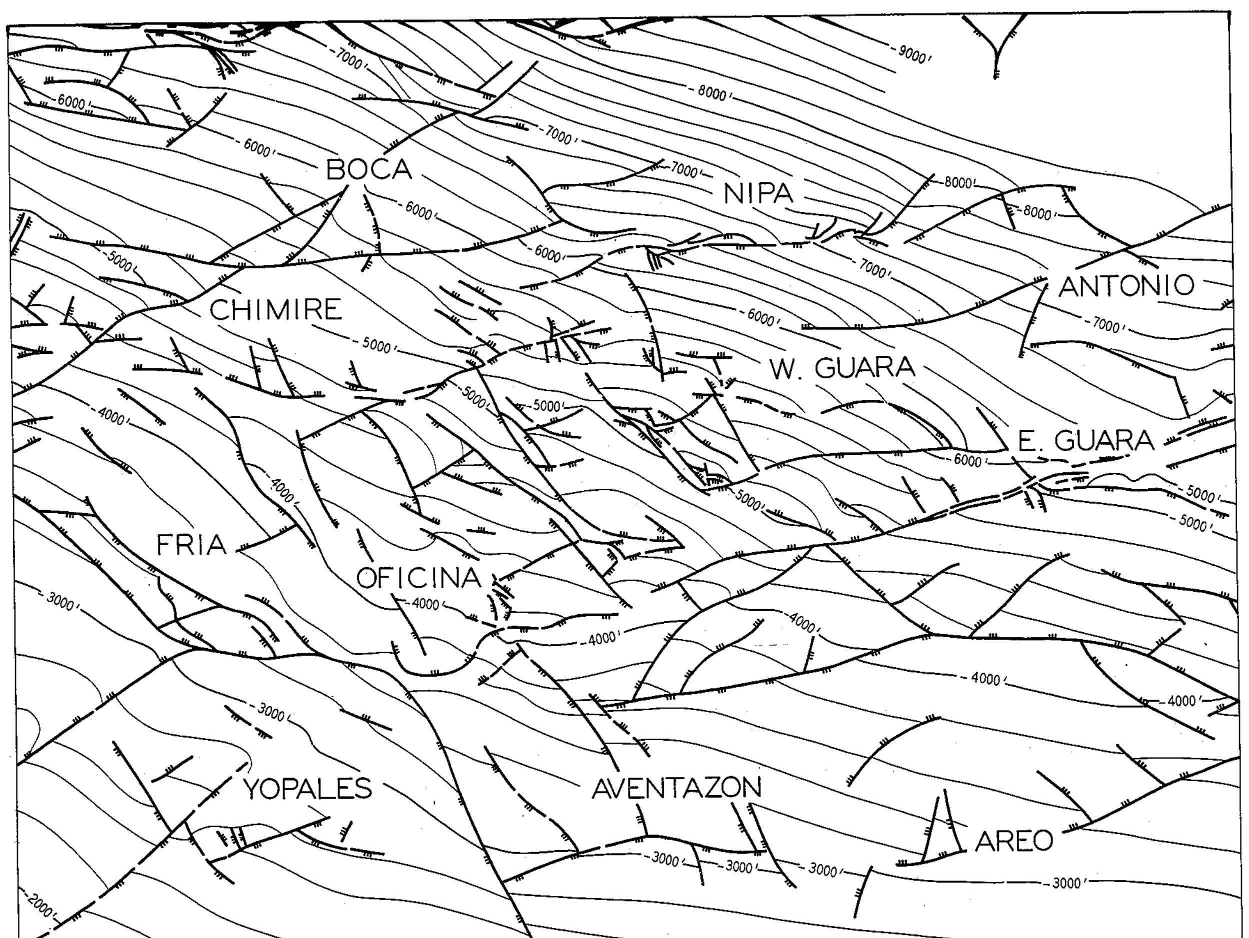

NE. VENEZUELA
ISOGRAVITY CONTOURS BASED
ON HIGHEST GRAVITY FOUND
C.I. = 5° A.P.I.
0 30 60
KM.
CARIBBEAN SEA
MARGARITA
CARACAS
BARCELONA
MATURIN
JUSEPIN
ANACO
GREATER OFICINA
GREATER MERCEDES
MOUNTAIN FRONT
FRONTAL THRUST
GUARICO THRUST
ORTIZ THRUST
ORINOCO
RIO
OUTCROP
AREA OF BASEMENT
10 30 40 50
50 45 40 30 20 15 10
50 45 40 35 30 25 20 15 10

FIG. 23



FAULT PATTERN GREATER OFICINA AREA
BASE OF "H" SAND
C.I. = 200'
0 2 4 6 8 10 KM.

FIG. 24

The occurrence of the predominantly very heavy oils, always associated with the Tertiary-Cretaceous unconformity above the Tertiary hinge belts, leads to the conclusion that these oils have migrated from Tertiary source beds updip into any available porosity. The constant association of these oils with fresh to slightly brackish water tends to confirm this conclusion.

It is interesting to speculate on the reason why no large commercial accumulations have been found in Cretaceous rocks. In the Barcelona basin, the Cretaceous rocks in the mountains are largely metamorphosed and the hinge belt probably lies north of the present mountain front. In the western part of the basin where the Cretaceous is within reach of the drill, it is everywhere deeply eroded and, in the eastern part where it may possibly be better preserved, it is beyond economic drilling depths. In the Maturín basin, it appears that the Cretaceous hinge belt lay in what is now the deepest part of the Tertiary basin, and in the Urica arch area the possible productive belt has been mostly destroyed by post-Paleocene erosion.

<u>Mio-Oligocene Half-Basins</u>: The great bulk of the oil found in eastern Venezuela occurs in the Mio-Oligocene half-basins and, with one or two exceptions, nearly all of this crop of oil is found in the southern hinge belt and on the Urica arch (Fig. 8). Almost all of the fields are multiple-sand fields; in some areas, there are as many as fifty different prospective producing horizons. In general, the individual sands above the basal sand section are usually less than fifty feet thick, and more often less than twenty feet. The character of the oil ranges from very heavy asphaltic tar oil to very light paraffinic oil. The A.P.I. gravity range is from less than 10° to more than 50° A.P.I. (Fig. 22).

The map (Fig. 23) shows contours based on the highest A.P.I. gravity of the stream produced from any field. The gravity range in any one field and in some cases in one individual sand may extend from less than 10° A.P.I. to the value shown on the contour map (Fig. 23).

South of the 15° A.P.I. gravity contour, a tar-oil belt twenty to sixty kilometers wide extends from western Guárico to the Delta of the Orinoco. This belt contains many thick sands saturated with oils so heavy that it is impossible to bail the oil because the bailer will not sink into it. However, there are very large quantities of 10° to 12° A.P.I. gravity oil which can be produced by conventional methods.

In the hinge belt itself the gravities range from 15° to 50° A.P.I., with the great bulk in the 20° to 30° range. North of the 50° contour line, although normal liquid production is found at shallower depths, high pressure condensate can occur at any horizon below 7,000 feet.

Although no oil has been found on the north side of the Barcelona basin except in the vicinity of the Urica arch, the gravity distribution in this part of the basin follows the same pattern as on the south side.

<u>Late Tertiary Basin</u>: East of the Urica arch in the Maturín basin, most of the oil produced comes from the hinge belt of the La Pica and younger formations on the north side of the basin. No oil has been found on the west and south side of the basin from equivalent formations (Fig. 14). There is no apparent reason for this absence of oil except possibly that the west end has not been explored by drilling, and on the south side the marine section does not contain any reservoir sands in the hinge belt.

The A.P.I. gravity distribution of the oils in this younger crop of oil with respect to basin position, is the same as in the older basins. Very heavy oils occur both above and below the unconformity at the base of the cycle on the narrow shelf area. Middle range gravities occur in the production belt on the hinge, and downdip high pressure gas or condensate are found.

In summary, in eastern Venezuela the distribution of oil with respect to basin position is as follows:

1) Very heavy oils are found on the shelf updip from the hinge belt; 2) 15° to 50° A.P.I. gravity oils are found in the hinge belt, the highest gravity found increasing progressively downdip; and 3) high pressure gas and condensate reservoirs are found at depth basinward from the 50° A.P.I. gravity contour line.

LOCATION OF OIL WITH RESPECT TO LOCAL STRUCTURE

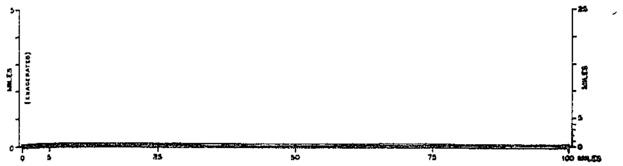
The only area in eastern Venezuela where accumulation is at least partially controlled by anticlinal folding, is along the anticlinal axis extending from El Toco to Santa Rosa and in the northeastern end of the Barcelona basin. However, even here it is doubtful if the anticlines furnished the primary trap because of the discontinuity of the sands in which the oil is found. Furthermore, if it is postulated that the accumulation takes place early in the history of a basin, the folds formed after the sediments of the Mio-Oligocene cycle had been deposited, could have had little influence except to locally displace already existent primary accumulations.

In the southern hinge belt, the accumulation is almost entirely controlled by two intersecting fault systems. The major faults are in general more or less parallel to the original depositional strike of the Mio-Oligocene cycle. The secondary fault system consists of short cross faults which abut against the major faults generally at a 45° to 60° angle on both the up- and downthrown sides. (Fig. 24). In some cases, the trap is formed by a combination of faulting and pinch-out of the sand body. This is especially true of so-called channel sands.

The intensity of faulting in the hinge belt is directly related to the rate of change of regional dip. A comparison of cross sections (Figs. 19, 20, 21) shows that the largest faults occur where the dip changes rapidly. In the Barcelona basin where the rate of change of dip is very low, there are fewer faults and they have less displacement than in the Oficina area. The faults with the largest displacement occur in the eastern end of the Maturín basin where the rate of change of dip is the highest.

In the shelf area, accumulation appears to be controlled almost entirely by stratigraphy because local structure seems to have no influence whatsoever. The oil occurs as a blanket accumulation across faults and local structural highs and lows. Practically, no well drilled in the tar oil belt has failed to find saturated sands.

Late Tertiary Basin: On the northern flank of the late Tertiary Maturín basin, the accumulation is primarily controlled by stratigraphy. In the Quiriquire field, the oil occurs entirely in an updip wedge out and the seal may be formed entirely by an asphalt plug at the outcrop. In the Greater Jusepín area, the La Pica sand section pinches out updip between the overlying nonmarine Las Piedras and the unconformity at the base of the La Pica Formation. Although there is considerable faulting in the producing section in the Jusepín area which directly affects production, it played a minor role in the primary accumulation.



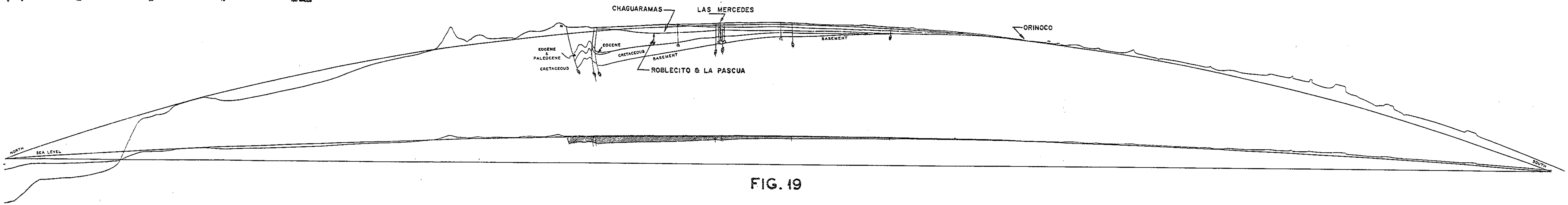


FIG. 19

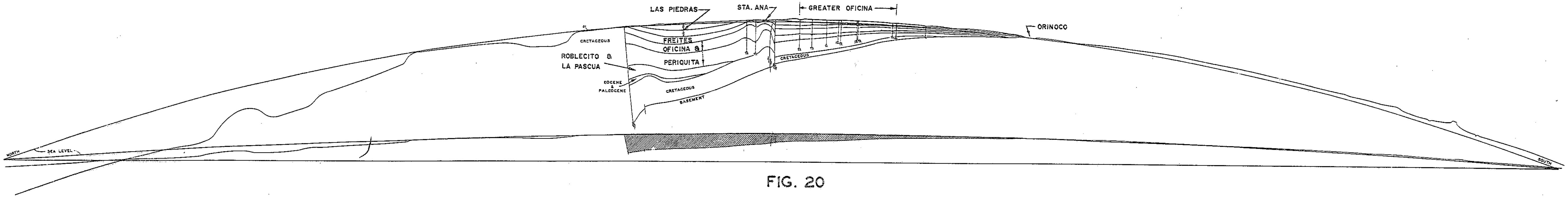


FIG. 20

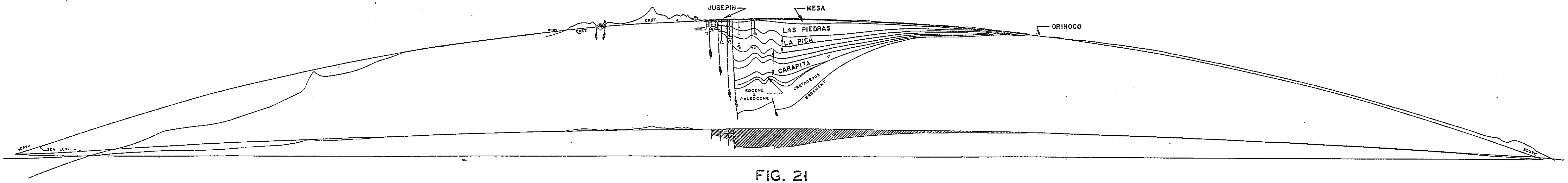


FIG. 21

One interesting feature in the Jusepín area is the occurrence of oil in the La Pica wedge-out in the western end of east plunging synclines, as in northern Jusepín, and in the Tacat area. One possible explanation of this condition is that the eastward tilt of all eastern Venezuela has affected the original position of the oil bodies, and the oil has migrated updip in a westerly direction.

RELATIONSHIP OF OIL ACCUMULATIONS TO LITHOLOGIC FACIES

The post-Eocene sediments of eastern Venezuela, in which practically all of the oil is found, are almost entirely composed of clastics. The central basin facies in all cases is a thick section of dark colored shale laid down under reducing conditions. On the north in the Mio-Oligocene half-basins, the downdip transition zone between the very coarse near shore clastics and the shale facies is very narrow, a matter of a few kilometers. On the south side of the basins, and across the Urica arch, the marine shales intercalate with sands over a very wide area. This zone of intercalated shales and sands happens to fall on the hinge belt of the basins where normal faulting increased the possibilities of traps for accumulations. The combination of the favorable stratigraphic and structural setting where source and reservoir beds intercalate, accounts for the large accumulations found in this belt (Figs. 16, 17, 18).

In the late Tertiary Maturín basin, the productive belt also occurs where the marine shale facies of the central basin area intercalates with the near shore coarser clastic facies. And again it is only where these intercalated facies occur on the hinge belt that production has been found so far. As already mentioned, on the south side of the basin the Freites Formation contains very few sands in the hinge belt and no production has been found. It is quite possible that a lot of the oil in the tar oil belt is actually of the same generation as on the north rim. Because of the lack of adequate reservoir beds in the hinge belt, the oil finally accumulated in the sands high on the shelf of the basin.

RELATIONSHIP OF OIL ACCUMULATION TO UNCONFORMITIES

It has been previously mentioned that the only place where production has been found in the Cretaceous is where the Oligocene and younger beds directly overlie the Cretaceous unconformably. On the northern rim of the late Tertiary Maturín basin, some oil is found beneath the unconformity of the La Pica Formation but only where the truncated edges of reservoir beds in the older Tertiaries abut against oil bearing reservoir beds of the younger cycle above. This poses a problem as to the source of the oil. Did the oil migrate vertically upward from older to younger beds, or did the oil migrate updip in the younger beds to become reservoired in older beds? Although the answer to this question may never be given, it does seem certain that the unconformity was instrumental in the juxtaposition of the oil bodies above and below the unconformity.

A further bit of information on the influence of major unconformities is the common occurrence of very heavy oil at the unconformity in the southern hinge belt and in the tar oil belt. Basinward this phenomenon seems to disappear, and the lightest oil is sometimes found immediately adjacent to the unconformity.

RELATION OF OIL ACCUMULATION TO DEPTH

Although depth in itself does not appear to be a controlling factor of the location and kind of hydrocarbon accumulations found, depth when related to basin position is important. The tar oil belt on the south is a good example. In western Guárico the tar oil sands on the shelf are found at a depth of less than three thousand feet. In Monagas and the Delta tar sands of equivalent age may be as deep as 6,000 feet because of the deposition of late Tertiary sediments across the former Oligocene shelf. In general it can be said that referred to the original basin, there is an increase in A.P.I. gravity and paraffinicity with an increase of depth. This is well shown by comparing the isogravity map (Fig. 23) and the total fill-map (Fig. 9).

The interdependence of depth and basin position is also shown by the distribution of high pressure condensate fields basinward from the 50° A.P.I. gravity contour. On the Urica arch and in the hinge belt, normal liquid production is found to depths below 11,000 feet. Basinward from the arch, high pressure condensate reservoirs are found at depths as shallow as 7,000 feet and liquid production only occurs in the low A.P.I. gravity oils.

OIL-WATER LEVELS IN THE BASINS

In the fields on the hinge belt of the Mio-Oligocene half-basins there is no common oil-water contact. Because of the lack of continuity of the sands caused by faulting and wedge-outs, each pool and very often each producing sand has its own individual oil-water contact level. This condition makes it necessary to complete the wells from individual sands, because in multiple sand completions, unless the oil-water contact is known in each sand, there is no way of knowing which sand will go to water first.

In the late Tertiary Maturín basin fields, the only field which may have a more or less common bottom oil-water contact is the Quiriquire field. But even here the downdip edge water occurs at different levels in the individual sand bodies. In the multiple sand fields in the La Pica Formation there is no common oil-water contact. However, one generalization can be made: on the northern flank very little commercial oil has been found at depths greater than 7,000 feet, either above or below the unconformity at the base of the La Pica.

SUMMARY

In eastern Venezuela the great bulk of commercial oil is found in the hinge belt of the structural basins contemporaneous with the sedimentary cycle in which the oil originated and in which the accumulations are reservoired. The hinge belts and interbasin arch between the Mio-Oligocene half-basins are the favored site of accumulations because the source and reservoir rock are interbedded in these areas. In the late Tertiary Maturín basin, only the northern hinge belt has the same combined favorable structural and stratigraphic setting, and production so far is limited to that area.

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NOTICIAS

El 28 de enero el Sr. Charles Spencer, de la Creole Petroleum Corporation en Caracas, visitó San Tomé para dictar una charla a los miembros de la A.V.G.M.P. en el Oriente de Venezuela. El tema escogido para esta ocasión fue el de la evolución de las técnicas de exploración petrolera en la gran área de Oficina. Fueron descritas las etapas sucesivas utilizando la refracción sísmica; la reflección sísmica para localizar las fallas mayores; la perforación de pozos ubicados para determinar las fallas menores, pero esenciales en el entrampamiento del petróleo; y de pozos ubicados para localizar los ejes en donde las arenas alcanzan sus espesores máximos.

Los miembros de la A.I.M.E. fueron también invitados a asistir a esta reunión.

En su reunión del 13 de enero la Junta Directiva aceptó la renuncia del Dr. Juan Chacín debida a su transferencia fuera de Caracas.

NUEVOS MIEMBROS

En la reunión del 13 de enero la Junta Directiva aceptó a las siguientes personas como miembros activos:

BRICEÑO, Jorge J., Geólogo, Corporación Venezolana de Petróleo, Maracaibo
FUENMAYOR, Angel N., Paleontólogo, Cía. Shell de Venezuela, Caracas
GUEVARA SANCHEZ, Edgar H., Estudiante, Universidad Central de Venezuela, Caracas
MACSOTAY, Oliver T., Estudiante, Universidad Central de Venezuela, Caracas
McGINNIS, William C., Geofísico, Texas Petroleum Company, Caracas
MENDEZ MUSKUS, Angel, Ingeniero de Petróleo, Texas Petroleum Company, Caracas
PEREZ MENA, Ramón L., Geólogo, Cía. Shell de Venezuela, Caracas.