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THE PETROLEUM GEOLOGY OF THE GULF OF SUEZ

by John E. Bobbitt, Jebco Exploration, Inc., and
Jay O. Gallagher, Gexco, Inc.

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ABSTRACT

The present-day Gulf of Suez Basin was initiated during the Oligocene as a result of relative motion between the Arabian, Nubian, and Sinai plates. At that time, pre-Miocene sediments were broken into fault blocks that were rotated and then inundated by the organically rich "globigerina" marls and shales of the Lower Miocene. These Lower Miocene sediments served as the primary source of the oil and gas found in the Gulf of Suez Basin, while the rotated pre-Miocene blocks formed structural focal points for the accumulation of the hydrocarbons generated. Subsequent deposition of the thick and widespread Middle Miocene evaporites ensured that all the generated hydrocarbons were sealed in the basin in reservoirs ranging in age from Miocene to Devonian.

INTRODUCTION

The most prolific and prospective oil province in Egypt is the Gulf of Suez Basin. Its productive history can be traced back to ancient times with oil being recovered from seepages at Gebel el Zeit and Gemsa by the Pharoahs. To date, 3.5 to 4.0 billion bbl of recoverable oil have been discovered in 24 oil fields within the basin. In spite of its long history of production and exploration, it is only in recent years with improved seismic and renewed exploratory drilling that the petroleum geology of the basin has been fully understood.

The Gulf of Suez Basin encompasses and, in general, parallels the coastline of the Gulf of Suez (Fig. 1). The basin extends, in an east-west direction, from the Sinai Shield on the east to the Esh El Mellaha Shield, in the Eastern Desert on the west. The average distance between these shield masses is 54 miles. In a north-south direction, the basin's northern limit lies just north of Suez City and extends to the south to Hurghada, a distance of approximately 210 miles.

EVOLUTION OF THE GULF OF SUEZ BASIN

The Gulf of Suez has formed primarily as a result of tensional movements, and ensuing subsidence, which to a minor degree occurred as early as Paleozoic times. Since these times, the formation of the Gulf of Suez has taken place in a number of distinct evolutionary stages (Fig. 2).

The presence of Devonian or older sandstones and Carboniferous black shales in numerous wells is evidence that a depression approximately coinciding with the Gulf of Suez existed at least as early as Carboniferous times. However, the thicknesses of these Paleozoic rocks are relatively minor compared with those of the main Paleozoic basin in the western and southwestern regions of Egypt. This comparison leads to the hypothesis that the Paleozoic rocks in the Gulf of Suez region were formed in an embayment that extended from the Mediterranean area southward to Hurghada at the mouth of the Red Sea.[8,12,16]

A hiatus caused by the Hercynian epeirogeny precluded sedimentation in the Gulf for a considerable time following the Paleozoic deposition. This is noticeable particularly further south, where commonly Upper Cretaceous deposits (Cenomanian) rest unconformably upon Lower Carboniferous black shales.

During Jurassic and Lower Cretaceous times, a minor transgression took place that was restricted to the northern part of Egypt and Sinai, submerging only the northernmost part of the present-day Gulf of Suez.

The conditions drastically changed with the advent of Upper Cretaceous time, when a major transgression of the sea covered the Gulf of Suez province, and most of the Eastern Desert, with Upper Cretaceous marine deposits. These seas persisted until the end of the Middle Eocene and covered most of Sinai and the Gulf of Suez, extending as far south as the 24th parallel. The Upper Cretaceous, Paleocene and Eocene deposits in the Gulf of Suez province were deposited in a normal platform environment. Their thicknesses and facies are similar to their equivalents in the Western Desert of Egypt. By late Eocene, the sea had retreated further north leaving most of the Gulf of Suez province

References and illustrations at end of paper.

subaerially exposed. During the early Oligocene, tensional forces began affecting the Eocene and pre-Eocene sediments through the development of normal faults in the Gulf of Suez.[22]

The tensional forces and compensation movements continued throughout the Oligocene, resulting in block faulting with subsequent erosion of the uplifted blocks. This extensive erosional phase resulted in a rugged surface of Mesozoic and Paleogene outcrops. Toward the end of the Oligocene, Africa began to separate from the Arabian peninsula and this time saw the origin of the Gulf of Suez and Red Sea rifts.[18] The main NW-SE trending normal faults that bound the Gulf of Suez province were developed at this time and extended from Suez City to the Red Sea.

By the advent of Aquitanian-Burdigalian (Lower Miocene) time, the Miocene sea had transgressed from the Tethys Sea southward, through the Gulf of Suez graben, toward the Red Sea. Reefs developed and flourished over and near the uplifted and eroded blocks that persisted as subaqueous highs within this early Miocene Sea. Fine clastic sediments rich in Mediterranean fauna first filled in the downthrown blocks and ultimately inundated the eroded subsea highs. Thus, lower Miocene sediments are found overlapping rocks of Eocene to Precambrian age.

The sediments deposited at this time mainly are marls, rich in organic matter with subordinate sand beds. The relatively rapid rate of sedimentation (approximately 120 m per million years), along with the great thickness and organic content provided optimum conditions for hydrocarbon generation.[10]

In Middle Miocene time, conditions changed once again in the Gulf of Suez province. During this period great thickness of evaporite accumulated in both the Gulf of Suez and Red Sea grabens. The deposition of the Middle Miocene evaporites was followed by a hiatus caused by the late stages of the Alpine Orogeny. Since the Pliocene there has been a continuous but restricted in volume deposition of sands, gravels and limestones (Fig. 2).

TECTONICS

The Gulf of Suez is a critically important area in the plate tectonic interpretation of the northern Red Sea. Geological and geophysical evidence indicates that three plates meet at the northern end of the Red Sea. These plates are known as the Arabian, Nubian, and Sinai plates, and it is the relative motion between them that has brought about the formation of the Gulf of Suez, Gulf of Aqaba, and Red Sea (Fig. 3).

A wealth of geological evidence indicates that as a result of sea-floor spreading, the Nubian and Arabian plates have separated to form almost the entire Red Sea.[5,9,13] This evidence suggests that about 190 km of movement was required to open the Red Sea at its northern end if the shorelines were once in contact. This suggestion is supported partly by evidence of large-scale transform motion along the Sinai-Arabian plate boundary. A detailed examination of the Dead Sea fault system, which forms the boundary between the Sinai and the Arabian plates, has established that there has been about 110 km of left lateral movement along the fault system, which occurred as 70 km of movement in the late Eocene/early Oligocene and 40 km in the early Pliocene.[6] There is, however, a discrepancy of 80 km between the magnitude of displacement along the Dead Sea fault and the 190 km required at this latitude to open the Red Sea. This difference must be taken up by movement between the Sinai and Nubian plates, which resulted in the formation of the Gulf of Suez.

To demonstrate the extension required to form the Gulf of Suez, a reconstruction of the situation has been made, showing the motions of the Arabian and African plates relative to the Sinai plate (fixed) (Fig. 3). The reconstruction shows that 60 to 90 km of extension is required to form the Gulf of Suez. However, the total width of the Gulf of Suez does not exceed 35 km in the north and 25 km in the south. Furthermore, there are blocks of continental material within the depression, that of Gebel Araba in the east and of Gebel Zeit in the west. The amount of extension in the Gulf of Suez, therefore, cannot exceed 25 to 35 km, and it thus is suggested that considerable extension has occurred by normal and block faulting to result in crustal thinning. Implicit in plate tectonic theory is the concept that plates move as rigid units without internal deformation. However, in the Sinai area, deformation within smaller blocks appears to have reached significant proportions.

Much has been made recently of suggestions that the sedimentary troughs in the North Sea containing significant oil accumulations are failed arms of triple junctions.[21] This situation is clearly the case for the Gulf of Suez, which is the failed spreading arm of the Sinai triple junction. The Sinai triple junction was formed in the late Eocene and early Oligocene with the opening of the Red Sea rift. At this time, separation took place along the Sinai-Nubian plate boundary (Gulf of Suez) and transform movement along the Sinai-Arabian arm (Dead Sea rift) to give a Ridge-Ridge-Fault triple junction. McKenzie[13] has shown by a consideration of plate geometry that such a situation is unstable and will evolve into a Fault-Fault-Ridge junction. This is believed to be the present situation in the northern Red Sea and offers an explanation as to the failure of the Gulf of Suez to continue development into a spreading center with pronounced right lateral movement along the Sinai-Nubian plate boundary (Fig. 3).

The Gulf of Suez depression is one of the most intensively faulted areas on the earth's surface. Fault movements have been active within the Gulf since early geological time. Reconstructed shorelines of the Carboniferous suggest that the shorelines were determined along lines that have the same trend as those in the crystalline basement complex. The present main depression formed as a result of tensional forces that occurred primarily during early Oligocene times. Folding has played only a minor role, if any, in determining the structure of the Gulf. All the folding throughout the area has been produced either by the bending of the strata before breaking or by movements that caused differential compaction of less rigid sediments (notably Miocene).

The configuration of the Gulf is controlled chiefly by the location of the large normal faults with the NW-SE trend that border the Gulf of Suez depression and run parallel to the Gulf itself. The relative ages of the linear fractures forming the shape of the depression cannot always be determined. Some faults are thought to be of Precambrian age and, therefore, are old features that controlled the initial shape of the graben,[17] while others have interpreted them as having developed as a result of a regular stress pattern sustained for a long period that also has influenced the outline of the depression.[22]

Within the confines of these major marginal faults, the Gulf of Suez depression is broken up by many smaller normal faults into several hundred fault blocks of varying sizes. The tectonic history of the Gulf of Suez depression has resulted in the relative sinking of these blocks comprised of sediments from Paleozoic to Eocene with different magnitudes and intensities. These movements have affected the Miocene stratigraphic successions that differ considerably in both facies and thickness from one block to another. Thus, it can be shown that within a limited area, deep-water deposition took place on the lower blocks, while shallow-water deposition was taking place on the higher, and concurrently other blocks were subjected to subaerial erosion. A number of the blocks are of sizable dimensions and have been active since early geological times, while others are splinter blocks that seem to be younger. Block faulting was especially active during the Middle Cretaceous, late Cretaceous, early Eocene, late Eocene, Oligocene and later. The movement at the beginning of the Oligocene seems to have affected most of the blocks, and it was during this episode that the initial rifts developed along what is now the Gulf of Suez.

STRATIGRAPHY

For hydrocarbon exploration the stratigraphy of the Gulf of Suez lends itself to being broken into three distinct phases revolving around the Miocene. The first of these phases is the pre-Miocene, which encompasses sediments ranging in age from at least Devonian to Eocene with their primary importance being their reservoir character. The second phase is the Miocene itself with its primary importance as the source of the hydrocarbons of the Gulf of Suez and a second and equally importance as the over-all seal for the basin. The third phase, the post-Miocene, is relatively thin with no importance as source, seal or reservoir (Fig. 4).

PRECAMBRIAN

In general, the Precambrian rocks within the Gulf region, or bounding it, are granites, with subordinate gneisses and other metamorphic rocks.[15] These Precambrian basement outcrops provided an excellent source for the coarse clastic deposits that were laid down during Miocene and post-Miocene times.

PALEOZOIC (DEVONIAN OR OLDER - LOWER CARBONIFEROUS)

Although in general, the marine Carboniferous black shales attain a thickness of ± 200 m, they are not considered by the authors to be good potential source rocks for present-day accumulations since they are indurated and have a low organic content. However, they do act as a good barrier or seal between the reservoir fluid contents of the overlying formations and the lower Paleozoic rocks.

Underlying the Lower Carboniferous shales and overlaying the basement rocks, a sandstone section approximately 400 m thick has been found in many wells. These deposits are devoid of fauna, are of a continental facies, and have been given the name Nubian sandstone.[14] In the Gulf of Suez province, this Nubian sandstone section is assumed to be Devonian or older in age. The sandstone is characterized by its coarseness, angularity, poor sorting, and variable colors. It has an average porosity range of 16 to 18 percent and a permeability range of 100 to 200 md in both horizontal and vertical directions. Thus, the Nubian sandstone section is an excellent reservoir rock for oil accumulations. In fact, it is one of the main pay zones in Ramadan, Ras Gharib, Hurghada, and July oil fields, and is the secondary pay at Bakr oil field.

PRIMO-TRIASSIC

Early Mesozoic deposits have been reported in only one locality on the western side of the Gulf of Suez,[1] where a section of red shales and sandstones at Wadi Qiseib (near Abu El Darag) has been defined as Permo-Triassic.

JURASSIC

Outcrops of Middle and Upper Jurassic-age marine sediments are found along the northern perimeter of the Gulf of Suez. They are composed of alternating carbonates and marls intruded by Oligocene basaltic and diabase dykes and sills. Thus far, only one well drilled in the Gulf of Suez has encountered a significant identifiable Jurassic section. This well, located in the extreme northeast part of the basin, penetrated a marine Jurassic section 826 m thick and was underlain by about 70 m of terrigenous rocks of possible Jurassic age.

The distribution of Jurassic sediments around the Gulf of Suez indicates that a shallow arm of the sea penetrated the northern part of the Gulf as far south as Wadi Araba. The Jurassic sediments include fluvio-marine and shallow marine deposits, and several minor unconformities occur within the succession.

LOWER CRETACEOUS

In many areas within the Gulf of Suez province, a thin subsurface section of barren terrestial to shallow marine sandstone is found separating the marine Cenomanian rocks (Upper Cretaceous) from the underlying Carboniferous black shales. This sandstone section, which closely resembles the Nubian sandstone, is considered by some authors[4] to be of lower Cretaceous age; however, they are more commonly recognized as being Upper Cretaceous. The sandstone has reasonably good reservoir characteristics and is a hydrocarbon reservoir in several wells in the Ras Gharib field. This sandstone has been referred to as the "A" series in early literature.

UPPER CRETACEOUS

The lower part of the Upper Cretaceous section, the Cenomanian and Turonian, is composed of limestone, sandstone, and subordinate shale and reaches a thickness of about 350 m. Porosities are good within the section and it acts as a reservoir in many fields found in the Gulf of Suez. The sandy limestone section (Turonian) has an average porosity range of 13 to 17-percent but a variable permeability. The upper part of the section is mostly chalky limestone of Senonian age and is over 200 m thick. The Upper Cretaceous succession, in general, is a fossiliferous transgressive marine deposit terminated by the open marine chalky facies of Senonian age.

PALEOGENE

The transgressive phase that started during the Upper Cretaceous continued uninterrupted throughout the Paleogene (Paleocene-Eocene), with only localized unconformities during the late Cretaceous and early Paleogene, as evidenced by the absence of Maestrichtian and Danian deposit locally.[2,3] Regardless of the local unconformities, the normal sequence from Paleocene to Lower Eocene is found in many fields.

The Paleogene in the Gulf of Suez province is represented by carbonates of Paleocene and Eocene age, while the Oligocene is poorly represented or missing.

PALEOCENE

Chalky, argillaceous limestones and greenish-gray (Esma) shales of Paleocene age are distributed widely in the Gulf region. The usual thickness of the Paleocene encountered in the Gulf of Suez region is approximately 60 m.

EOCENE

The cherty and argillaceous limestones of Lower and Middle Eocene occur throughout the Gulf region. In the subsurface section of some wells, the Eocene rocks are known to be cherty, pyritic, fossiliferous, argillaceous limestones. In the Sudr field, the Eocene limestone was found to be fissured, highly fractured, and cavernous. At Bakr field, the Eocene limestone has a porosity range of 22 to 30 percent. In both the Bakr and Sudr fields, the Eocene limestone acts as an excellent reservoir rock. The subsurface thickness of Eocene rocks in the Gulf area varies widely, depending on the structural situation of the wells and the attendant degree of erosion.

The uppermost part of the Eocene deposits frequently are missing from the crest of pre-Miocene structures due to the major unconformity between the Eocene and the Miocene deposits. On some structures within the Gulf region, the entire Paleogene section is missing and Miocene deposits lie unconformably upon Cretaceous or older rocks (Ras Gharib, Morgan, S. Gharib Marine). The average thickness of Eocene rocks encountered is about 350 m.

The Lower and Middle Eocene marked a period of widespread submergence and calcareous sedimentation associated with the deepening of the Gulf. This was followed in the Upper Eocene and Oligocene time by a general uplift, retreat of the sea, and erosion.

OLIGOCENE

The occurrence of possible Oligocene deposits in the Gulf of Suez province is limited to red shales found in the far northeast part of the basin. The identification of these occurrences as Oligocene in age is questionable.[22] Usually the Miocene rocks are found unconformably lying on Eocene or older rocks.

MIOCENE

The Miocene section in the Gulf of Suez province can be differentiated into the Lower Miocene (Gharandal group) and the Middle Miocene (Evaporite group). Upper Miocene deposits are not present in the region as a result of another major unconformity (late stages of the Alpine Orogeny) between the Miocene and the overlying Pliocene and Recent deposits.

LOWER MIOCENE (GHARANDAL GROUP)

The Lower Miocene is made up of the Nukhul, Rudeis, and Kareem formations. This section is mainly shales and marls with subordinate sandstones, carbonates, and minor anhydrite beds. The Gharandal group is present throughout the Gulf of Suez basin with the exception of the extreme flanks and the more prominent pre-Miocene highs where the group is missing through nondeposition.

The Nukhul formation is represented by reefs and carbonates on pre-Miocene topographic highs and by a sandy facies in the surrounding lows. Overlying the Nukhul, the Rudeis formation is composed mainly of deep marine shales and fossiliferous marls (the famous Globigerina marl). The Rudeis formation grades upward into the Kareem formation with an anhydrite demarcation between them. The Kareem formation also is a shale and marl unit that is interrupted by sand bodies, as in the Rudeis formation. These form stratigraphic traps in several fields. The porosity of the Nukhul sandstones tend to be lower, 13 to 14 percent, while the porosities of the Kareem and Rudeis are in the 20 to 25 percent of range.

The shales and marls of the Rudeis and Kareem formations are considered to be the main source rock for the hydrocarbons found in the Gulf of Suez Basin.

MIDDLE MIOCENE (THE EVAPORITE GROUP)

The Middle Miocene is divided into the Belayim, South Gharib, and Zeit formations. The Kareem formation (Lower Miocene) is normally overlain by the Belayim formation, but over some of the more prominent pre-Miocene highs, all or part of the Gharandal group may be missing due to nondeposition. Thus, in such localities the Belayim formation may be resting on Rudeis to pre-Miocene sediment. The Middle Miocene Evaporites group attains a thickness of up to 3,200 m in wells. Rock salt predominates where the evaporites reach such exaggerated thickness.

The Belayim formation is composed of an evaporitic facies at the bottom and a clastic section at the top. The sandstones of the Belayim act as primary reservoirs in several fields where the porosities are in the 20 to 25 percent range. On the high pre-Miocene structures where the Lower Miocene units were not deposited, the Belayim formation, which, in this case, represent the first Miocene sediments consists of a reef limestone with excellent reservoir characteristics. The South Gharib formation is the most persistent evaporite section in the Middle Miocene deposits. It is composed mainly of anhydrite and rock salt with minor thin shale beds.

The Zeit formation consists primarily of alterations of shale with gypsum or anhydrite. Minor inclusions of rock salt are found at some localities. This formation probably represents the oscillating movements of the Miocene basins from supersaline to fresh-water conditions.

The great thickness of the evaporites of the Gulf of Suez has led some workers to consider them as deep-water evaporites formed in a deep-water barred basin.[11,19] Such a mechanism of evaporite deposition calls for a narrow, restricted connection with a source of supersaline water that permits intermittent flow of supersaturated brines. However, this classical bar theory for the origin of evaporites has been challenged in recent years. Studies of modern evaporites in Abu Dhabi indicate that significant thicknesses of salt can be accumulated in a sabkha environment.

The type locality of the Miocene section in the Gulf of Suez is in the Wadi Gharandal area, in the western Sinai peninsula, and has been described in detail by Sadek (1959). In this area terrigenous sediments (Gharandal group) are overlain by evaporites (Evaporite group). The sediments that make up the Evaporite group in Wadi Gharandal consist of gypsum and anhydrite, dolostones, dolomitic limestones, and algal limestones. In both the Wadi Gharandal section and in the classic sabkha deposits of Abu Dhabi, the sequence consists of reefs on the seaward side followed landward by oolites, lime mud, dolostone, and sulphate evaporites. Also, in both areas, the gypsum is dominantly nodular and is considered to be a replacement of typical sabkha anhydrite.[7] Therefore, it is suggested by some that the Miocene evaporites in the Gulf of Suez may have originated on coastal sabkhas (supratidal flats), similar to those existing in the Persian Gulf at the present time. No biological organisms were able to survive in this supersaline environment thus the source (Indo-Pacific or Mediterranean) of these brines is not known.

Interestingly, in spite of the great thicknesses of evaporites (and more particularly, salt) there have been few instances of recognized salt flowage structures in the Gulf of Suez and these have been restricted to the formation of salt pillows or embryonic diapirs with no instances of piercement of the overlying sediments.

PLIOCENE TO RECENT

The Post-Miocene deposits in the Gulf of Suez province are widespread. They contain sands, gravels, clays, and (in some areas) oolitic limestones.

PETROLEUM GEOLOGY

Two elements predominate in considering the petroleum geology of the Gulf of Suez. The first is the Miocene sediments since not only do they provide the source and the seal for all the oil accumulations found in the Gulf of Suez, but they also provide reservoirs for a major portion of the present-day reserves of the basin. The second element is the pre-Miocene highs that provide structural and stratigraphic focal points for oil accumulation.

At the end of Oligocene time, the topography of the Gulf of Suez basin was dominated by rotated fault blocks that had been subjected to varying degrees of erosion (Fig. 5). These highs continued to dominate during the deposition of the Miocene and substantially affected both the structure and lithology of the Miocene and younger sediments. Structurally, the pre-Miocene highs acted as a competent core over which the less competent Miocene sediments were draped by the effect of differential compaction and the continual subsidence of the pre-Miocene lows, thus forming compactional anticlines. From a lithological viewpoint, the pre-Miocene highs offered shallow-water platforms on which reefs flourished during the early Miocene. In the structural lows immediately adjoining the highs, greater thicknesses of sediments tended to accumulate along with a higher percentage of coarse sediments in the Miocene. However, the rapid rate of deposition during the Miocene precluded a completely orderly process of deposition and some lenticular sands were deposited over the pre-Miocene highs. In some cases, the reservoir qualities of these sands were probably enhanced by the winnowing effect of the wave base action in the shallow water over these highs.

Within the pre-Miocene highs, the erosional effects that occurred during Oligocene times enhanced the reservoir properties of Eocene and Cretaceous limestones where present, while at other localities, the Nubian sands of Paleozoic age were exposed. Thus, the pre-Miocene highs were prepared to act as excellent reservoirs for the oil generated from the encasing Lower Miocene sediments. Although the Nubian sands were productive in some of the first fields discovered in the Gulf of Suez, it is only in recent years, with the discovery of July and Ramadan, that their full potential as prolific reservoirs has been recognized. These discoveries, as a result of, or when considered in conjunction with the improved seismic definition of the pre-Miocene highs, have heightened significantly the already important role of these highs in petroleum exploration in the Gulf of Suez basin.

SOURCE ROCK

The organically rich shales and "Globigerina Marls"[20] of the Rudeis and Kareem formations of Lower Miocene age generally are considered to be the source rock for all the oil found in the Gulf of Suez basin. Although the Upper Cretaceous chalks and the Eocene limestones possibly could have sourced oil, any resulting accumulations probably would have been dissipated by Oligocene diastrophism.

RESERVOIR

Sediments ranging in age from Paleozoic to Middle Miocene have acted as reservoirs in the discovered oil fields. The bulk of the present-day reserves are producing from Miocene reservoirs, but it is expected that reservoirs of pre-Miocene age will become increasingly important. Basically, sediments of any age can and will act as reservoirs if they are placed in a trapping configuration in juxtaposition with the Lower Miocene source beds.

SEAL

Fortuitously, within the Gulf of Suez basin, the widespread deposition of a continuous and in some areas extremely thick, evaporitic section during the Middle Miocene provided the essential element to the retention and preservation of oil accumulations, that is, a seal. The evaporites are present throughout the basin with the exception of the far north and extreme flanks. Although great thicknesses of salt are found in areas of pre-Miocene lows, there are few instances of substantial diapiric salt movements as are found in other salt basins around the world. This probably is due to the relatively thin overburden failing to exert sufficient pressure to initiate and continue salt movement.

TRAPS

The stratigraphic element in oil trapping has been most important in the process of oil accumulation in the Gulf of Suez. As is often the case, it is difficult to categorize neatly many of the fields as either stratigraphic or structural and, as a result, must be referred to as stratigraphic-structural traps. An idealized sketch of the known trapping mechanisms in the Gulf of Suez is shown in Fig. 5. Above the pre-Miocene highs are found relatively pure stratigraphic traps in the lenticular sands and reefs of the Lower Miocene. In the more continuously deposited sands of the basal Miocene, the element of structure begins to dominate as the trapping mechanism. Below the unconformity at the base of the Miocene are found the stratigraphic/structural traps formed by the rotated and eroded fault blocks of pre-Miocene sediments being encased by the impermeable Lower Miocene shales and marls.

SUMMARY

The geology conditions found in the Gulf of Suez admirably fulfill all the elements necessary not only to the basic accumulation of oil, but also to the accumulations or large quantities of oil. With improved seismic methods and a growing understanding of the geological complexities of the Gulf of Suez, the discovery of additional giant fields may be confidently expected.

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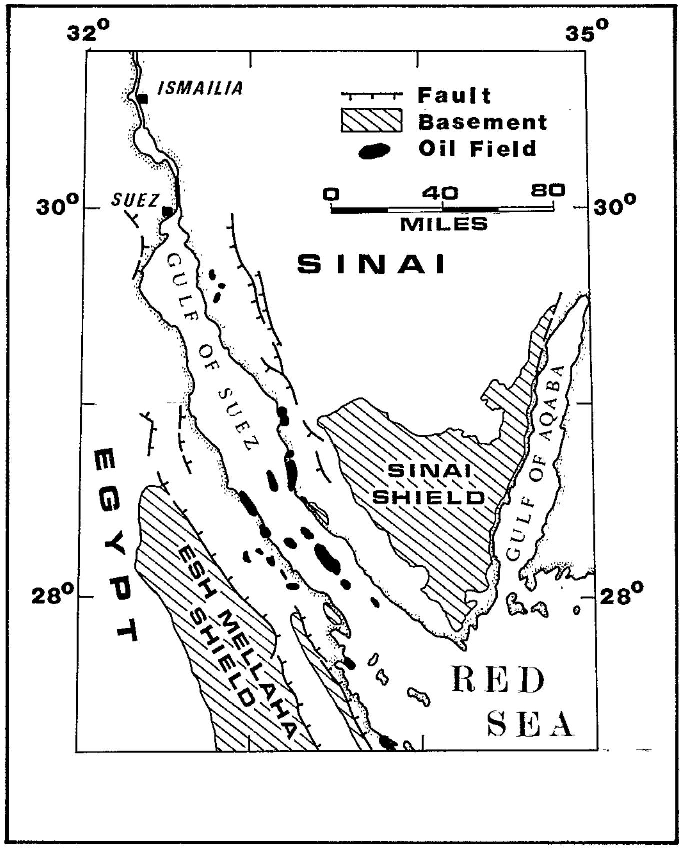

Fig. 1 - Location map.

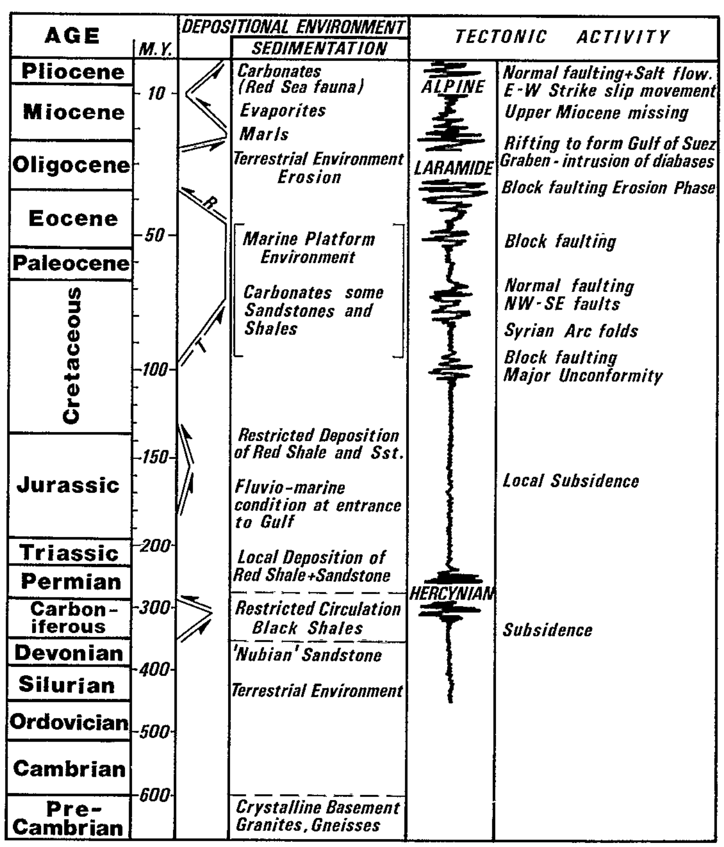

Fig. 2 - Evolution of the Gulf of Suez.

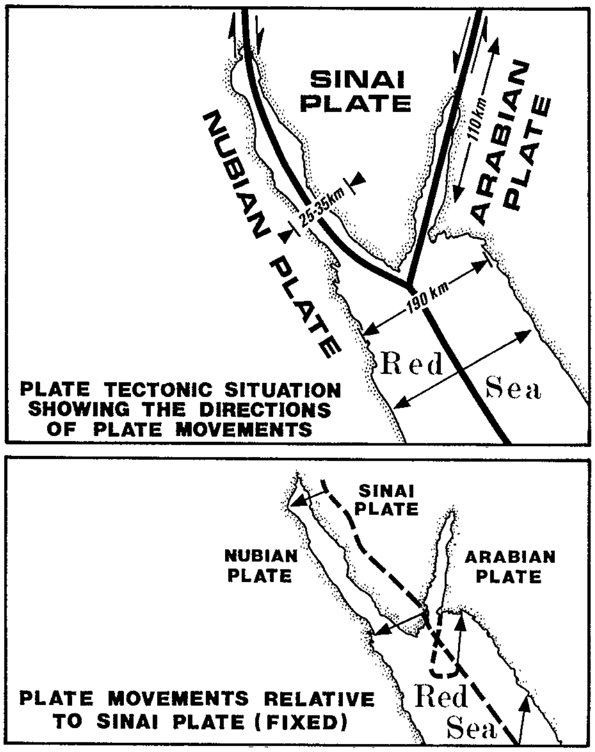

Fig. 3 - Plate tectonics in the Northern Red Sea.

AGE		FM.	Litholo.	OIL	DESCRIPTION	Av. Thick.
Pliocene-Pleistoce.					*Gravel, Sand, Marl and Shale*	*1540'*
MIOCENE	Upper				*Limestone*	*ALPINE 130'*
	Middle	*ZEIT*		•	*Evaporites with some Shale and Sandstone*	*3088'*
		SOUTH GHARIB				
		BELAYIM		••		
	Lower	*KAREEM*		••	*Globigerina Marls and Shales with Sandstones*	*2920'*
		RUDEIS		••		
		NUKHUL		•	*Basal Conglomerate & Sst.*	
Oligocene					*Basalt (in Northern area only)*	*220'*
Eoce.	Middle			•	*Primarily Limestone with some Marls, Shales & Sst.*	*LARAMIDE 1000'*
	Lower				*Limeston with Flint*	*212'*
Paleocene						
Cretac.	Senonia.				*Chalk*	*294'*
	Turonia.			•	*Limestone, Dolomite and Marls*	*436'*
	Cenoma.			•	*Sst., Shale, Marl & Limestone*	*277'*
Jurassic		*			*Sandstone, Marl & Limestone*	
Permo-Tr		*			*Sandstone*	*HERCYNIAN*
Carbonife.		*BLACK SHALES*			*Sandstone Shale and Limestone*	*648'*
Pre-Carb.		*NUBIAN*		••	*Sandstone*	
P€					*Granites and Gneisses*	

*** Present only locally in Northern Area**

Fig. 4 - Generalised geologic columnof the Gulf of Sue .

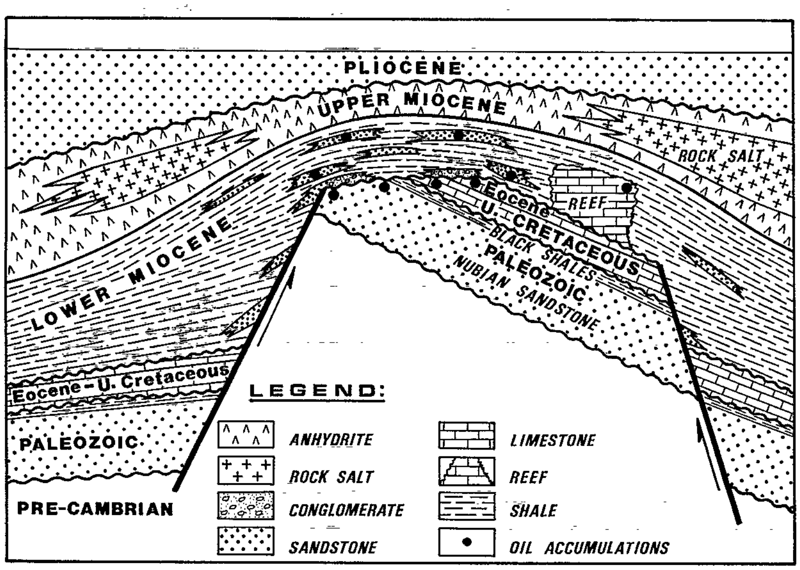

Fig. 5 - Typical Gulf of Suez structure.