

The Petroleum-Bearing Formations In The Western Desert of Egypt And East Libya-Are They Correlatable?

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Abstract: Many speculations have been raised among geologists in Egypt in the sixties of the 20th century about the so-called relation between the petroleum-bearing section in East Libya and the lithostratigraphic petroleum-bearing section in the Northwestern Desert of Egypt. These geological speculations did not take into consideration the stratigraphic and tectonic frameworks in the Sirte embayment and the North western corner of the Egyptian Western Desert which is referred to as the Siwa Basin (Egypt). The tectonic frameworks of both basins were the result of basement tectonics magnitude and attitude and their differential echo, which governed the modeling of these sedimentary basins. This concept will clarify, or at least should modify, the former speculations about the hydrocarbon -bearing rock units in the Western Desert of Egypt and East Libya petroleum basins in general.

Keywords: the western desert of Egypt, east Libya, stratigraphic, tectonic frameworks, petroleum

1 Introduction

The petroleum-bearing formations in the Western Desert of Egypt and East Libya have long been an enigma to most geologists in petroleum industry. Many speculations have been raised among geologists in Egypt since the sixties of the 20th Century. These speculations were based on the announcement that the Sirte Basin ranks the 13th among the World's petroleum provinces. The petroleum reservoirs in this prolific basin range in age from the Precambrian fractured basement, in knobs of probable Early Paleozoic sandstone (clastic reservoirs in the Cambrian - Ordovician Gargaf sandstones), and lower Cretaceous Nubian Sandstone to Paleocene reef bodies and Eocene carbonates.

These geological speculations did not take into consideration the stratigraphic, tectonic frameworks and the source-reservoir relation in the Sirte embayment and the northwestern corner of the Western Desert of Egypt, which is referred as the Siwa

Basin.

The petroleum-bearing section in the Egyptian Western Desert is reported till now in the Mesozoic ages from the Triassic, Jurassic ages ascendingly till the Cretaceous most productive age (Aptian Dolomite, Cenomanian clastics and / or Turonian carbonate and clastics). Incontrary, the petroleum-bearing section in East Libya is profitably productive from Paleocene reefs. However, the Western Desert of Egypt adjacent to East Libya is devoid of Paleocene reef body and the Paleocene section is relatively very thin and mostly undifferentiated from the Eocene with no hydrocarbon showings till now.

2 History of petroleum exploration

The Western Desert of Egypt covers an area of about 700,000 km² or more than two thirds of the whole area of Egypt (Fig. 1).

The history of petroleum exploration in the Western Desert of Egypt started in 1938, by the Standard Oil Company. A memorandum for the general information on living and working conditions in Egypt for prospective employees (for petroleum exploration) had been prepared by S.S. Rice, 1938, who sent a copy to Ruedeman on January 26, 1939, (the representative of Standard Oil Company) in Budapest " Hungary ". Rice (op. cit), stated and reported that, the company seeks employees who will carry through their assignments to a finish. Those who become discourage quickly and resign cause additional expense to the company, and additional burden upon those who remain at the expense to themselves in securing transportation home. Accordingly, the petroleum exploration in the Western Desert of Egypt was secured by a lock and key in that time.

The petroleum exploration in the Western Desert started again in 1940, by the Anglo-Egyptian Oil Company (AEO) which drilled the Dabaa exploratory well in the coastal area which was reported dry. In 1949, the South Mediterranean Oil Company (SOMED), drilled the Khatatba well. Abu Roash wells nos. 1 and 2 were drilled by (SOE) in 1946.

Active exploration in the northern part of the Western Desert began in 1945, when Sahara Petroleum Company (SAPETCO) was granted exploration rights over the entire area of 230,000 km². SAPETCO, drilled nine deep test wells, but they were reported as dry wells. Accordingly, this company withdrew from its lease in 1958, inspite of the fact that three periods of exploratory seismic work were distinguished in the Western Desert. The first period from 1933 through 1954 which was characterized by limited activity. The second period lasted from 1954 to 1958, while the third started in 1964, when Philips Petroleum Company (PPCO), and Pan American Oil Company (AMOCO) signed agreements with the Egyptian General Petroleum Corporation (EGPC).

The history of oil-producing fields in the Western Desert of Egypt started in 1966

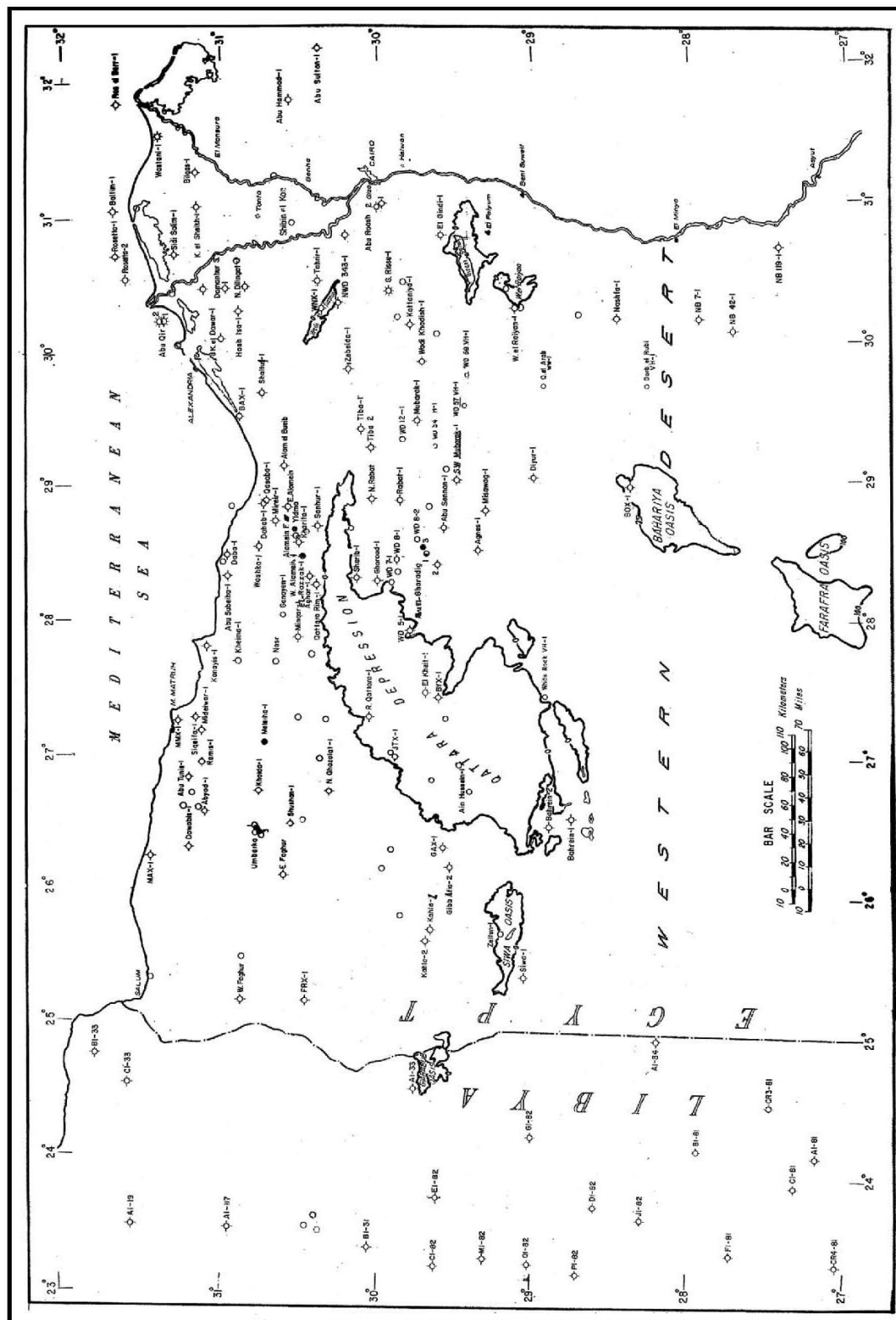


Fig. 1 Location Map of the Western Desert of Egypt

with the discovery of the Alamein oil field by PPCO (Metwalli and Abd El-Hady, 1973a, 1973b ; 1975a and 1975b). Activities by AMOCO resulted in the discovery of Abu El-Gharadig oil and gas-gas condensate field in 1971, while in the Nile Petroleum Company (NIPCO) concession area, El-Razzak oil field was discovered in 1972. The latter two fields were discovered as a result of seismic activities of the Colombian and Western Geophysical companies, (Metwalli et al., 1979 and 1982). Oil production in the Alamein field is from the Aptian dolomite which was the most important pay-zone in the Northern Western Desert as proved in the Alamein, the Razzak and Yidma oil fields. On the other hand, the Alamein Dolomite is nonproductive in other fields which are producing from other formations, e.g. the Baharyia Formation / Cenomanian clastics in Mubarka, Abu El-Gharadig, Meleiha and Salam oil fields. A group of other discoveries are producible from the upper and / or lower Bahariya clastics, e.g. Meleiha S.E., Aman, Lotus, Zahra, Emry, Falak and Badry fields (Metwalli et al., 2000).

In addition to the former American-Egyptian agreements and exploration which resulted in the formerly discovered and productive fields, the Soviet V/O Technoexport signed an agreement with the General Petroleum Company of Egypt (G.P.C.) to study the geology of the U.A.R, contract 1500 on June, 1966 which resulted in book I (1968). As a part of this contract the Siwa-Basin was extensively explored geophysically and geologically by drilling fourteen wells. The first exploratory well, Siwa-1 was spudded on July, 1969. Other eight exploratory wells were drilled with a Paleozoic target and other five wells with a Mesozoic target. All the fourteen drilled wells were reported as dry wells and Siwa-1 well which reached a total depth (T.D.) of about 10,245 ft and reached the basement rocks was considered as a parameter well.

The geology of Libya had been reported by many Italian geologists, notably by Desio and his coworkers who published several reports based on their studies in Libya from 1911 to 1943. In addition French geologists published some of their work in Fezzan Province of southwestern Libya, chiefly from 1943 to 1955. The works of the Italian followed by the French geologists have been cited by Hill (1959) in a bibliography of Libya.

The intensive search for oil in Libya began in 1953, and by 1958 a few promising discoveries had been made. Before 1956 exploratory activity in Libya was confined to photogeology, surface mapping and reconnaissance aeromagnetic surveys. Drilling commenced in Libya in 1956. A well located on a surface structure deep in the interior in the southwestern part of the country, was potentially oil productive, but the discovery could not be commercially developed. The first well drilled in the Sirte Basin, in central Libya had good oil shows in the Cretaceous ; this was followed by the first oil discovery in the same region.

The giant Zelten oil field was found in 1959, and after that a series of fields found

in the Sirte Basin proved that a major new oil province had been opened. More than thirty oil fields were discovered in the Sirte Basin, e.g. Waha, Defa, Sorra, Lahib, Archad, Calanscio, Nafoora, Amal, Hofra and Sarir oil fields etc. (Fig. 2). The spectacular Zelten discovery in 1959 has been followed by a succession of others as mentioned (Conant and Goudarzi, 1967).

3 General geologic setting of the western desert of Egypt and east Libya and oil-bearing formations

The Western Desert of Egypt is the second petroleum province next to the Gulf of Suez petroleum province. Although the Western Desert covers about 700,000 km², or more than two thirds of the whole area of Egypt, the explored area is mainly north of Latitude 28° and oil exploration is recent compared with that of the Gulf of Suez where the first well was drilled in 1908.

During the last 30 years, particularly in the last decade it has had much oil exploration activity by several different oil companies.

The Alamein area, has been the scene of a fierce battle during World War II, which left behind a widespread complicated minefields that retreated a vast area for many years till now for the petroleum searching activities in this interesting part of the north African craton, which might undergoing a historic change in petroleum exploration after the cleaning of the remaining minefields.

In general, the area is level, with a maximum relief of 100 m. The oldest outcropping rock units are of middle Miocene ; however, older stratigraphic units of varying ages starting with the Precambrian are penetrated in several wells in its northern part. The area includes a relatively thick marine and non-marine section of sedimentary rocks overlying the basement rocks. Not much work has been published on the geology and structures of the basement rocks for lack of accurate records on thickness variations of the total sedimentary section overlying the basement complex (Fig. 3a,b). However, the Alamein well-1 (1-X) was drilled to a total depth of 14,505 ft which penetrated the middle Jurassic sandstones (Metwalli and Abd El-Hady, 1973a,b and 1975a,b).

El-Sweify, 1975, reported that the basement rocks were penetrated by drilling only in Siwa-1 well at 3375-3415 m depth, and in Zeitun-1 well at 3518-3527 m depth. These two wells are located in the southern territory of Siwa - Faghur area, at the southern flank of the so-called "Siwa - Gibb Afia ridge. He added that the Bahrein 1 and 2 wells, Kohla-2, Gibb Afia-1 (GAX-1) and 2, Ghazalat-1 (GTX-1), North Ghazalat-1, El Basur-1, Faghur-1 (FRX-1) and East Faghur-1 were also drilled in his studied area and were abandoned in the lower Paleozoic rocks, but Kohla-1 was abandoned within the Carboniferous rocks.

The thickness of the Paleozoic section reaches about 2400 m above the basement rocks (Siwa-1 + 2408 m and in Zeitun-1, + 2419 m). But, the Paleozoic

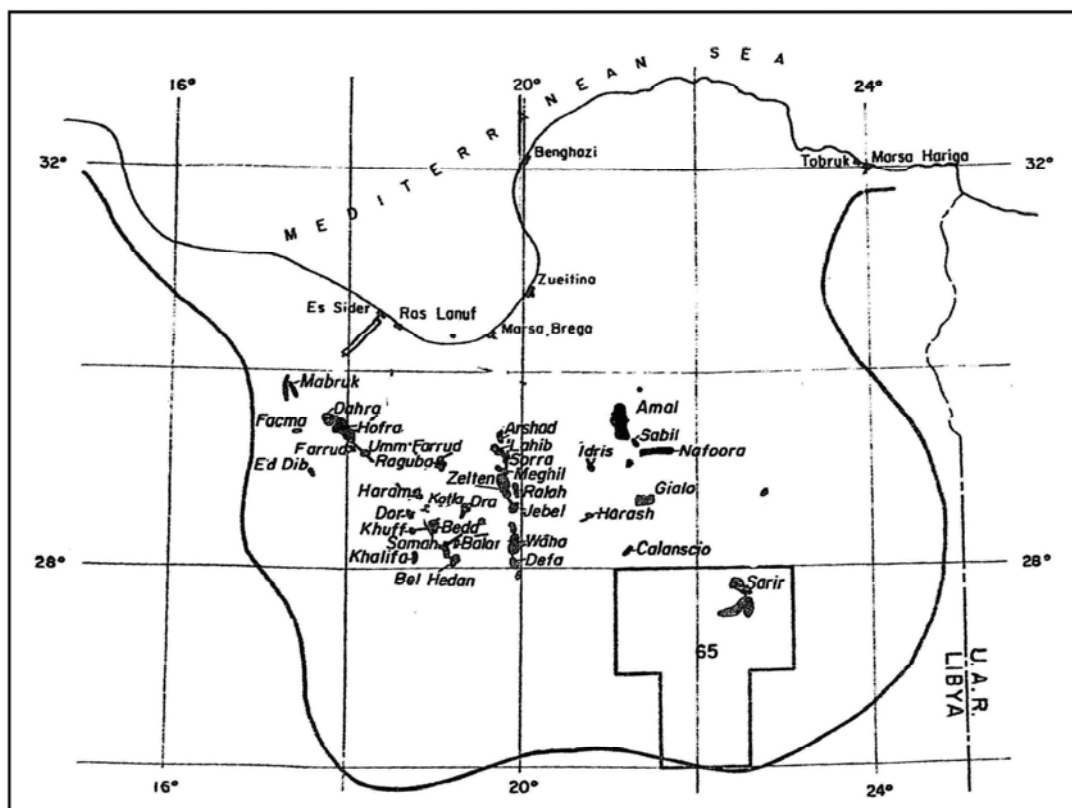


Fig. 2 Oil fields in Sirte Basin, Libya, (after Sanford, 1970)

subcropping section reaches a minimum of 2410 m in Kohla-2 well. However, at Faghur area(further northward) the basement rocks are expected to be at a deeper horizon than that at Kohla and Siwa areas.

The Paleozoic rocks in the Siwa - Faghur Basin are devoid of hydrocarbon showings in the Devonian and Carboniferous parasequences as tested by drilling.

In Siwa structural depression the groundwater-bearing horizons is recorded in the Miocene, Eocene and upper Cretaceous limestones beside the Nubian Sandstone aquifer and their main feeding source are the Pleistocene pluvial periods (Hammad et al., 2002).

The fresh and relatively saline groundwater aquifers are oxidizing waters in the lithostratigraphic section in the Siwa Basin which is not a favourable section for petroleum generation and even oil and gas prone.

The Nubian Sandstone fresh water aquifer which is the main Nubian artesian aquifer in other locations in Siwa - Faghur Basin overlies the basement rocks as a result of paralic sedimentation and barren of organic matter forms a prominent oxidizing environmental conditions which are not favourable for hydrocarbons generation and accumulation inspite of its intercalation with shale streaks and interbeds. However, in East Libya the environment of deposition of the Nubian

Sandstone changed and its term is commonly restricted to continental beds between

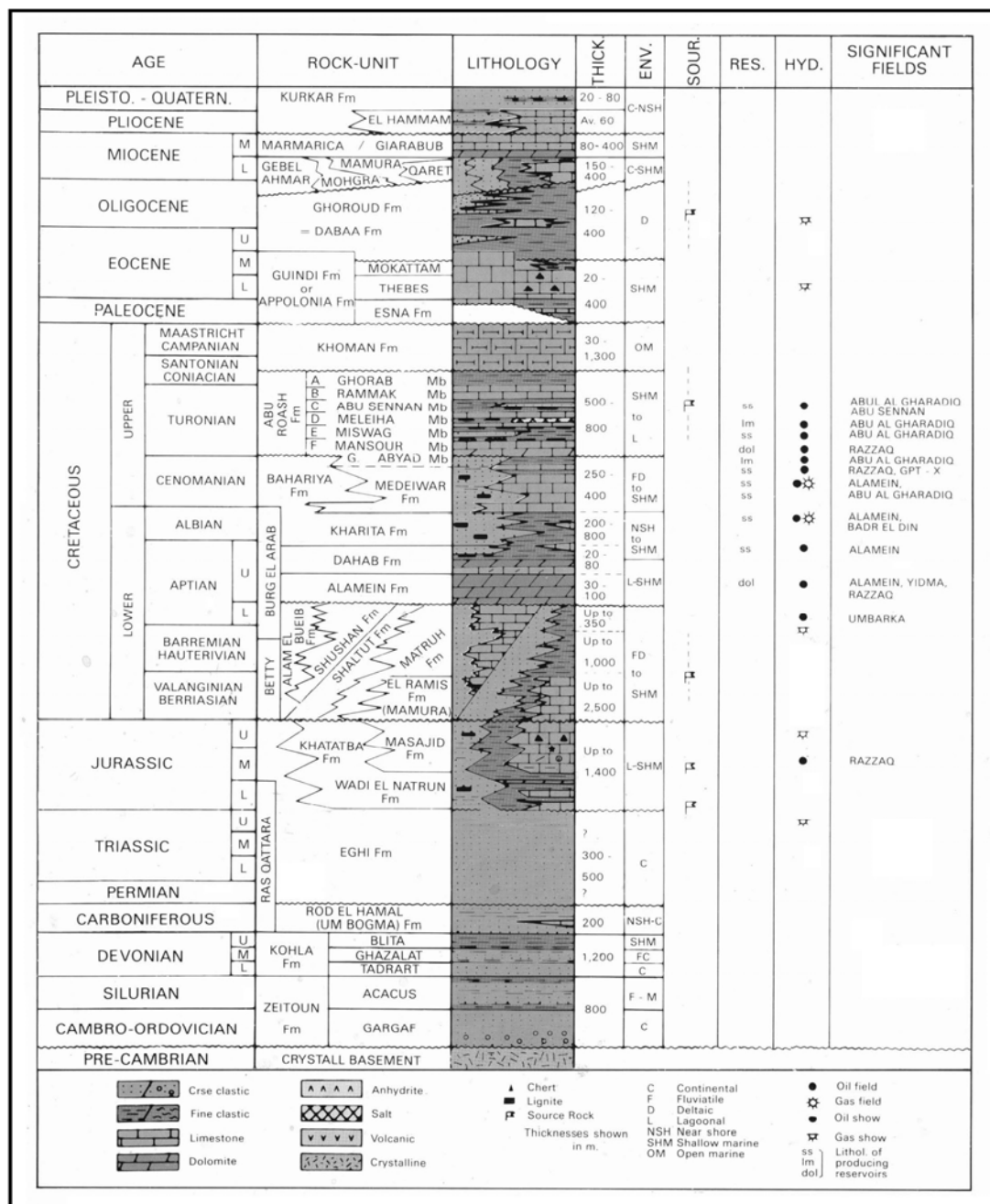


Fig. 3a Generalized Petroleum-Bearing Lithostratigraphic Column of the Northern Western Desert of Egypt (after several sources)

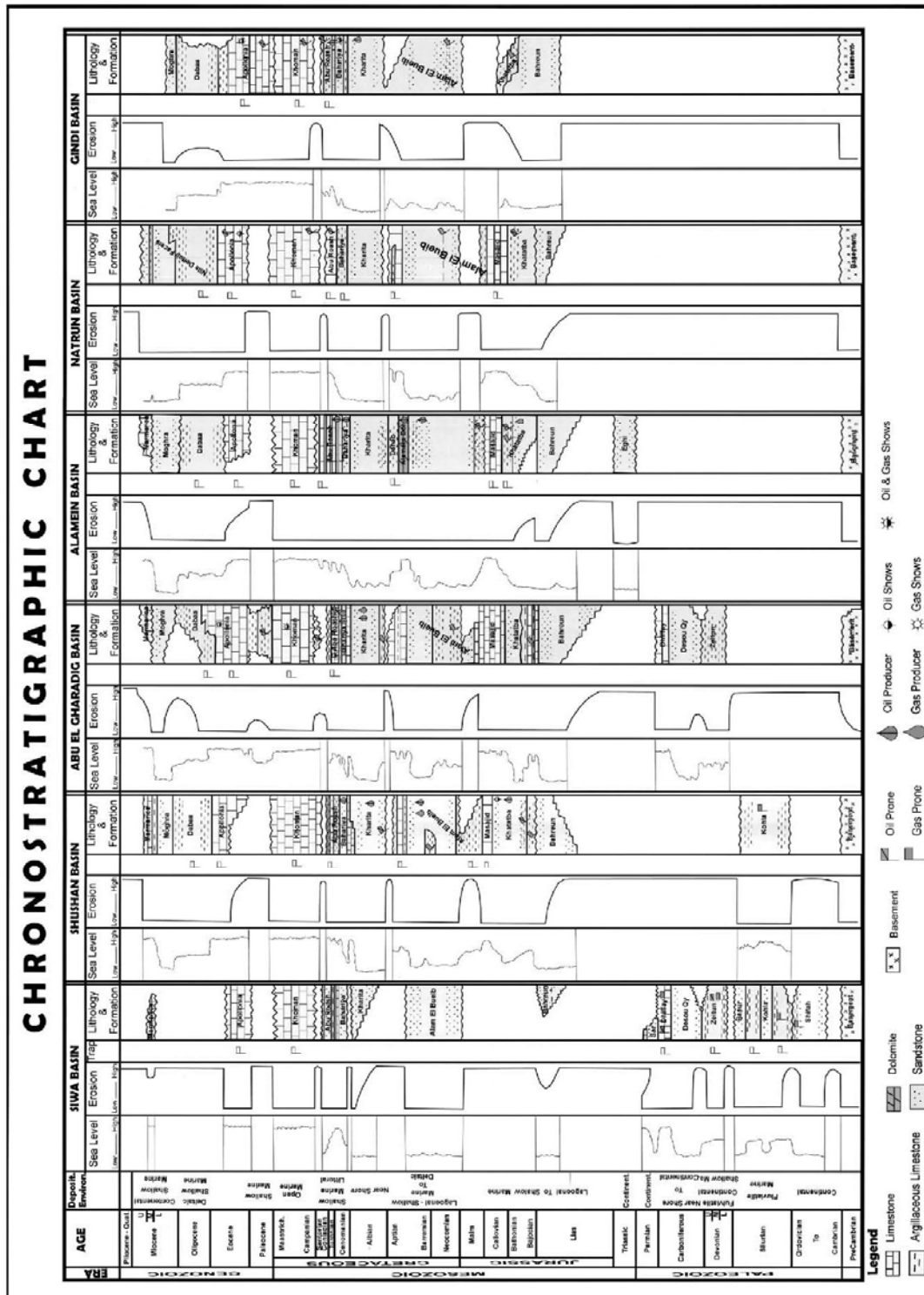


Fig. 3b Chronostratigraphic Chart of the Western Desert of Egypt Basins

the marine Carboniferous and marine Cretaceous. It is oil-bearing of Early Cretaceous age at depths 9,000 - 14,000 ft (2700 - 4,275 m) are only about 125 miles (200 km) from the Egyptian borders, thus it seems possible that the embayment reached that country. But, drillings in Siwa-Faghur Basin reflected that the Nubian Sandstone is barren of organic remains and hydrocarbons showings which contradicts with Conant and Goudarzi speculation (1967) about the Nubian Sandstone as oil-bearing in Siwa-Faghur Basin.

Libya is on the Mediterranean foreland of the African Shield, a foreland that has been the site of deposition of vast blankets of continental debris, and of several incursions by the sea with a consequent accumulations of a wide variety of sedimentary rocks. Most of the exposed basement rocks are certainly of Precambrian age, but K-Ar dating indicates that some of the buried granites in the floor of the Sirte embayment may be of Early Paleozoic age, perhaps the result of a widespread Early Paleozoic Pan-African orogeny (Kennedy, 1965).

The Mesozoic rocks in the Sirte embayment, as in other parts in Libya are chiefly of marine origin but locally grade into near shore or continental facies. Hetcht et al., 1964, reported that in the Sirte embayment rocks of Late Cretaceous age are much more varied as a result of the block faulting that took place during the time of sedimentation. There great thicknesses of dark coloured shale are present in the grabens, and are believed to be important source beds of oil and gas. They proposed that elsewhere limestone, dolomite, and calcarenite abound and locally serve as oil and gas reservoirs.

The Cretaceous Sirte shale is considered as the primary hydrocarbon source bed (Ahlbrandt, 2001). Reservoirs range in rock type and age from fractured Precambrian basement, clastic reservoirs in the Cambrian-Ordovician Gargaf sandstones, and lower Cretaceous Nubian Sandstone to Paleocene Zelten Formation and Eocene carbonates usually in the form of bioherms (Fig. 4a,b).

The tectonic development of North African basins is reported regionally by Coward and Ries (2003). They stated that, mostly the Paleozoic and Mesozoic basins of North Africa have generally followed, and reworked, earlier basement trends formed by: 1. the NW-SE accretion of continental and oceanic terranes onto a Pan - African nucleus in northeastern Africa, and 2. the collision of this amalgam of accretionary terranes with the West African Craton. During the upper Precambrian Pan-African Orogeny, the West African Craton formed a rigid block which indented this amalgam of accreted mobile belts to form much of North Africa. Intrusion of this indenter into North Africa caused the expulsion of narrow, triangular - shaped blocks of lithosphere to the North and South in a tectonic style very similar to the Miocene-Pliocene deformation of Tibet. They added that, subsequent rifting of the Pan-African mountain belt resulted into a series of grabens, which were infilled with upper Precambrian - Cambrian molasse. These are the precursor basins for the

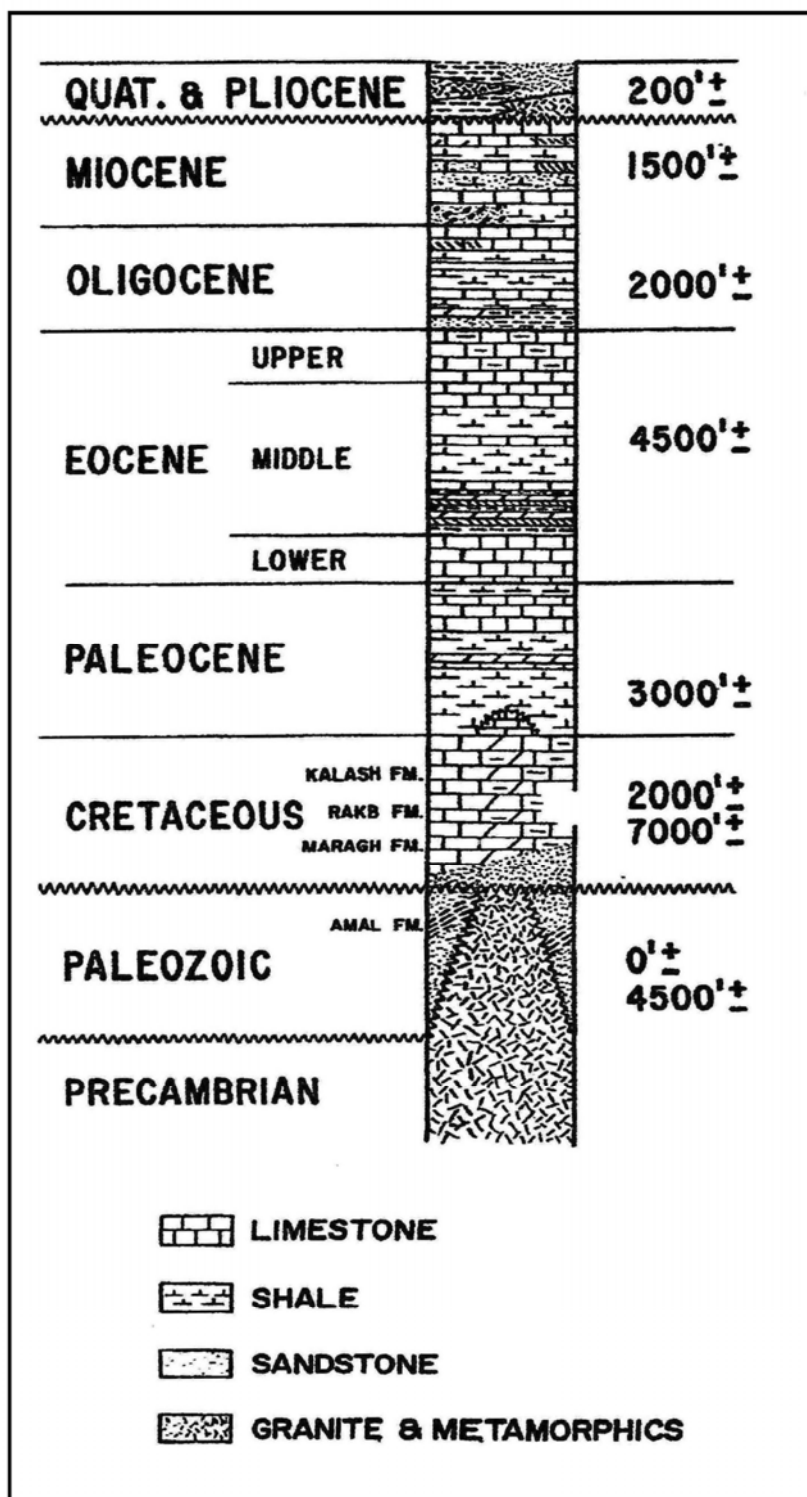


Fig. 4a Generalized Stratigraphic Column, Sirte Basin, Libya (after Roberts, 1970)

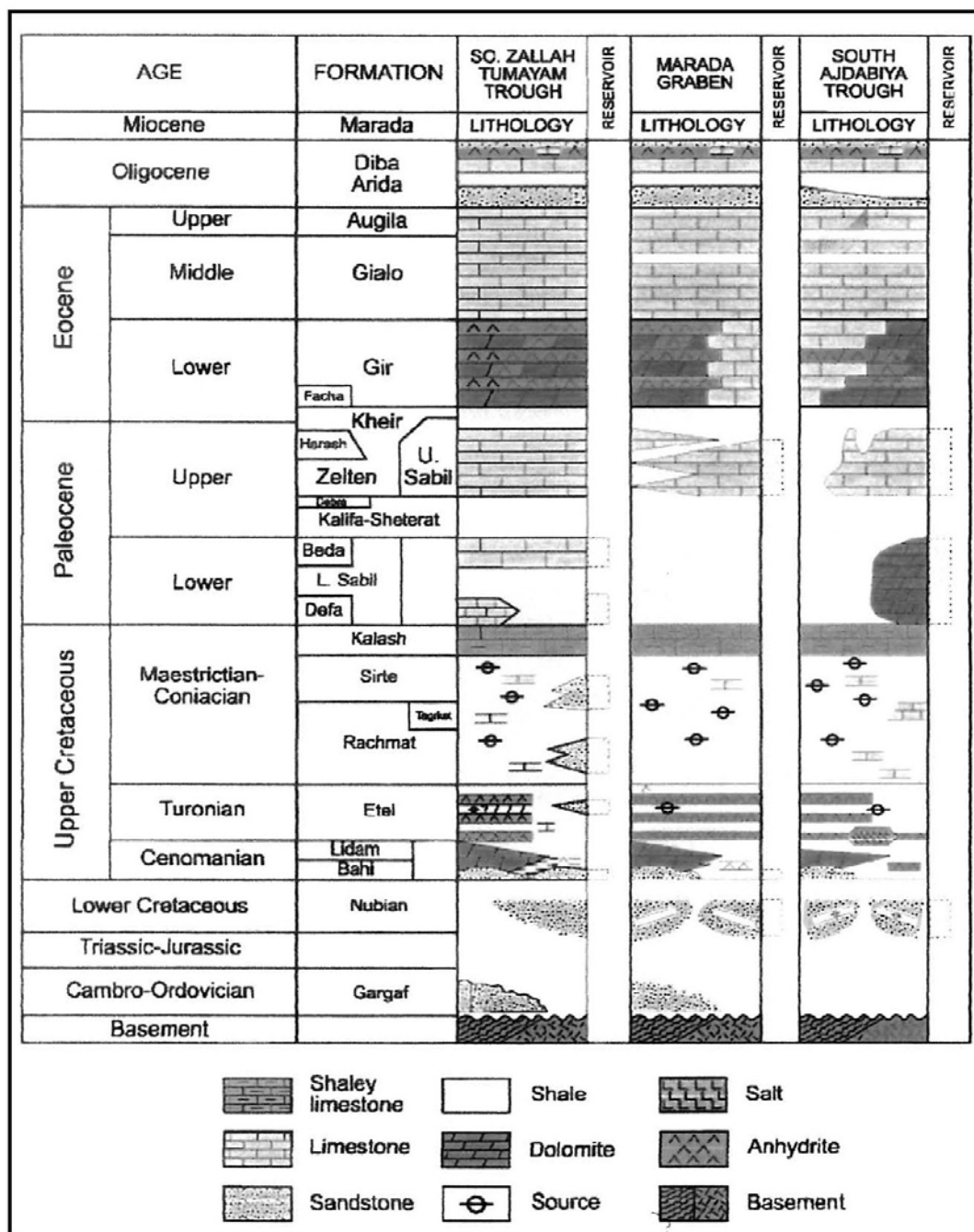


Fig. 4b Generalized stratigraphic correlation chart of three areas in the Sirte Basin, Libya. The main reservoir and source intervals are indicated on the chart. Hatched boxes represent main reservoirs (after Rusk, 2001)

Paleozoic sediments which cover much of North Africa. In addition, Coward and Ries (op. cit), stated that, the North African Paleozoic basins were inverted during the Hercynian-Appalachian Orogeny. In the Ahnet Basin the shortening was approximately NNE-SSW, perpendicular to the trend of the structures. This inversion was particularly marked in the Ougarta-Ahnet Basin where it produced a series of open to closed, North-South to NW-SE trending folds above reactivated basement faults (Fig. 5).

Although the timing of formation of the Sirte Arch is uncertain, sufficient uplift of the area now known as the Sirte Basin took place to cause erosion of pre-Cretaceous sediments over a wide area. An argument favouring the deformation to be of Mesozoic age rather than Paleozoic age may be that it was related to the West-to-East migration of a mantle plume across North Africa that was followed by Cretaceous rifting (Guiraud and Bosworth, 1997). The youngest rifting in North Africa is now east of the Sirte Basin in the Red Sea where rifting is active today.

The subsidence curves and subsidence rate curves for the Sirte Basin, were constructed from the stratigraphic record, show that subsidence was continuous through-out Late Cretaceous and Tertiary times, reaching a maximum during the Paleocene and Eocene, when a major reactivation of faults occurred (Gumati and Kanes, 1985). They added that, shales and carbonates were deposited during all of the Late Cretaceous and Tertiary. Abrupt lateral facies changes occur from the platform areas toward the deeper troughs along with steep down dip thickening. These conditions were probably assisted by contemporaneous faulting along structurally weak hinge lines where the dominant structural elements are normal step faults. The widespread distribution of the Maastrichtian carbonate facies over much of the platform and basinal areas suggests that tectonics were relatively inactive during the Maastrichtian.

Gumati and Kanes (op. cit.), concluded that, all platforms in the region are covered by limestone and remained relatively stable during the Early Paleocene. The Paleocene facies changes from widespread deposition of shale in the troughs to shallow-shelf carbonates on the platforms may result from change in the sediment supply, reactivation of faults, or rapid subsidence. The combined effect of these factors was to provide a clear, well-aerated, shallow water environment in which marine shelf carbonates were deposited. Progradation of carbonate facies over shale facies in the troughs continued during the Late Paleocene. This basinward extension of carbonates resulted in eventual blanketing of nearly the entire Sirte Basin by the Zelten limestone. The subsidence curves and the subsidence rate curves for the Sirte Basin indicate that the highest subsidence and sedimentation rates occurred during the Paleocene and Eocene.

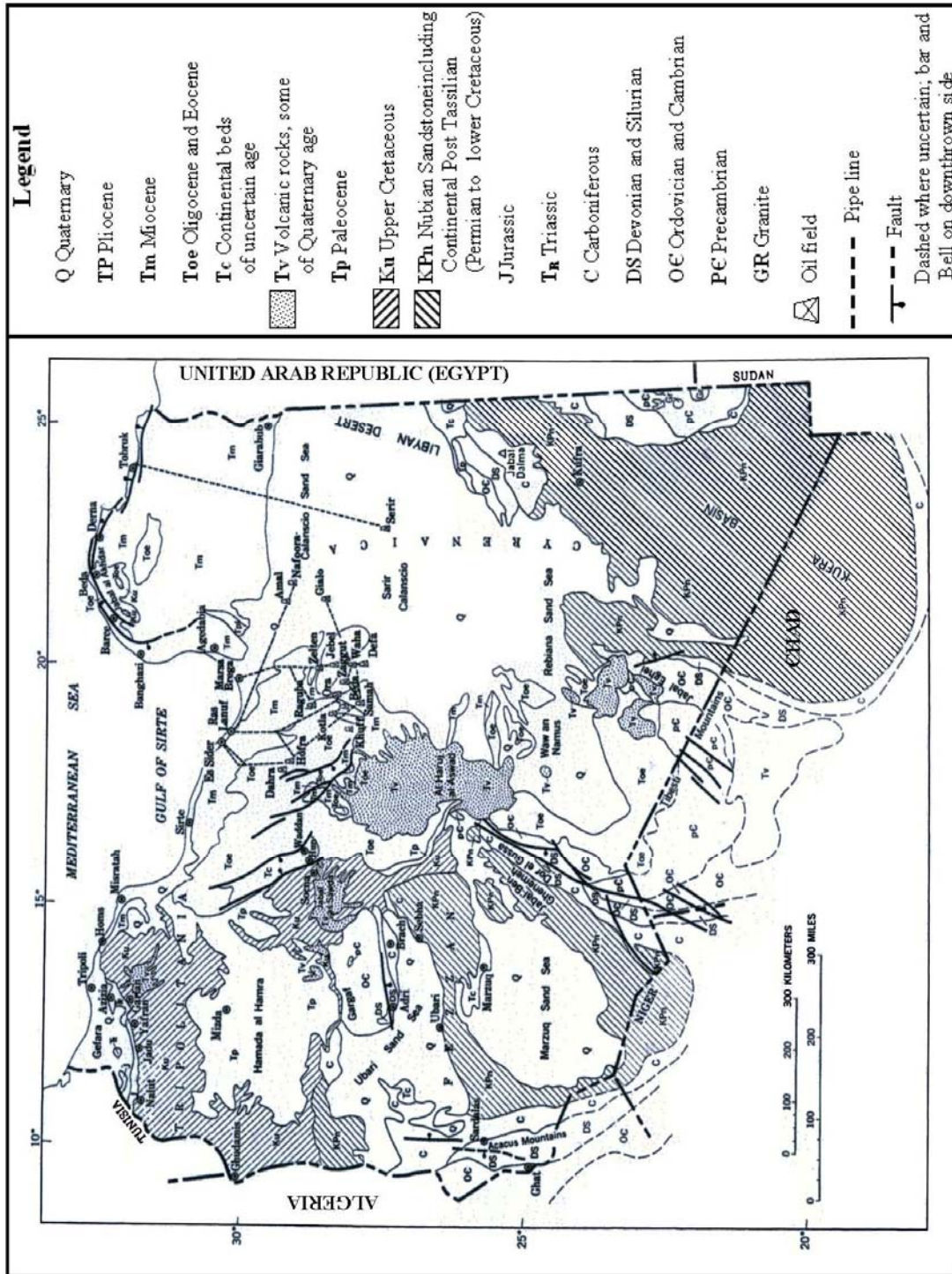


Fig. 5 Geologic Map of Libya (after Conant and Goudarzi, 1967)

The subsidence curves and their rate for the Sirte Basin which indicated the highest subsidence and sedimentation rates which occurred during the Paleocene and Eocene ages did not affected in the present writer's view the Siwa-Faghur basin in the Western Desert of Egypt. The Western Desert of Egypt can be visualized to represent an elevated area started from the upper Cretaceous period as a result of basement tectonics which uplifted the area vertically. This proposed uplifting invaded the area and continued with increased intensity during the upper Cretaceous-lower Tertiary time which prevented the formation of depocenters during the Paleocene. The Paleocene is represented only by the upper Paleocene which ranges in thickness from 20-40 m only. The high attitude of the basement fault-blocks which underlie the Paleozoic Nubian Sandstone and/or the thin undifferentiated Paleocene-Eocene section in the Siwa-Faghur Basin prevented the occurrence of the suitable lithofacies for petroleum generation, migration and accumulation in this Western Desert basin adjacent to the Libyan Sirte Basin as formerly discussed.

Terry and Williams, 1969, studied in detail the Idris "A" bioherm and oil field, Sirte Basin, Libya. The Idris bioherm province developed on the crest and flanks of a broad, low relief anticline in concession 103. They stated that, the bioherms began as foraminiferal banks that built on local mounds on the floor of a shallow sea. Algae helped to bind the foraminifera loosely. Later, sparse coral growth bound a predominantly coral detritus until a more favourable environment allowed a richer coral growth which produced a massive coralline reef. A major transgression killed reef growth with an argillaceous deposition and marked the end of the Paleocene epoch (Fig. 6).

It is recognized that the Paleocene in the Siwa-Faghur Basin is devoid of any reef body as revealed by drilling. Accordingly, the comparison of the Paleocene sediments in the Siwa-Faghur Basin in the Egyptian Western Desert and in the Sirte Basin, Libya revealed that they are not correlatable lithologically and paleontologically. The Paleocene lithostratigraphic section in the Western Desert of Egypt is a rudimentary section as a result of a transgressive phase which did not permit reefs growth. It represents thin argillaceous deposits which are mostly undifferentiated within the lower Eocene section at the end of the Paleocene age.

Rusk, 2001, reported the recoverable reserves in approximately 320 fields in Libya's Sirte, Ghadamis, Murzuq, and Tripolitania Basins. Approximately 80% of the cited reserves were discovered prior to 1970. He added that, complex, subtle and, in particular, deep plays were rarely pursued during the 1970s and 1980s because of definitive imaging technologies, limited knowledge of the petroleum systems, high costs and risk adversity. Consequently, extensive undiscovered resources remain in Libya. He predicted most of the undiscovered resources in Libya will be found in the vast, underexplored deep areas of the producing basins. Beside the onshore six areas cited, he directed the attention to the offshore eastern Tripolitania Basin in the west.

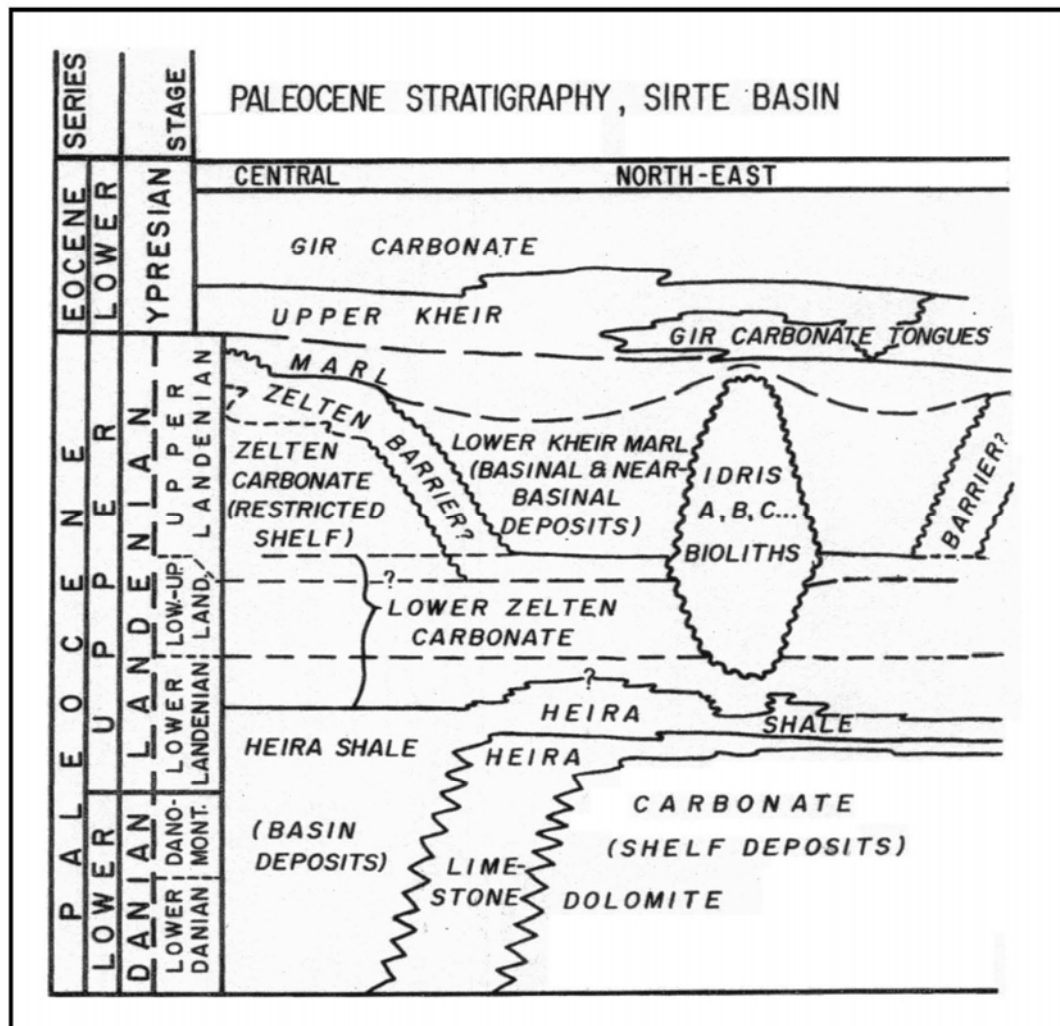


Fig. 6. Regional Paleocene Stratigraphic Setting, Sirte Basin, Libya
(after Terry and Williams, 1969)

The former discussion is concerned with the onshore petroleum basins in the Egyptian Western Desert and East Libya and their petroleum-bearing lithostratigraphic sections and their comparison and correlation.

4 Analysis example The offshore petroleum prospection in the northern western desert of Egypt and east Libya

The offshore petroleum occurrences of oil and gas in the Northern Western Desert of Egypt have been taken into consideration since the end of the sixties of the 20th Century the discovery of Abu Qir gas field at the eastern limit of the Western Desert offshore concessions.

The discovery of Abu Qir gas field in 1968 was a stimulus for further offshore

drilling, but the two proved gas wells (Miocene clastics pay-zone) were abandoned as a related concession to the Nile Delta continental shelf—continental slope areas in that time for future use in industry. The offshore drilling in the continental shelf – continental slope areas of the Northern Western Desert of Egypt did not start till the presentation of the present paper in 2010 research seminar in our geology Dept., as the present writer explained and recommended.

Intensive offshore prospection and drilling in Libya started since 1974 at West Libya near the international borders of Tunisia. For the first time since 1974, the State – owned Ageco expanded its license area north of its Sarir field in East Libya, and the NOC (National Oil Company, Libya) took the remaining vacant offshore area in the Gulf of Gabes (Nicod, 1977).

According to fragmentary information the only offshore well completed in 1982 was an oil discovery, Agip M1-NC 41/137, located in the Libyan part of the Gulf of Gabes. Apart from Agip which drilled one well in the northwest offshore (Pelagian basin, Gulf of Gabes). Of major interest was Agip's decision to develop the offshore Burni field (125 km northwest of Tripoli in the Pelagian basin). This field was scheduled to go on stream in 1986 with an initial production of 75,000 BOPD, (Nicod, 1983).

At the end of 1983, area held under concession agreements or production-sharing contracts covered onshore, shelf, and 52,416 km² in deep waters. No new contracts were awarded reportedly, and 29,301 km² were relinquished during the year. Among the relinquished areas only 816 km² covered an offshore block in the Pelagian basin.

In 1983, most seismic exploration was onshore (in the Sirte Basin, West Libya, and southwest Libya), but some marine surveys were conducted in northeastern waters (Gulf of Bomba).

Nicod, 1984, reported in 1983, about 61 exploratory wells. From them 8 wells were completed. Successful offshore wells were drilled in the Pelagian basin (northwest offshore) by Agip. At the end of 1983, Libya's reserves probably amounted to 23 billion bbl of crude oil (presumably not including the 6-7 billion bbl estimated reserves of the offshore Bouri discovery) and about 20 tcf of associated and natural gas.

Michel, 1985, reported that a few changes occurred in 1984 oil and gas developments in Libya. Petroleum concessions and production-sharing contract areas totaled 639,145 km² including only (98,310 km² offshore). Of great significance was the offshore oil discovery Agip made at 1-NC 120 (total depth 11,900 ft) off Benghazi. This well flowed up to 5,263 b/d of 36 API° crude from a three-pay section of lower Cretaceous age at 7,993 ft. Probable reserves are said to be 500 million bbl.

Michel, 1986, reported that according to fragmentary information, it is assumed that about five offshore test wells were drilled in 1985. Offshore, state – owned Sirte Oil Co., discovered oil at G1-NC 35A (4,694 b/d of 31 API° oil) and at J-1-NC 35A

(6,136 b/d). Some of the remaining offshore wells presumably were abandoned.

The coastal area in Libya extends 1900km which reflects the wide area of the continental shelf-continental slope areas in comparison with the Mediterranean coastal area in Egypt as offshore drilling is concerned.No more data or even fragmentary information about the offshore drilling in Libya are reported after 1986.

5 Conclusion

From the forementioned discussions and interpretations the following conclusions arise.

(1)The Western Desert of Egypt can be visualized to represent an elevated area started from the upper Cretaceous period as a result of the basement tectonics which uplifted the area vertically. This proposed uplifting invaded the area and continued with increased intensity during the upper Cretaceous-lower Tertiary time which prevented the creation of depocenters during the Paleocene age;

(2)The high attitude of the basement fault-blocks which underlie the Paleozoic Nubian Sandstone and/or the thin undifferentiated Paleocene-Eocene section in the so-called Siwa-Faghur Basin prevented the occurrence of the suitable lithofacies for petroleum generation, migration and accumulation in that Western Desert Basin adjacent to the Libyan Sirte Basin and the adjoining petroleum fields;

(3)The comparison of the Paleocene sediments in the Siwa-Faghur Basin in the Egyptian Western Desert and in the Sirte Basin, Libya, revealed that they are not correlatable lithologically and paleontologically. The Paleocene age in East Libya (Sirte Basin) is very prolific and a group of reefs giant reservoirs are reported. While, no signs of reef formation or facies in the Paleocene of the Western Desert of Egypt;

(4).Parameter drillings in the offshore concessions of the Northern Western Desert of Egypt are recommended to clarify the geologic speculations.

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