CHAPTER (2)

GEOLOGIC SETTING

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2.1 Introduction

The study area lies in the northern part of the Western Desert of Egypt. It is delineated by Lat. 29° 25`-30° 10` N and Long. 26° 29`-29° 00` E (Fig. 1.1). The study area includes most of the oil and gas fields of the central northern portion of the Western Desert as: Abu Gharadig field, BED field, GPC field and Sitra field. The objective of this chapter is to outline the general geologic setting of the central part of north Western Desert as regards the subsurface stratigraphy, the structural elements, the tectonic framework and the geologic history.

2.2 Subsurface Stratigraphy

The general stratigraphic succession of north Western Desert of Egypt includes different sedimentary sequences ranging in age from the Cambrian to the Recent (Fig. 2.1). The average thickness of this sedimentary cover increases northwards where it exceeds 7500 m. Since Zittle (1883), many workers had studied and revised these sedimentary successions such as: Shata (1953 and 1955); Kostandi (1959); Amin (1961); Norton (1967); Abdine and Deibis (1972); Abu El-Ata (1981); Schlumberger (1984); Barakat et al. (1988); Said (1990); Darwish et al. (1994); Aboul Ela et al. (1996). According to these authors, the generalized stratigraphic succession (Fig. 2.1) that rests over the basement complex is composed from base to top as follows: Paleozoic, Mesozoic and Cenozoic rock units. The Mesozoic sediments attracted the attention of most of the operating companies in this region, for the existence of the potential source rocks, consequently the hydrocarbon reservoirs. Therefore, the Jurassic and Cretaceous sequences are the main scope of analysis, drilling and evaluation for their relatively high oil and gas productivity.

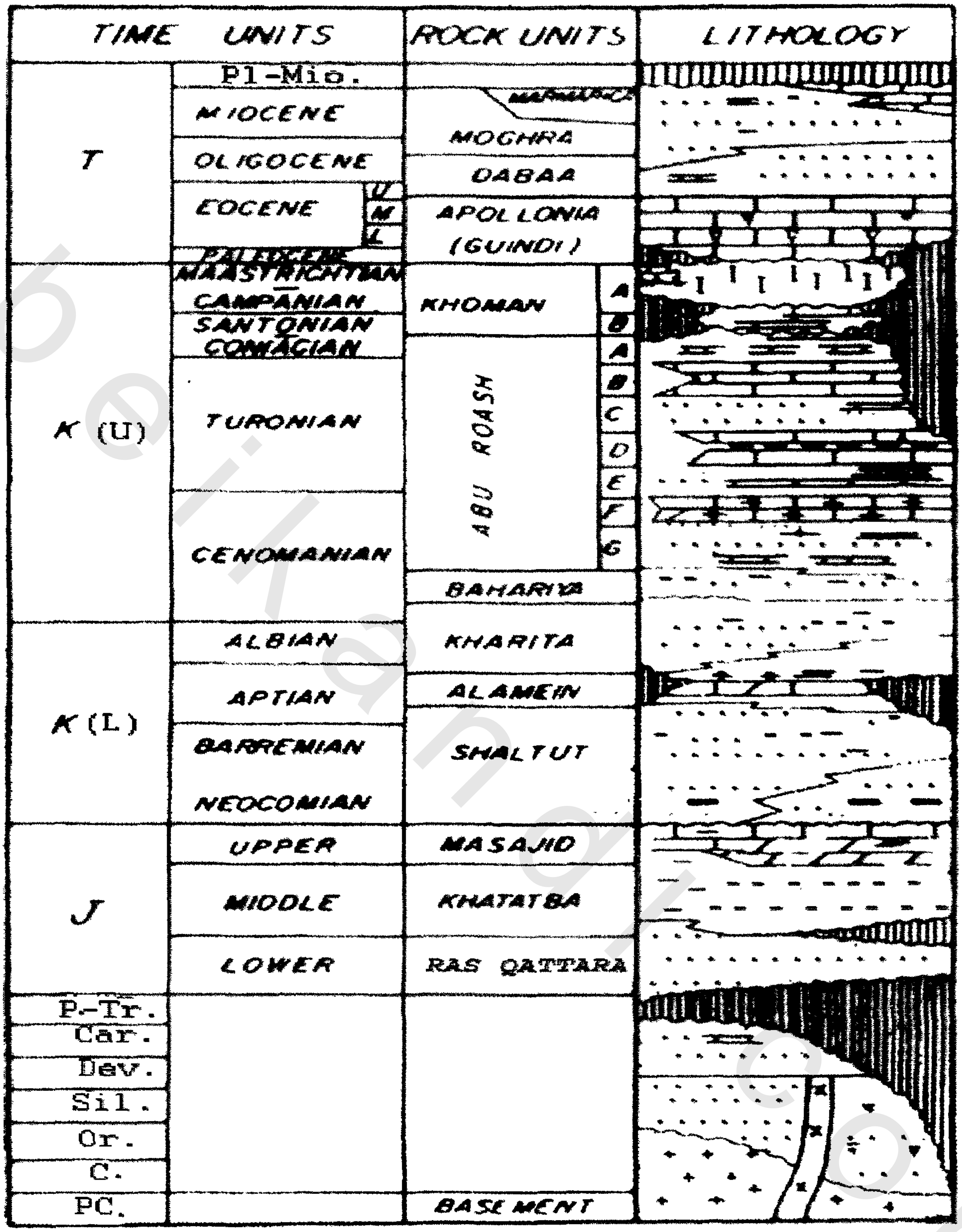
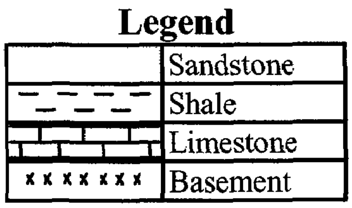


Fig. (2.1): Generalized Litho-Stratigraphic column of north Western Desert, (after E.G.P.C., 1982).



2.2.1 Jurassic

The Jurassic comprises three marine rook units, each of which onlaps the underlying one. Southward and westward they overlap the continental Ras Qattara sediments and the eroded Paleozoic sequence. The Jurassic is divided into the following marine formational units from base to top:

(A) Ras Qattara Formation: This name was proposed by Eloui and Abdine (1972) instead of Libyan Eghei Group of Norton (1967) to represent the continental facies of the Permian-Triassic-Jurassic in north Western Desert. Abu El-Ata (1981) restricted the use of such name to the continental to fluvio-marine environments of Jurassic, because it has more marine affinity than the underlying Triassic and Permian rocks. By this way, Ras Qattara Formation is equivalent to the marine Jurassic formations (or a part of them), which are given other names elsewhere. The rocks forming this unit are mainly alternating sandstones and shales, which overlie the Camel Pass Basalt of Triassic age.

(B) Khatatba Formation: Such a unit was called by Norton (1967) to represent the back-reef facies that prevailed in the eastern part of north Western Desert during the Middle Middle Jurassic. It is composed of a thick calcareous shale sequence consequently it is considered a suitable source rock characterized by rich organic content.

(C) Masajid Formation: This unit was named by Norton (1967) to designate the fore-reef facies of the Upper Middle to Upper Jurassic in north Western Desert. Masajid Formation is made up of platform carbonates, including reefal, dolomitic and argillaceous limestones.

2.2.2 Cretaceous

A widespread unconformity is recorded at the Jurassic-Cretaceous boundary. The Lower Cretaceous transgression started from the north and northwest. The Lower Cretaceous basin of north Western Desert is extending from

Salum in the northwest to the Nile basin in the northeast (Gezeery et al., 1972). The Upper Cretaceous transgression started in Cenomanian from the north and spread as far south as the Bahariya Oais. It represents one of the widest transgressions known in the geologic history of Egypt. The three Upper Cretaceous basins of north Western Desert follow an east-northeast to west-southwest trend, the largest of which in Abu Gharadig basin extends over the central part of north Western Desert. It contains the thickest Upper Cretaceous sequence allover Egypt (Aadland et al., 1972).

2.2.2.1 Lower Cretaceous: It is divided into three rock units which are described below as follow:

(A) Shaltut Formation: Mohsen et al. (1974) and Gezeery et al. (1974) considered Shaltut Formation as the lateral brackish water to estuarine variant of the marine Matruh Formation. It is composed of argillaceous sandstone of Neocomian-Barremian to Lower Aptian interval.

(B) Alamein Formation: Eloui and Abdine (1972) raised the rank of such a unit from a member to a formation after Norton (1967) to represent the back-reef environment that prevailed in north Western Desert in the Middle Aptian. It consists mainly of tight microcrystalline limestone, dolomitic limestone and dolomite.

(C) Kharita Formation: Mohsen et. al. (1974) raised the order of this clastic unit from a member of Norton (1967) to a formation, to designate the continental facies that prevailed in north Western Desert during the Late Aptian-Albian. It is composed of non-marine clastics (argillaceous sandstone) which overlies the marine Aptian Alamein Formation and underlies the fluvio-marine Cenomanian Bahariya Formation. In the study area, the argillaceous sandstone facies is predominant within Abu Gharadig Basin, where most of the productive horizons of the Kharita Formation have been recorded.

2.2.2.2 Upper Cretaceous: The dividable rock units of this thick section are described as follows:

(A) Bahariya Formation: It was named by Norton (1967) to define the fluvio-marine conditions of the Lower Cenomanian in north Western Desert. Lithologically, the Bahariya Formation consists generally of sandstones, siltstones and to a lesser degree carbonates. This formation is normally characterized by numerous thin shale streaks which decrease the vertical permeability. The Bahariya Formation which is widely spreading out through the area, has good porosity and is equivalent to the Nubia \`A\` recognized in Gulf of Suez (RRI, 1982).

(B) Abu Roash Formation: This unit was named by Norton (1967) to designate the marine neritic to open basinal facies that prevailed in north Western Desert during the Late Cenomanian to Santonian interval. This formation is mainly composed of thick sequence of limestones, shales and sandstones. The litho1ogy of Abu Roash Formation reflects alternations of transgression and regression phases, characterized respectively by cyclic shallow to deep marine carbonates and shallower deposits of alternating shales and sandstones. Abu Roash Formation is subdivided into seven lithostratigraphic members which are termed alphabetically from \`A\` to \`G\`. New names were denoted for these members but they are not widely used. The members \`A\`, \`C\`, \`E\` and \`G\` are predominantly calcareous sandstones with argillaceous intercalations whereas the members \`B\`, \`D\` and \`F\` are predominantly carbonates with argillaceous intercalations. The seven members are defined below as follows:

1-Abu Roash \`G\` Member: It is made up of shales that contain fine grained sandstones in both the upper and lower parts. A lime mudstone occurs in the middle part of the member with additional limestone intercalations in its lower part. It was deposited in an open marine environment.

2-Abu Roash `F` Member: It is dominated by argillaceous limestone with shale streaks.

3-Abu Roash `E` Member: This member is generally dominated by clastic sediments as sandstone, silty shale, but also contains variable proportions of limestones. Based on the fossil and lithologic contents, Abu Roash `E` Member can be subdivided into two parts. The lower part is laid down under middle to outer neritic open marine conditions and made up of lime mud to wackestone with shales. This is followed by an upper part which is composed of inner neritic to littoral facies of shales interbedded with fine gluaconitic sandstones.

4-Abu Roash `D` Member: This member is composed of limestone intercalated with shale. It is mainly made up of low energy carbonates deposited in a shallow marine, inner neritic environment.

5-Abu Roash `C` Member: This member is mainly made up of shales with interbeds of glauconitic sandstone and minor limestone streaks. It was deposited in a restricted shallow marine shelf, under low to moderate energy conditions and subjected to intermittent clastic influx from the south and southeast.

6-Abu Roash `B` Member: This member consists mainly of massive limestone with thin shale streaks. The lithology of Abu Roash `B` Member suggests its deposition under marine to inner shelf environment.

7-Abu Roash `A` Member: It is composed of rapidly alternating limestone and shales with minor streaks of sandstone. An inner neritic depositional environment with an upward deepening trend is suggested. Abu Roash `A` Member is overlaid by the Khoman Formation. The thickness of Abu Raoash `A` Member varies dramatically due to the differential effects of faulting and unconformity which took place near its top.

(C) Khoman Formation: This unit was named by Norton (1967) to describe the open marine facies occurred during the Campanian-Maestrichtian allover of north Western Desert. It is composed of massive, chalky limestone, moderately soft, fossiliferous and argillaceous toward the base. With regard to its lithology, the Khoman Formation is subdivided into three distinctive units (Demerdash et al. 1984) from top to bottom, as follows:

1-Unit III: It forms the upper unit and made up of chalk with cherty zones.

2-Unit II: It forms the middle unit and made up of brown limestone, argillaceous with locally thin dark calcareous shales.

3-Unit I: It forms the basal unit and made up of pyritic shale with lime-mud wackstone intercalations. A progressive deepening of the depositional environment from a shallow marine-shelf realm of the upper part of Abu Roash Formation deposits to an open marine-calm water regime is suggested. The Khoman Formation gradually thins southward, whereas to the north, it underlies unconformably the Tertiary carbonates and overlies Abu Roash Formation within the study area.

2.2.3 Tertiary

The transitional period between the Late Cretaceous and Early Tertiary corresponds to the Early Alpine Orogenic phase during which the Syrian arc system of deformation was most active. At the end of Cretaceous time, sedimentation was continuous in the structurally low and subsiding areas, but depositional gaps and erosional truncations were common on the pre-existing highs, which were reactivated especially during the Paleocene. By this way, the Tertiary sediments rest conformably over the Upper Cretaceous sediments in Abu Gharadig basin. The Tertiary sedimentation represented by a regressive cycle of deposition ceased in the Messinian time.

The Tertiary rock units are arranged from base to top as follow:

(A) El-Guindi Formation: This unit was named by Norton (1967) as the Apollonia Formation and emended by Eloui and Abdine (1972) as the El-Guindi Formation, to describe the open marine section north of Faiyum depression (north Western Desert). This formation is mainly formed of limestone with shaly and cherty interbeds near the top. This formation is divided into four members, on lithologic basis: D, C, B and A from base to top as follows:

1-(D-Member): It is mainly composed of shales with limestone streaks.

2-(C-Member): It is made up of carbonates with sandy chert in some parts.

3-(B-Member): It is mainly consistis of shales with limestone intercalations.

4-(A-Member): It is made up from non clastics.

The El-Guindi Formation overlies unconformably the Upper Cretaceous sequence (either the Khoman or Abu Roash Formations) on the high structures which are affected by the Syrian arc system of folding and faulting. Paleocene Esna Shale is commonly missing on the fold crests.

(B) Dabaa Formation: This unit was named by Norton (1967) to designate the fluvio-marine facies in north Western Desert during the Upper Eocene-Oligocene. It is composed sandy and carbonaceous shales with few streaks of limestone near its base.

(C) Moghra Formation: It was named by Said (1962) to designate the fluvio-marine facies in north Western Desert during the Early Miocene. The Moghra Formation is composed of sandstones with interbeds of shales and occasional limestone streaks. It rests unconformable over the Dabaa Formation and underlies the Marmarica Formation of the Middle Miocene. The Oligo-Miocene rocks are ended by the Marmarica Formation (Middle Miocene), which is unconformably overlaid by the Quaternary deposits.

2.3 Structural setting

The major structural deformations of north Western Desert are dealt with special emphasis on their imprints on the local structural features on the study area. Many workers were and still are interested in delineating these features on a regional-sense, studying the effect of the neighboring regions and provinces on north Western Desert province. Some others are working on the surface and subsurface geologic conditions responsible for the synthesis of Qattara depression physiographic features as well as the giant Abu Gharadig basin with the mutual relations between them. The third group of workers is interesting in mapping the structural elements on local scale area. Shata (1953) concluded that, the general axial trend of structure in north Western Desert is NE-SW, which is aligned with the Syrian Arc system. The structures of system were starting at least from the Middle Cretaceous and continued throughout the Tertiary and probably in Quaternary periods. There is also another trend of structures oriented NW-SE, but of secondary importance and is almost reflected in elongated noses closed from their northwestern side and open from the southeastern one. Shukri (1954) deduced that, Egypt can be visualized as an area with elongated ridges rising from the bottom of the Cretaceous sea. These ridges are running in a northeast-southwest direction, extending across Egypt and are a continuation of the well known the Syrian Arc system. Sigaev (1959) divided the surface of the country into two major structural regions, as follow: 1-The Lower structural complex (Pre-Cambrian). 2-The Platform or upper structural complex (Pre-Cambrian to Recent). The second complex is further subdivided into five structural stages: Pre-Jurassic, Jurassic-Nubian, Pre-Eocene, Eocene and Oligocene-Quaternary structural stages. Said (1962) subdivided the fold system in north Western Desert into three major groups: (1) North-South folds that implicated in the subsurface and affect the

Paleozoic rocks. (2) Northeast-Southwest folds that shown in the surface and subsurface, and arranged in lines having the Syrian arc folding trend. (3) Northwest-Southeast folds that expressed the surface and subsurface and affect the Oligocene and younger sediments. Mohsen, Naggar and Taher (1973), after studying the isopach map of the Cretaceous rocks, suggested the existence of two furrows running in the Northeast-Southwest direction separated and bounded by ridges running in the same direction. Meshref and El-Sheikh (1973) concluded that, the E-W and the N 65° E trends are more developed in north Western Desert. These trends are related to a northern horizontal pressure that affected Egyptian territory at different geologic times. Abdel Fattah (1975) concluded that, the western part of Abu Gharadig basin consists of two main half-grabens separated by a ridge oriented NE-SW. The eastern half-graben is larger and deeper than the western half-graben. These two half-grabens are separated from the northern Qattara ridge by a fault plane orienting E-W. Moreover, the entire Abu Gharadig basin is affected by WNW-ESE trending normal faults. Meshref et al. (1980) interpreted a basement tectonic map for the northern part of the Western Desert as alternating anticlinal uplifts and troughs of regional ENE trend and a set of faults of NW direction that cross the older ENE structures. Also, a second trend of faulting is observed in the NE direction. Two major basins called the northern basin and Abu Gharadig basin are separated by two major anticlinal uplifts. Abu El-Ata (1981), in his integrated study on the structure and tectonics of the eastern part in north Western Desert, established six regional structural-tectonic deformation systems. The oldest, Meridional system of East Africa comprise the first folds formed in the Pre-Cambrian-Early Paleozoic which trend NNW-SSE, during the Late Paleozoic-Early Mesozoic, these folds changed their directions to become NNE-SSW with the generation of triple rifting as the Atlas system. During the Middle to Late

Mesozoic, the Syrian Arc system of folds and faults were formed in the NE-SW direction. During the Early Tertiary, the Red Sea system of faults and folds were initiated in the NW-SE trend. During the Late Tertiary, the Mediterranean Sea system of faults and folds regenerated in the E-W direction. Finally, during the Quaternary, the Aqaba system of faulting is synthesized in the N-S direction. Meshref (1982), on the basis of analysis of the aeromagnetic map and the subsurface data of north Egypt (north of Lat. 27°) delineated several uplifted structures separated by ENE trending basins. Robertson Research International (1982), established the major structural deformations affecting Abu Gharadig basin. Abu Gharadig basin is bounded from the north and the south by a number of regional faults and spurs. The northern faults are trending mostly WNW-ESE and throwing to the south, while the southern ones are running principally ENE-WSW and throwing to the south. Zante (1984), in an internal report for Shell Winning N.V. described the structural features of Abu Gharadig basin (principally its western part) as two main half grabens separated by a NE-SW oriented ridge, called the `Mid basin arch`. The eastern half graben is larger, deeper rises gently up to Sitra platform to the south. It is separated from the northern Qattara ridge to the north by a large fault zone of arcute shape. The deepest part in the western half graben is to the south where it is separated from the southern Sitra platform by large E-W faults. The entire western Abu Gharadig basin is affected by a series of WNW-ESE normal faults. Abu El-Ata and Abdel-Nabi (1986) concluded that, Abu Gharadig Basin subdivided by two NE-SW mid basin ridges into three sub-basins. The central basin is outlined to the north and south by two semi-basinal areas through two left-lateral major oblique faults. These are followed to the north and south by two high areas through other two right-lateral major oblique faults. The northern high is further subdivided to Qattara ridge and Badr El-Din platform that slopes northward to Alamein basin. The southern high is subdivided to Sitra ridge and Bahrein platform. Also, the entire range of Abu Gharadig basin is dissected by two trends normal faults. These are trending NE-SW and NW-SE, in which the younger NW-SE faults crossed and break-down the older NE-SW ones.

2.4 Tectonics

The tectonic setting of north Western Desert could be established from the collection of the surface and subsurface structural elements. North Western Desert of Egypt is subjected to different tectonic regimes which have a major effect on the hydrocarbon accumulations. Sigaev (1959) mentioned that, during the Paleozoic and the earliest part of Mesozoic, the greater part of Egypt was subjected to uplifting. Since the Jurassic and up to the end of Eocene, subsidence took place particularly toward the end of the Cretaceous. He subdivided the Western Desert to three different tectonic regions:

1-Southern-Lybian large domal uplifts (anticlines).

2-Northern-Egyptian synclinal basins (synclines).

3-Nile synclinal basin.

Said (1962) mentioned that, the noticeable episodes of diastrophism in the Western Desert are as follows:

1-Early Paleozoic (Caledonian).

2-Late Paleozoic (Variscian epoch).

3-Late Jurassic (Nevadian).

4-Upper Cretaceous-Lower Eocene (Laramide).

5-Mid-to Late Tertiary (Syrian).

Abu El-Ata (1981 and 1988) concluded that the complexity in structural regime and the diversity in structural trends throughout the various periods constituting the Phanerozoic section of north Western Desert were originated from the consequent change of the acting stresses. By this way, the oldest

Meridional system of the Pre-Cambrian-Early Paleozoic is resulted from a stress trending ENE-WSW during the separation of the Eurasian and African plates from the two American plates. The Atlas system of the Late Paleozoic-Early Mesozoic is created from a stress trending WNW-ESE during the up-arching of the mid-continental part. The Syrian Arc system of the Middle to Late Mesozoic is initiated from a stress trending NW-SE. The Red Sea system of the Early Tertiary is synthesized from a stress trending NE-SW. The Mediterranean Sea system of the Late Tertiary is produced from a stress trending nearly N-S. Finally, the Aqaba system of the Quaternary is formed from a stress trending mostly E-W. Meshref (1982) considered that, north Egypt is affected by three tectonic events arranged from the oldest to the youngest, as follows:

1-Paleozoic to Triassic: resulted in NW or WNW trending structures.
2-Cretaceous: resulted in ENE (Syrian Arc system) trending structures.
3-Late Eocene to Early Oligocene: resulted in the EW, NW (Suez) and NNE (Aqaba) trending structures.

The first two tectonic trends may be explained to be due to a couple of forces affecting north Africa at that time, while the third tectonic event is due to the collision of Africa with Asia which resulted in a northern compressive force. Demerdash et al. (1984) concluded that, the Late Cretaceous tectonic event in Abu Gharadig Basin started in Coniacian/Santonian times and reached its climax in the Early Santonian. Awad (1984) deduced that, Qattara depression are and its continuation eastward till the Nile Delta subjected to several tectonic events. The most effective tectonic event controlling the shape and development of this feature began by the Early Cretaceous and were very effective during the Late Cretaceous, resulting contemporaneous faults (trending NE-WSW) and large amounts of the Upper Cretaceous sediments. Zante (1984) studied the tectonic activity which occurred in Abu Gharadig basin during the geologic history. The deposited Paleozoic rocks have been uplifted during the Pre-Jurassic times. During the Jurassic-Lower Cretaceous times, the regional subsidence resumed with very little tectonic activity, resulting in the tilting of Sitra platform towards the north accompanied by a minor faulting. Qattara ridge became uplifted and subjected to erosion in the Late Aptian to Albian times. At that time movements led to the formation of Abu Gharadig basin. The major fault zone that separates Qattara ridge from Abu Gharadig basin was active during the Late Jurassic times. Most of the faults were active in the Aptian times in Abu Gharadig basin. The rate of displacement was large enough to affect the sedimentary basin. During the Late Cretaceous times, tectonic activity increased drastically, as cyclic deposition observed within Abu Roash Formation. A phase of compression and regional uplift took place in the Santonian times which formed some ridges. Erosion over the high areas took place before a renewed subsidence and deposition of the Khoman chalk and younger formations. The tectonic activity was limited to a lesser extent, causing uplift for the ridges in the Tertiary periods. Abu El-Ata and Abdel-Nabi (1986) considered that, Abu Gharadig basin is affected by three main stresses responsible for the synthesis of such basin and its subdivisions. The Late Mezozoic NW-SE stress created the two mid-basin ridges and the minor and major NE-SW faults, the Early Tertiary NE-SW stress formed the deeper basinal parts and the NW-SE faults, while the Late Tertiary NNW-SSE stress initiated the nearly E-W major faults and connecting the others in, at least, two major oblique faults defining the present configuration of Abu Gharadig basin. Sultan and Halim (1988) concluded that the most prominent structural trends in north Western Desert of Egypt are NW to WNW, NE to ENE and E-W trending faults. Most of the existing oil fields in the region are located at the instruction between NW to WNW and NE to ENE trending fault systems. They concluded also that five sub-basins can be identified in north Western Desert, which are Alamein, Shushan, Khalda, Matruh and Qattara. The Western Desert can be subdivided into a number of large-scale structural provinces (Fig. 2.2), which developed preferentially along pre-existing lines of weakness in the basement and in response to lateral movements between Europe and Africa. In general, the Western Desert is characterized by a southwestward thickening of the Paleozoic section and northward thickening prism of the Mesozoic and Tertiary strata, which is interrupted by the major east-west trending Sharib-Sheiba high. This regional uplift separates Abu Gharadig basin from the coastal Matruh, Shushan, Dahab-Mireir and Natrun basins (EGPC, 1992). On the other hand, Kattaniya High is a horst block in the eastern part separating Natrun basin from Gindi basin. The overview of EGPC (1992), reveals that, six major geotectonic cycles or phases can be recognized in the Phanerozoic in the Western Desert, these are: Caledonian cycle (Cambrian-Devonian), Variscan Hercynian (Late Paleozoic), Cimmerian/Tethyan (Triassic-Early Cretaceous), Sub-Hercynian-Early Syrian Arc (Turonian-Santonian), Syrian Arc main phase (Paleogene) and Red Sea phase (Oligocene-Miocene). Based on the results and conclusions mentioned by different authors e.g. Metwalli et al., (1979); Meshref, (1982); Sultan and Halim, (1988); Bayoumi and Lotfy, (1989); EGPC, (1992); Abdel Aziz, (1994); Khalil and Denchi, (2000); and others distinguished the main structural elements of north Western Desert which could be outlined as follow: Three major fold trends of different ages in the Western Desert are determined. The first one, which is detected in the subsurface, trends north-south affecting the Paleozoic rocks. The second fold trend is northeast-southwest, which was active during the Upper Cretaceous-Lower Tertiary time (Syrian Arc system). This fold trend is recognized on the surface exposures while it is detected in the subsurface by geophysical surveys. The third fold trend is the northwest-southeast which characterizes the Tertiary surface rocks particularly in Siwa-Moghra-Wadi El Natrun district. On the other hand, faulting is evidenced in the Lower Cretaceous sediments of north Western Desert and strike faults are parallel to the Syrian arcs, believed to be contemporaneous with the Late Cretaceous folding through rejuvenation of old Tethyian faults. Other faults trending northwest to southeast are detected crossing the anticlinal structures, mapped in north Western Desert. In general, the Paleozoic basins and ridges represent long north-south features, which suggest possible basement faulting. During the Jurassic, the major basin changed its trend slightly to occupy a northwest-southeast direction. The narrow and elongated nature of the Paleozoic ridges was not reflected during this age. The Lower Cretaceous basin in north Western Desert can be dealt with as one major basin extending from Salum in the northwest to the Nile basin in the northeast. There are three sedimentary basins of the Upper Cretaceous age (Abu Gharadig, Umbarka-Alamein and Nile basins). These basins follow an east-northeast to west-southwest trend. The largest of which is Abu Gharadig basin. Gindi basin of Tertiary age is located to the east from Abu Gharadig basin, and is connected with the Western Desert foreland.

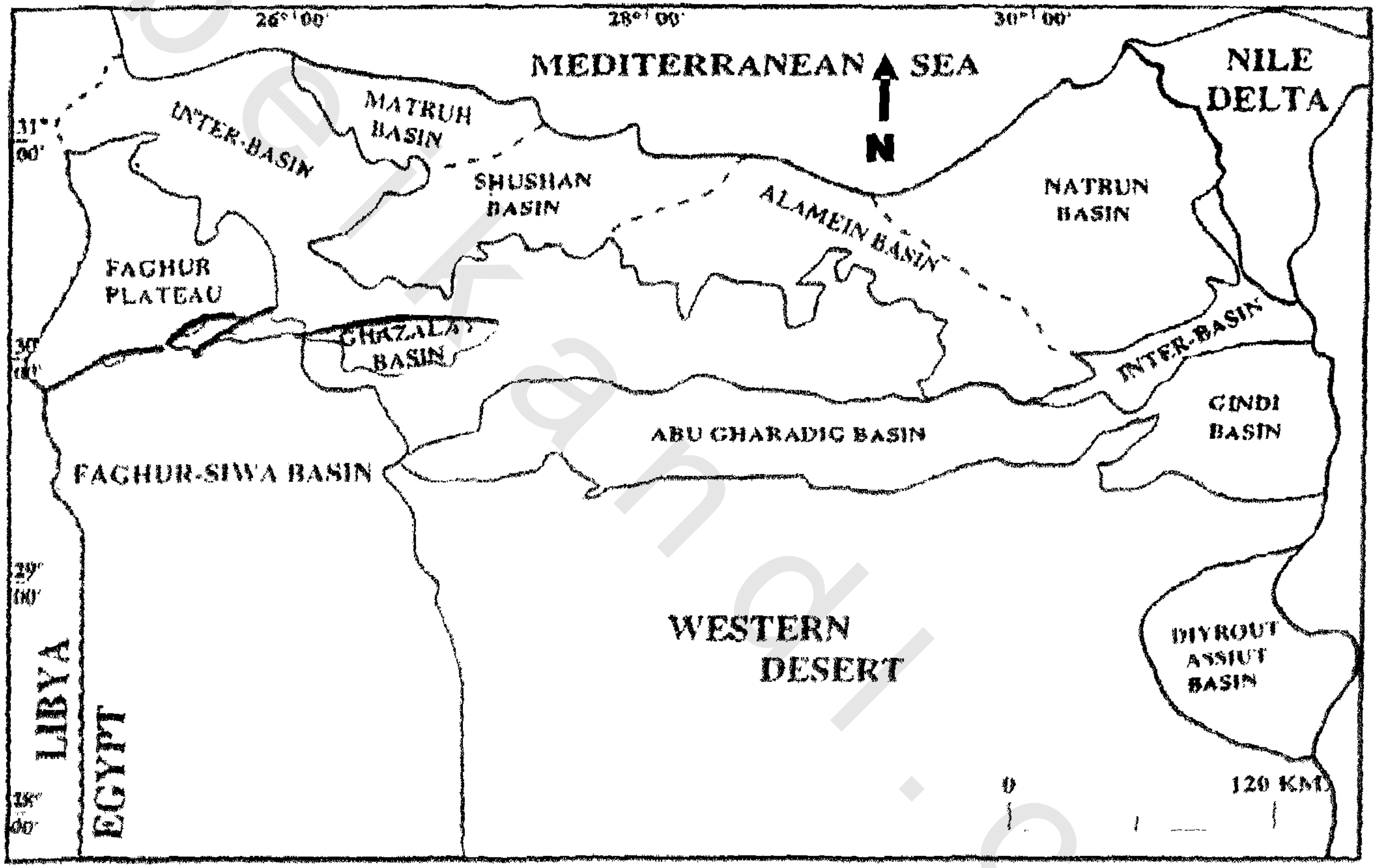


Fig. (2.2): Sedimentary basins of the Western Desert, (after E.G.P.C., 1992).

2.5 Geologic history

The geologic history of north Western Desert can be summarized as follows:

2.5.1 Paleozoic

The Paleozoic of the Western Desert consists mainly of continental sediments resulting from the denudation of the Precambrian highs. During the entire Paleozoic and a considerable part of Mesozoic, the greater part of Egypt subjected to uplifting (Said, 1990). The Paleozoic era started with a shallow sea that inundated the central part of the Western Desert in the Cambro-Ordovician time. This sea transgressed over the basement complex with moderate relief. Most of north Western Desert was probably outside the main Paleozoic sedimentary basin of Libya, except Siwa district, where the sediments are predominantly clastics and apparently represent the Lower Paleozoic (Barakat, 1982). The second transgression took place during the Carboniferous period and gave rise to the diagnostic black shales of this age. The cumulative Paleozoic sediments amount to 2400 and 4000 meters recorded in Siwa basin and the northwestern area, respectively (RRI and EGPC, 1982).

2.5.2 Mesozoic

By the end of the Paleozoic, broad regional highs and lows may have existed, and a major disconformity is observed between the Paleozoic and Mesozoic. During the Permian and Triassic periods almost the whole Western Desert remained as a dry land except for a few tracts occupied by estuaries or shallow inland seas, in which the eroded clastics of the Carboniferous rocks deposited red beds (Barakat, 1982). A new transgression took place during the Jurassic, probably originated from the north or northeast where the Lower Jurassic overlies Carboniferous. A fairly thick and uniformly developed the marine Middle Jurassic is recorded in the northern and northeastern parts of the Western Desert. The Upper Jurassic is variable in thickness and its top is often eroded. In the extreme northeastern part of the Western Desert the cumulative thickness of the Jurassic formations is estimated up to 1300 meters (Barakat, 1970, Khaled, 1974 and Keeley et al., 1990). The Jurassic-Early Cretaceous tectonic event affected the east-west oriented northern basin that covered the entire of north Egypt during most of the Jurassic period. A widespread unconformity is recorded at the Jurassic-Cretaceous boundary with evidence of emergence and local uplift, particularly at the northeast. The Cretaceous period witnessed four transgressive cycles in Egypt: Aptian, Cenomanian, Coniacian and Campanian-Maastrichtian transgressions. The Lower Cretaceous transgression started from the north and northwest. In north Western Desert, Burg El Arab Formation (Alam El Bueib Member) was deposited in the form of fluvial deposits. Genuine marine conditions persisted only in the extreme northwestern part of Egypt at Sidi Barrani and Mersa Matruh areas where Sidi Barrani and Matruh Formations were deposited. At Mersa Matruh, the Lower Cretaceous sediments attain a thickness of about 3770 meters, whereas those to the south reach 1700 to 2000 meters. The Upper Cretaceous transgression started in the Cenomanian from the north and spread as far south as the Bahariya oasis. During the Turonian genuine marine conditions prevailed over a large part of north Egypt. The Turonian witnessed an important pulse of the Laramide movement, which elevated the coastal areas of Sinai, the Sidi Barrani coastal area, Qattara ridge, Bahariya arc and numerous structures across Sinai. The Santonian represents a regressive phase during which the sea occupied only the tectonic basins of north Egypt that became clearly distinguished. A major transgression took place during the Campanian time, and chalky limestones were deposited in north Egypt. After a short regressive interval during the earliest Maestrichtian, the sea advanced and covered larger areas of Egypt than at any other time. The sea became considerably deeper and pure chalks of the Khoman Formation were accumulated in north Western Desert (Said, 1990). A series of folds trending northeast to southwest (Syrian Arc) started during the Senonian and continued intermittently to the Paleocene and locally to the end of Eocene. These folds extend across north Sinai and further west in the Western Desert.

2.5.3 Cenozoic

A widespread emergence occurred by the close of the Cretaceous, as all sections penetrated show a clear hiatus at the Upper Cretaceous-Lower Tertiary boundary. The diastrophic movement persisted with small magnitude during the Tertiary and motivated basaltic flows to cut across the sedimentary cover through deep-seated fissures. The Tertiary sediments were deposited over platforms with no clear evidence of strong diastrophism (Said, 1990).