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PETROGRAPHICAL CHARACTERISTICS AND DEPOSITIONAL ENVIRONMENTS OF THE UPPER PALEOCENE-LOWER EOCENE SEQUENCE IN CENTRAL EGYPT.

A.T. Abd El-Hameed

Geology Department, Faculty of Science, Tanta University, Egypt.

ABSTRACT

The Upper Paleocene-Lower Eocene sequence in Egypt, comprising the Tarawan Chalk, Esna Shale and their conformably overlying Thebes Formation, have been examined from three different areas in Central Egypt; Gebel Duwi, Quseir area, Gebel Taramsa, west of Qena, and Gebel Ghanima in the Kharga Oasis. The main lithological features and petrographical characteristics of different rock units and their bearing on facies analysis are briefly discussed. In addition, the depositional environments and lateral variation of facies are also considered.

Microscopic examination of carbonate lithologies has resulted in the recognition of 20 lithofacies based on the vertical variation in lithology, faunal content, texture, primary structures and sedimentological characteristics. The identified facies belong to four main petrographic groups; mudstone, wackestone, packstone and grainstone reflecting the environmental changes during the Late Paleocene-Early Eocene interval. This interval represents a transgressive phase during which both the Tarawan Chalk and Esna Shale facies were laid down followed by a regressive phase where the limestones of the Thebes Formation were deposited.

Kaolinite, smectite and illite as well as small amounts of non-clay minerals were identified in the argillaceous rocks of the Esna Shale. Their abundance signifies a humid episode of intense chemical weathering caused by increased temperature and excessive rainfall. On the other hand, diagenesis has a profound effect on the studied carbonates and hence, modified their texture, structure and petrophysical properties. Several diagenetic phases were recorded, including: dolomitization, silicification, cementation, recrystallization, dissolution and compaction.

INTRODUCTION

The Upper Paleocene-Lower Eocene succession in Egypt covers a wide area in the Eastern Desert, Nile Valley, Western Desert and Sinai. This sequence generally falls into four major rock units arranged stratigraphically as the upper part of the Dakhla Shale, Tarawan Chalk, Esna Shale and Thebes Formation.

The Dakhla Shale is generally formed of greyish shales with occasional marl intercalations. It was first described by Said (1961) at its type locality of Mut, Dakhla Oasis. The Tarawan Chalk was formally described by Awad and Ghobrial (1965) in its type locality at Gebel Tarawan, Kharga Oasis. It is composed mainly of thick bed of fossiliferous chalk, grading locally into chalky limestone or sometimes marly limestone.

The Esna shale was first described by Beadnell (1905) in its type locality at Gebel Oweina, near Esna. This unit has a very wide geographical distribution and consists normally of grey to greenish, fissile shales, sometimes grading into calcareous shale or marl with gypsum veinlets and ferruginous nodules.

The name, Thebes Formation was first introduced by Said (1962) to describe the thick limestone succession overlying the Esna Shale in its type locality at Gebel Gurnah, Luxor, Nile Valley. The formation consists predominantly of hard, massive limestone, dolomitized in some parts and normally contains chert bands and scattered flint nodules.

Many detailed paleontological and stratigraphical studies have been carried out on the Upper Paleocene-Lower Eocene sequence in Egypt (e.g. Youssef, 1949; 1954; Nakkady, 1958; Said, 1961; 1962; Said and Sabry, 1964; Awad and Ghobrial, 1965; El-Naggar, 1966; 1970; Krasheninnikov and Abd El-Razik, 1968; Khalifa, 1970; Ismail and Abd El-Razik, 1969; Issawi, 1972; Kenawy, 1972; Omara et al., 1972; Barakat and El-Dawoody, 1973; Soliman et al., 1989).

For the purpose of the present study, three stratigraphic columnar sections (Fig. 1) were sampled from the Upper Paleocene-Lower Eocene successions at Gebel Duwi (Quseir area), Gebel Taramsa (west of Qena) and Gebel Ghanima (Kharga Oasis). Sampling was restricted only to Tarawan Chalk, Esna Shale and Thebes formations and the lithostratigraphic units have been adopted following those of Awad and Ghobrial (1965), Beadnell (1905) and Said (1962), respectively.

The present work is based on the study of 94 samples collected from the three studied areas. Sixty four samples were thin sectioned for petrographic study and the depositional environment of different rock units was briefly discussed. Lithological facies were recognized on the basis of the depositional texture (Dunham, 1962; Flugel, 1982) and

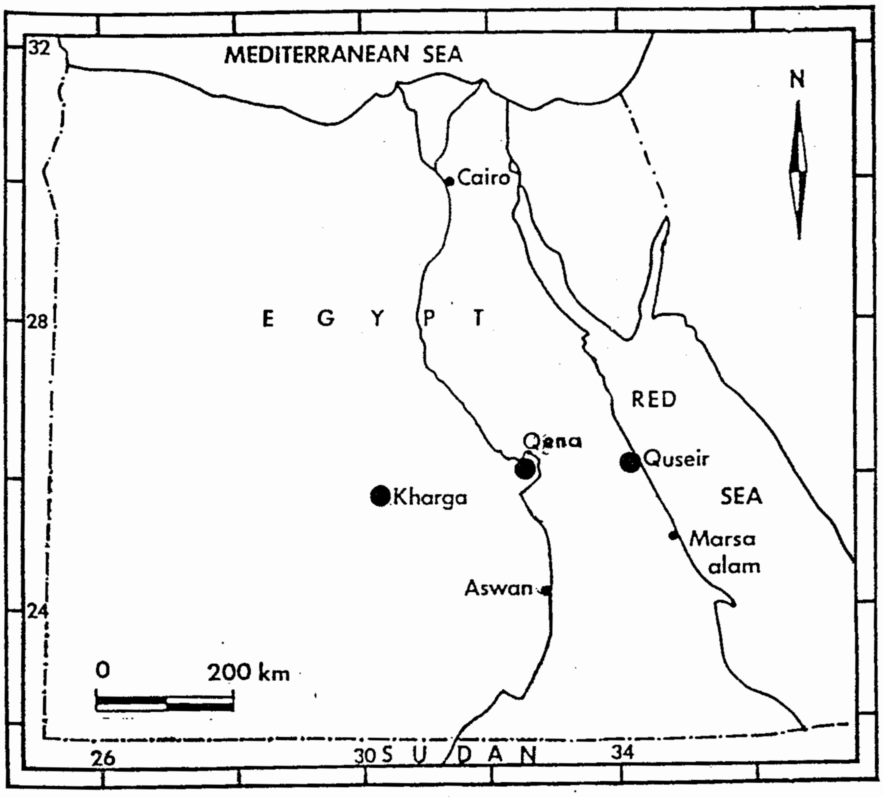

Fig. 1. Location map of the studied sections.

grain size of sediment (Folk, 1962). The staining techinques of Dickson, (1965) and Hutchinson (1974) are employed to differentiate between the carbonate minerals. Owing to the difficulty of preparing thin-sections of shales, few samples are examined microscopically. In addition, the clay minerals forming the shaly sequence are identified in 16 samples and their origin was also discussed. Figures 2-5 illustrate the detailed lithology of the above mentioned sections and the location of different samples, while Table 1 presents a brief description of lithologies.

PETROGRAPHY

Lithological Features

The main lithological features of the Tarawan Chalk, Esna Shale and Thebes formations of the present study are briefly discussed below:

1- There is a marked difference in grain size between the limestones of the Thebes Formation and the underlying Esna Shale and Tarawan Chalk in the three studied sections. This change in facies is attributed to the abundance of larger foraminifera (e.g. *Nummulites, Operculina, Alveolina* ...etc) and dwarfed megafossils (mainly pelecypods and echinoderms) in the Thebes limestones compared to the underlying beds enriched in planktonic foraminifera. Although planktonic foraminifera could live anywhere in the sea or may be carried locally into shallow waters (Heckel, 1972), however, they are most numerous and increase in abundance in an offshore direction in modern pericontinental sediments (Walton, 1964).

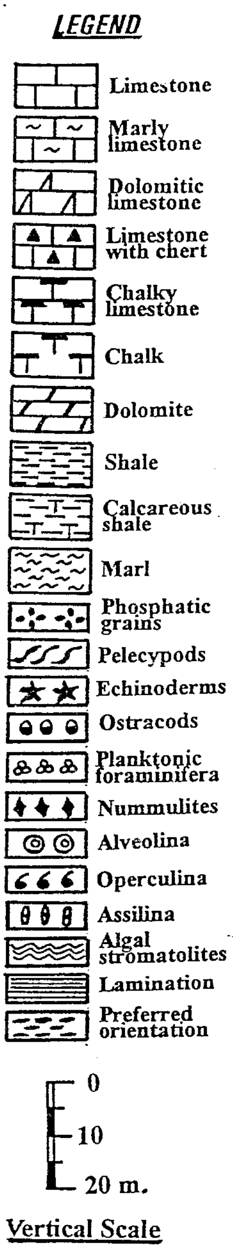

Fig. 2. Symbols used in lithological description of the present study.

Table 1. Lithological description of the three studied sections.

G. Duwi

Thebes Formation :

Limestone, yellowish white, hard, compact, highly fossiliferous, thin chert bands and flint nodules in parts. Several intercalations of marl, marly limestone and dolomite interbeds.

Esna Shale :

Shale, dark grey to greenish grey, laminated and gypsiferous, alternating, marl, chalk and marly limestone interbeds.

Tarawan Chalk :

Chalk, white, massive, rich in planktonicforaminifera, few marl interalations.

G. Taramsa

Thebes Formation :

Limestone, white to pale grey, hard, compact, small scattered flint nodules, rich in micro-and- megafossils. Several intercalations of marly and chalky limestone interbeds.

Esna Shale :

Shale, brownish grey to greenish grey, calcareous, laminated, gypsiferous and rich in microfossils.

Tarawan Chalk :

Marly limestone, yellowish white, massive, slightly ferruginous, rich in planktonic foraminifera.

G. Ghanima

Thebes Formation :

Limestone, white, hard, compact, highly fossiliferous, cavernous in parts, with several intercalations of dolomite and dolomitic limestone interbeds.

Esna Shale :

Shale, greyish green to brownish grey, laminated, with thin marly limestone interbed.

Tarawan Chalk :

Marly limestone, yellow, massive, rich in planktonic foraminifera, with occasional large forams.

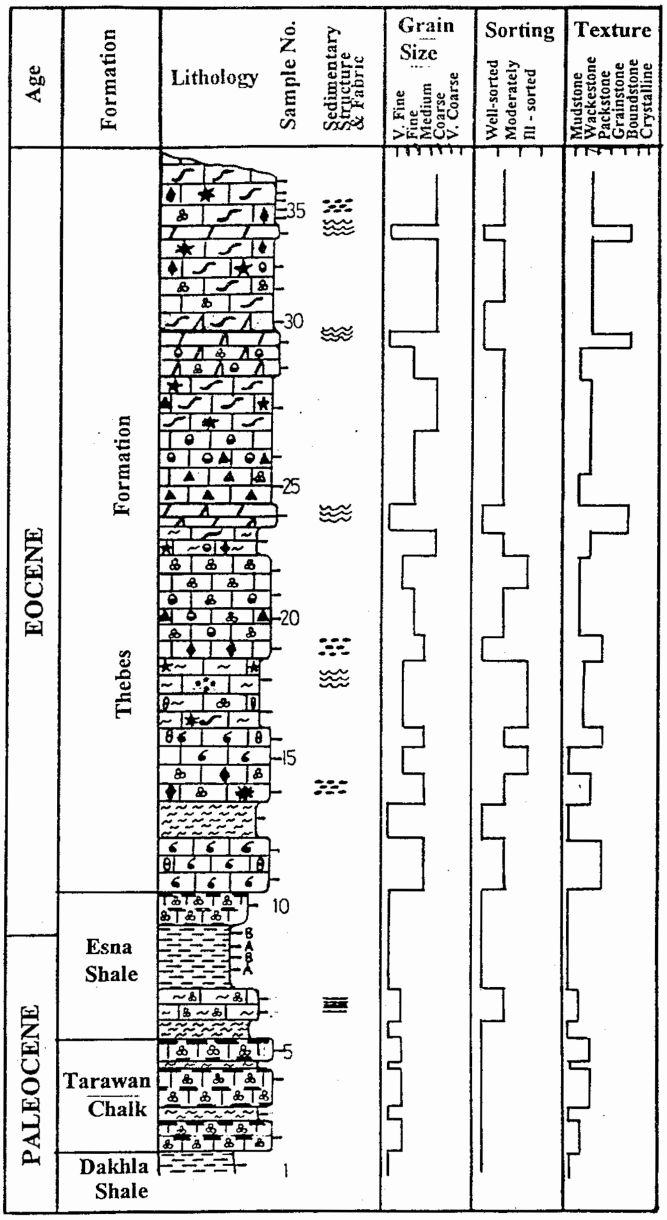

Fig. 3. Lithostratigraphy and textural attribute of G. Duwi section, Quseir area. ***(See Fig. 2. for explanation of symbols).***

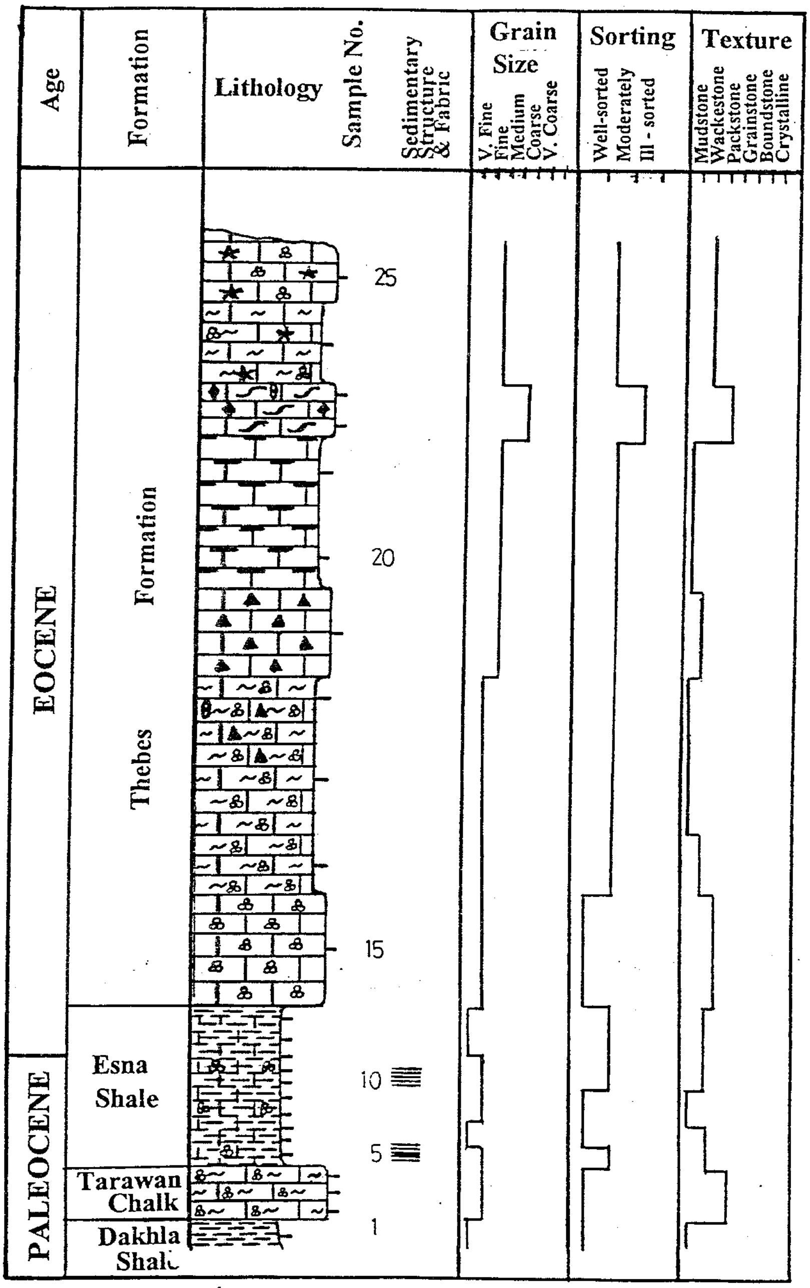

Fig. 4. Lithostratigraphy and textural attribute of G. Taramsa section, W. of Qena. ***(See Fig. 2. for explanation of symbols).***

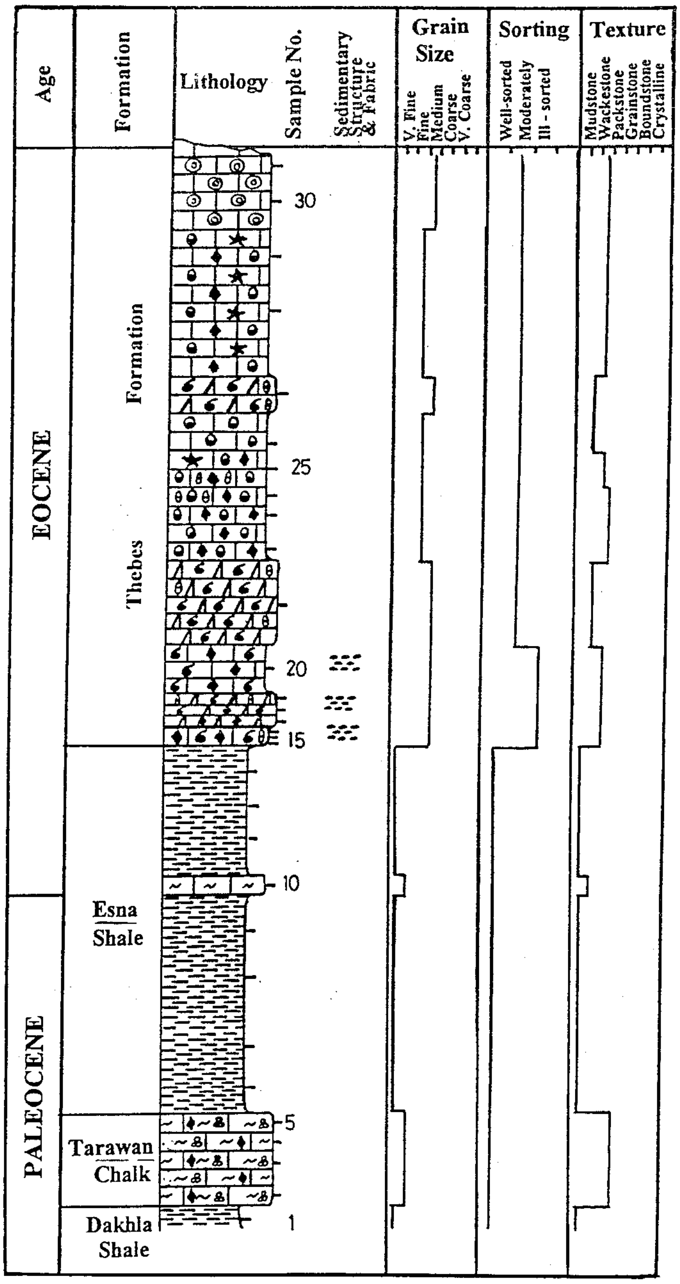

Fig. 5. Lithostratigraphy and textural attribute of G. Ghanima section, Kharga Oasis. *(See Fig.2. for explanation of symbols).*

2- The lower part of the three successions comprising the Tarawan Chalk and Esna Shale is homogeneously composed of fine to medium-grained, nearly well-sorted, biomicrite, while the overlying Thebes limestones display rather coarse to very coarse, ill-sorted grainy facies. The predominance of mud-supported sediments in the lower part reflects deep marine calm environment while the overlying grain-supported facies signifies deposition in relatively shallower marine waters.

3- The contact between the limestones of the Thebes Formation and the underlying Esna Shale in both the Duwi and Taramsa sections is graditional where the calcareous character of these shales increases upward. Unlikely, there is an abrupt change of facies between the two formations from argillaceous to carbonate character at Gebel Ghanima section.

4- In general, continental contribution of argillaceous materials and detrital minerals (e.g. clay minerals, quartz, feldspars, ...etc) is maximum during the deposition of the Esna Shale compared to the overlying and underlying marly or argillaceous limestone beds where the calcareous character predominates. The abundance of clay mineral assemblages in the Esna Shale reflects a humid episode of intense chemical weathering.

5- Silicification predominates in the cherty limestones of the middle part of the Thebes Formation in both the Duwi and Taramsa sections, whereas no silicification was observed in the Ghanima section. In the former two sections, some parts of the calcareous allochems are partly replaced by chalcedonic quartz which displays radial-fibrous structure. The dissolution of siliceous organisms (e.g.

radiolaria, diatoms and siliceous algae) and breakdown of clastic silicate minerals (e.g. amphiboles, pyroxenes) may account for the formation of diagenetic replacive silica (Nagtegaal, 1980).

6- Dolomitization and silicification are intimately related processes in the present lithologies, and the former is generally present in the Thebes Formation where chert nodules are abundant. The remarkable abundance of chert nodules at some horizons might have facilitated a relatively easy penetration of the dolomitizing solutions (Dabous and Mohammed, 1989).

7- Diagenesis has a profound effect on the studied carbonates and hence, modified their texture, structure and petrophysical properties. Several diagenetic phases are recorded including: dolomitization, silicification, cementation, recrystallization, dissolution and compaction. A brief summary of each process will be discussed later.

PETROGRAPHIC CHARACTERISTICS

Microscopic examination of 64 thin sections representing different lithologies in the three studied sections has led to the recognition of 20 lithofacies (Plates 1-3). The main characteristics of each facies are briefly discussed below :

Lime mudstone:

This facies is recorded from the calcareous beds of the Esna Shale, Duwi section, and it is mainly composed of very fine micritic groundmass containing few dispersed foraminiferal tests. The majority of micrite crystals are more or less of the same size. Others show aggrading recrystallization reaching to the microspar size (Folk, 1974).

Framboidal pyrite is recorded as disseminated and/or concentrated patches indicating reducing condition.

Dolomitic mudstone:

The sediments of this facies (P1.1A) are also recorded from the upper chalky bed of the Esna Shale (sample no.10), Duwi section. The framework is similar to the foregoing facies, but it differes in the presence of discrete, euhedral, rhomb-shaped dolomite crystals scattered in the micritic matrix. These dolorhombs are clear, without zoning, idiotopic to subidiotopic, showing clear signs of replacing micrite crystals, though the manner of replacement is observed to be selective. Selectivity occurs where there is a high concentration of argillaceous material.

Stromatolitic dolomitic mudstone:

This facies was observed in the dolomitic beds of the Thebes Formation of Gebel Duwi. In thin sections, algal stromatolites are observed in concentrated laminae (P1.1B) alternating with dolomitized micritic ones, indicating quiet, calm conditions. Microfossils show no signs of reworking, supporting the prevalence of calm conditions. There are some scattered quartz grains.

Foraminiferal wackestone:

This facies is reported from the Tarawan Chalk and the lower part of the Esna Shale of the Duwi section. It consists mainly of planktonic foraminiferal tests, shell fragments and few phosphatic grains embedded in a micritic groundmass (P1.1C). The rock has low porosity represented by intragranular and small vuggy pores. This facies was probably deposited in relatively deep and calm marine environment.

Foraminiferal dolomitic wackestone :

The sediments of this facies represent the lower part (samples nos. 6 and 7) of the Esna Shale of the Duwi section and samples nos. 21 and 27 of the Thebes Formation of the Ghanima section. They are similarly composed of foraminiferal tests, particulary planktonic types (globigerine tests) embedded in a dolomitized micritic groundmass. Dolomite is generally idiomorphic and is always coated by ferruginous material probably due to weathering effect (El-Kammar, 1984).

Bioclastic dolomitic wackestone :

The sediments of this facies (P1.1D) represent the middle part of the Thebes Formation (samples nos. 20, 21, 25 and 28) of Gebel Duwi. This facies consists of calcareous shell fragments, echinoid spines, ostracods and planktonic foraminifera embedded in a dolomitized micritic groundmass. Dolomitization is present as irregular patches of idiomorphic dolomite (0.01-0.02 mm) with no obvious zoning. The microfossil association signifies deposition in a shallow marine environment with photic and calm condition.

Ostracods wackestone:

This facies dominates in the upper part of the Thebes Formation in Gebel Duwi (sample no. 26) and Gebel Ghanima section (samples nos. 22, 25 and 28). The sediments are substantially composed of a micritic groundmass containing some dispersed ostracodal tests and other shell fragments (P1.1E). Dissolution is responsible for most of the mouldic and vuggy pores in the present facies.

Alveolinid wackestone :

This facies was only observed in Gebel Ghanima section in the uppermost part of the Thebes Formation (samples nos. 30 and 31). The framework is made up largely of *Alveolina sp.* (P1.1F) and other microfossils that signifies deposition in shallow marine environment. The chamberlets of the foraminiferal tests are rarely filled with sparite and these microfossils are dispersed throughout a microsparite matrix with aggrading sparite patches, especially along the open spaces.

Nummulitic wackestone :

The sediments of this facies dominate in the lower part of the Thebes Formation (samples nos. 15-20) in Gebel Ghanima section. They are substantially composed of a micritic groundmass containing some scattered *Nummulites* species and other shell fragments. The microfossils are observed having a clear effect of preferred orientation which is attributed to compactional load effects.

Phosphatic echinoidal wackestone :

This facies is recorded at sample no. 18 in the lower part of the Thebes Formation of Gebel Duwi. The framework is built up of echinoid shell fragments embedded in a micritic matrix, with some scattered phosphatic grains (~10%) and few iron-stained detrital quartz (P1.2A). The shell fragments show no signs of reworking, supporting the prevalence of calm condition. Syntaxial overgrowth and aggrading recrystallization are abundant in this facies.

Foraminiferal packstone:

This facies was observed in the upper part of the Tarawan Chalk of Gebel Duwi at sample no. 4. The sediments are substantially composed of a micritic groundmass containing a large number of planktonic foraminifera. However, a later diagenetic ferrugination (mainly by hematitic materials) has obscured the internal structure of the tests. The abundance of planktonic foraminiferal species in this facies reflects sedimentation in a warm deep marine environment of normal salinity.

Operculinid packstone :

This facies is recorded from the lowermost part (sample no. 14) of the Thebes Formation of Gebel Ghanima section. The framework is composed mainly of abundant *Operculina* species (P1.2B) and other shell fragments embedded, with preferred orientation, in a micritic matrix. It grades vertically into nummulitic wackestone facies. Rare discrete dolomite rhombs are embedded in the micritic matrix. There are minor scattered quartz grains.

Molluscan packstone :

The sediment of this facies is observed in the uppermost part of the Thebes Formation (samples nos. 36 and 38) of Gebel Duwi section. It is mainly composed of abundant pelecypod shells of different sizes (P1.2C), and few other echinoidal shell fragments, all are embedded in a micritic matrix. Molluscan shells are sometimes recrystallized to coarse-grained sparry calcite (P1.2D). Dolomitization is absent, and the rock is almost free of terrigenous material. Quartz grains are rarely present and almost observed randomly scattered. Shallow marine environments are suggested for the sedimentation of this facies.

Silicified molluscan packstone:

This facies is recorded in the upper part of the Thebes Formation (samples nos. 27 and 34) of Gebel Duwi. It is to some extent similar to the foregoing facies, except for the silicification process, which reaches a high degree of obliteration of the skeletal structure of shells (P1.2E).

Dolomitic silicified molluscan packstone:

This facies was also recorded from the upper part of the Thebes Formation at Gebel Duwi (sample no. 30). It is lithologically very similar to the above facies, except for the presence of some parts of the calcareous shells replaced by chalcedonic quartz (P1.2F). Dispersed euhedral rhomb-shaped dolomitic crystals are observed especially around the vugs. Most of the crystals are clear and average 0.2-03 mm in size. This facies reflects deposition in a shallow marine environment.

Dolomitic nummulitic packstone :

The sediments of this facies characterize the lowermost part of the Thebes Formation of Gebel Ghanima (samples nos. 17-19). It consists mainly of a large number of *Nummulites* and shell fragments embedded in a dolomicrosparite groundmass (P1.3A). Larger hypidio-xenomorphic dolomite crystals (0.01-0.02 mm in diameter), lacking zoning or opaque nuclei, are occasionally dispersed throughout the groundmass.

Dolomitic foraminiferal grainstone :

This facies was observed in the Tarawan Chalk of both Ghanima (samples nos. 3 and 5) and Taramsa (sample no. 3) sections. It is generally enriched in planktonic foraminiferal tests which are embedded in a dolomitized micritic groundmass (P1.3B). The chamberlets of the foraminifera are often filled with ferruginous material and sometimes with sparite. Euhedral rhomb-shaped dolomite crystals are concentrated in areas filled with ferruginous material. Also, patches of reddish stainings occur and indicate that ferrugination occured after dolomitization. However, this facies suggests a relatively deep marine environment of normal salinity and oxidizing conditions.

Nummulitic grainstone :

The sediment of this facies was recorded from the middle part of the Thebes Formation of Gebel Duwi (sample no. 13). The facies consists of a large number of well-oriented, heavily micritized nummulite shells (P1.3C) which are embedded in a sparite cement having some drusy calcite patches. Diagenetically, the sediments of this facies showed signs of reworking and were affected by micritization (P1.3D) and recrystallization processes. It signifies deposition in a shallow marine environment. However, clear signs of intense reworking indicate a high-energy environment, while preferred orientation of shell fragments is due to the effect of compactional load.

Molluscan grainstone:

This facies characterises the most upper part of the Thebes Formation (samples nos. 22 and 23) of Gebel Taramsa section. The framework is built up of a large number of pelecypod shells of different sizes embedded in a micritic groundmass (P1.3E). Few dispersed large foraminiferal tests and echinoid spines are also observed. The rock generally contains abundant vugs, sometimes filled with sparite, and intragranular pores.

Bioclastic grainstone :

This facies was recorded from both the lower and upper parts of the Thebes Formation of Gebel Duwi section. The framework is made up of molluscan shells, echinoid fragments, *nummulites* and planktonic foraminifera, all embedded in a micritic groundmass (P1.3F). Porosity is moderate and represented mainly by small vugs, intragranular and mouldic pores.

DIAGENETIC PROCESSES

Several diagenetic processes have operated on the investigated carbonate rocks, among these are dolomitization, silicification, cementation, recrystallization, dissolution, and compaction. A brief discussion of each process is given below:

Dolomitization

Dolomitization is the most profound diagenetic change in the studied samples. It is believed to be promoted in limestones containing chert nodules (Burgess, 1979) or in argillaceous-rich carbonates (Zen, 1959; Sweet, 1965; McHargue and Price, 1982). This observation is noticed in the present carbonates of the Thebes Formation as dolomitization was abundant where chert nodules are dominant and facies are mostly argillaceous.

Dolomitization is present as irregular patches of hypidio and/or xenotopic dolomites (0.01-0.02 mm), lacking zoning or opaque nuclei. It is also present as euhedral, rhomb-shaped crystals (up to 2μ in diameter) dispersed throughout the groundmass (P1.1A). Individual euhedral crystals of dolomite are observed inside skeletal grains filled with microcrystalline quartz, suggesting that dolomitization has preceded the precipitation of silica (Dapples, 1967).

Silicification

This process predominates in the cherty limestones of the Thebes Formation where some parts of the calcareous skeletons, but rarely groundmass, are partly replaced by chalcedonic silica (P1.2E, F). The pseudomorphosed parts of some larger foraminifera showed radial-fibrous structure and sometimes undulose extinction. A less common form of silica is represented by interlocking quartz grains (0.5-4μ in diameter) in a random orientation. However, authigenic quartz crystals are encountered in vugs and channels produced by earlier solution.

Cementation :

Cementation takes place as intra-skeletal fillings and/or vienlets filled with sparite or microsparite carbonates. Most cementation occurs where pH of the pore water increases to more than 9 (Friedman, et. al., 1974; Tucker and Wright, 1990), when sea water is forced into the sediment (Shinn, 1969, James and Ginsburg, 1976; McIntyre, 1977), where CO2 degassing occurs (Hanor, 1978), and/or where certain bacteria are present (McIntyre and Videtich, 1979).

The cementing material observed here, is mainly composed of calcite as the primary form and in some cases changing to dolomite. Calcite in the form of drusy sparite is believed to be the result of direct precipitation from waters rich in carbonate (Scoffin, 1987). Dolomite, on the other hand, is attributed to diagenetic effects on the argillaceous-rich carbonate portions leading to the release of the Mg^{2+} and Fe^{2+} needed for dolomitization of the nearby carbonates (Metwalli, et al., 1987).

Recrystallization:

Recrystallization is not uncommon process in the investigated samples. Complete conversion of the original micritic matrix by aggrading recrystallization (Folk, 1965) into microspar or pseudospar is widely recorded in thin sections (P1.IF). This conversion apparently resulted in the development of dismicrites and finally to a neomorphic fabric in which the original texture of the rock is obliterated. Molluscan grains are observed to be recrystallized into coarse-grained sparry calcite.

Dissolution:

Dissolution was effective in increasing the original porosity of the studied rocks leading to the development of mouldic, intragranular (P1.1F) and vuggy pores. It is suggested that the dissolution was active mainly by the action of circulating meteoric waters during the post-uplift stages (Moore, 1989).

Compaction:

Compaction due to burial is more evident in the rocks which did not undergo early cementation. In the present samples, it is believed that physical compaction was responsible for the clear effect of preferred orientation of the skeletal grains at some horizons (P1.3D). Compaction effects are also believed to be responsible for the development of postdepositional flowage of originally semi-consolidated sediments (P1.3F). This primary sedimentary feature is also observed in the lower part of the Esna Shale of Gebel Taramsa section.

CLAY MINERALOGY

Clay mineral analysis was conducted on 16 argillaceous samples from the Esna Shale of the three studied sections (Table 2). Analyses were performed using X-ray diffraction on both oriented aggregates and bulk samples of sediment fractions. Three separate analyses were run: (1) on untreated slide, (2) after saturation with ethylene-glycol, and (3) after heating to 550 ^{o}C for 2 hours.

Table 2. Relative content of the clay mineral groups in some selected samples from the Esna Shale.

Location	Sample No.	% Kaolinite	% Smectite	% Illite	Location	Sample No.	% Kaolinite	% Smectite	% Illite
Taramsa Section	5	27.3	32.0	40.7	Duwi Section	8A	34.2	25.9	39.9
	6	33.3	66.7	—		8B	37.0	55.6	7.4
	7	17.0	49.8	33.2		9A	36.8	63.2	—
	9	29.9	70.1	—		9B	39.8	54.1	6.1
	10	38.3	33.3	29.4					
	12	41.5	41.5	16.6					
	13	100	—	—					
	14	42.3	57.7	—					
					Average		36.9	49.7	13.4
					Ghanima Section	6	70	—	30
						7	78	22	—
						8	22	30	48
Average		41.2	43.8	15.0		9	100	—	—
					Average		67.5	13.0	19.5
Average all samples							46.7	37.6	15.7

Examination was carried out using X-ray diffractometer with Cu K α-radiation generated at 40 kV and 30 mA. The samples were scanned between 4^{o} and 45^{o} 2θ with speed rate 0.1^{o} 2θ/min. Percentage evaluations of the clay mineral groups were based on peak areas of the glycolated samples, corrected by factors of X1, 2 and 4 for smectite, kaolinite and illite; respectively (Biscaye, 1965).

The principal clay minerals identified (Fig. 6), in oriented slides, are kaolinite, smectite and illite, and their relative abundance is given in Table 2. The non-clay minerals detected on bulk samples include quartz, feldspar, calcite, dolomite, halite, gypsum, siderite and hematite.

On average, kaolinite constitutes about 46.7% of the clay fraction of the samples, followed by smectite (37.6%) and illite (15.7%). Smectite (0-70%) dominates the clay fractions of the samples in both the Duwi and Taramsa sections, whereas kaolinite is more abundant in the Ghanima section. On the other hand, illite (0-48%) is present only episodically throughout the sequence, but is slightly more abundant in the Taramsa section.

Much is known about the origin of clay minerals in modern environments (Millot, 1970; Gaucher, 1981; Weaver, 1989). Both smectite and kaolinite form as a result to intense chemical weathering on land. Smectite forms in poorly drained, tropical to subtropical areas of low relief marked by flooding during humid seasons and subsequent concentration of solutions in the soil during dry seasons. The necessary requirements for its formation include the availability of ions (Ca, Mg, Fe and Na), a comparatively high SiO_2/Al_2O_3 ratio, and the presence of volcanic detrital material (Weaver, 1958).

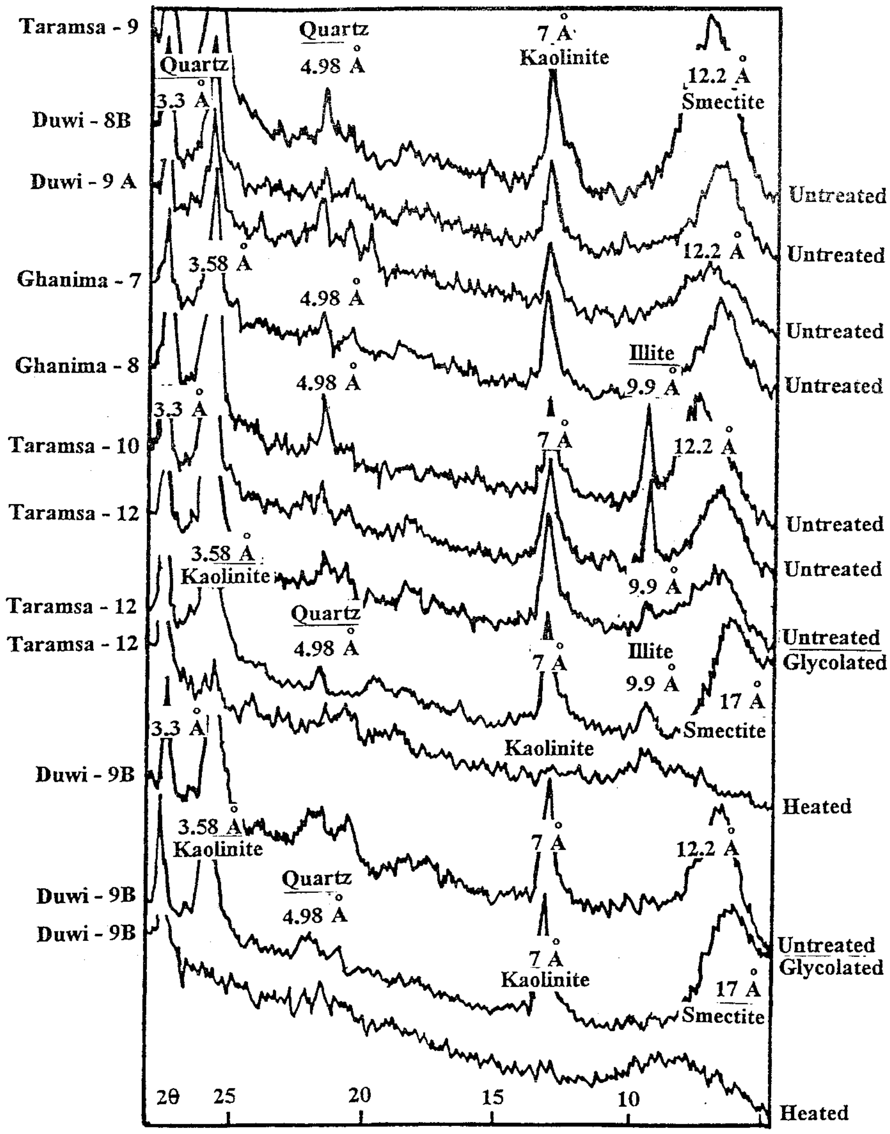

Fig. 6. X-ray diffractograms of some selected samples from the Esna Shale.

The formation of smectite is favored by a warm climate associated with alternating wet and arid seasons (Paquet, 1970). Therefore, the present smectites were probably transported to the site of deposition either in runoff during wet seasons and/or as eolian particles during dry seasons.

Kaolinite typically develops in tropical soils on well-drained surfaces of diverse rock type receiving high precipitation, and its formation requires a minimum soil temperature of ~15 ^{o}C (Gaucher, 1981). It is usually formed in moderately warm, humid, well-drained continental areas where precipitation and associated leaching favor the weathering of the parent rock (Robert and Kennett, 1994).

Kaolinite formation requires strong leaching and the presence of aluminium silicates (Weaver, 1958). Chemically soluble elements are preferentially removed, leaving residual silica and aluminum, which are involved in the formation of kaolinite (Millot, 1970). Therefore, the extensive chemical weathering of igneous and metamorphic rocks and the humidity of the climate during that time were probably responsible for the formation of the present kaolinite.

Illite is mostly derived from erosion of parent rocks of poorly developed or immature soils. It is usually formed in areas of steep relief where active mechanical erosion reduces the development of soils, especially during tectonically active periods (Robert and Kennett, 1992). Illite may also be formed as a result to kaolinite transformation by the action of salt waters (Kulbicki and Millot, 1963). The present illites may have originated from erosion of parent rocks and subseuently have been transported to the sites of deposition.

CONCLUSIONS

The Upper Paleocene-Early Eocene sequence in central Egypt is generally divided into the Tarawan Chalk (Late Paleocene), Esna Shale (Late Paleocene-Early Eocene) and the overlying Thebes Formation (Early Eocene). The Tarawan Chalk consists mainly of fine to medium grained, nearly well-sorted biomicrite enriched in planktonic foraminifera. The Esna Shale, on the other hand, varies from argillaceous to carbonate character and it is characterized by the predominance of clay mineral assemblage (kaolinite, smectite, illite) as well as small amounts of non-clay minerals. Their abundance signifies a humid episode of intense chemical weathering caused by increased temperature and excessive rainfall.

The Thebes limestones display rather coarse to very coarse, ill-sorted grainy sequence rich in larger foraminifera (e.g. *Nummulites, Operculina, Alveolina* ...etc) and megafossils (mainly pelecypods and echinoderms). The predominance of dwarfed megafossils in the grain-supported sediments of the Thebes Formation implies deposition in relatively shallow marine waters. The abundance of planktonic foraminifers in the underlying mud-supported sediments of the Tarawan Chalk and Esna Shale, on the other hand, reflects deep marine calm environment.

Petrographic investigations of the three studied sections made reveal the presence of 20 lithofacies based on the vertical variation in lithology, faunal content, texture, primary sedimentary structures and sedimentological characteristics. These facies belong to four petrographic groups: mudstone, wackestone, packstone and grainstone and each group was subdivided into a number of types reflecting the environmental changes during the Late Paleocene-Early Eocene interval.

Diagenesis has a marked effect on the present carbonate lithologies and hence, modified their texture, structure and petrophysical properties. Several diagenetic phases are recorded including dolomitization, silicification, cementation, recrystalli-zation, dissolution and compaction. Dolomitization and silicification are intimately related processes in the Thebes Formation, and the former is generally present where chert nodules are abundant. Silicification, however, predominates in the middle part of the Thebes Formation in both the Duwi and Taramsa sections, whereas no silicification was observed in the Ghanima section.

REFERENCES

Awad, G.H. & Ghobrial, M.G. 1965: Zonal stratigraphy of Kharga Oasis. Geol. Surv., U.A.R. paper 34, 77 p.

Barakat, M.G. and El-Dawoody, A.S. (1973): A microfacies study of the Upper Cretaceous-Paleocene-Lower Eocene sediments at Duwi and Gurnah sections, Southern Egypt-Ann. Inst. Geol. Publ. Hung., Budapest, 391-414.

Beadnell, H.J.L. 1905 : The relations of the Eocene and Cretaceous systems in the Esna-Aswan reach of the Nile Valley. Quart. Jour. Geol. Soc. London, V. 61, P. 667-678.

Biscaye, P.E., 1965: Mineralogy and sedimentation of Recent deep-sea clay in the Atlantic Ocean and adjacent seas and Oceans. Geol. Soc. Amer. Bull. 76, P. 803-832.

Burgess, C.J. 1979 : The development of a Lower Jurassic carbonate tidal flat, Central High Atlas, Morocco-2 : diagenetic history-J. Sed. Petrol., 49: 413-428.

Dabous, A.A., and Mohammed, M.H., 1989: Petrography and lithofacies studies on the lower Tertiary sediments of Esna-Qena district, Upper Egypt. M.E.R.C. Ain Shams Univ., Earth Sc. Ser., V.3, P. 137-149.

Dapples, E.C. 1967: Diagenesis of sandstones, In: Larsen, G. and Chilingar, G.V. (Editors)-Diagenesis in sediments-El Sevier Publishing Co., Amsterdam, 91-125.

Dickson, J.A.D., 1965: A modified staining technique for carbonates in thin section. Nature, v. 205, P. 587.

Dunham, R.J., 1962 : Classification of carbonate rocks according to depositional texture: In Ham, W.E. (ed.): Calassification of carbonate rocks. Am. Assoc. Pet. Geol. Bull., V.I., P. 108-121.

El-Kammar, A.M. 1984: Geochemical and petrological changes occurring during the weathering of Fe-rich dolomite, Abu-Tartur Plateau, Western Desert, Egypt-Libyan Jour. Sci., 13: 41-54.

El Naggar, Z.R. 1966: Stratigraphy and classification of the type Esna group of Egypt. Bull. Am. Ass. Petrol. Geol., V. 50, P. 1455-1477.

El Naggar, Z.R. 1970: On proposed lithostratigraphic subdivision for the Late Cretaceous-Early Paleogene succession in the Nile Valley, Egypt. U.A.R. Sci. Arab. Petrol. Cong., Kuwait, Paper 64, 50 P.

Flugel, E., 1982: Microfacies analysis of limestones. Springer-Verlag, Berlin, 633PP.

Folk, R.L., 1962: Spectral subdivision of limestone types: In W.E. Ham, ed., Classification of carbonate rocks. Am. Assoc. Pet. Geol. Memoir 1, P. 62-84.

Folk, R.L. 1965: Some aspects of recrystallization in ancient limestones-In: Pray, L.C. and Murray R.C. (Eds.) Dolomitization and limestone diagenesis-a symposium Soc. Econ. Paleontologists Mineralogists. Spec. Pub. 13: 14-48.

Folk, R.L., 1974: Petrology of Sedimentary Rocks. Hemphill Publ. Co. Austin, Texas, 159 P.

Friedman, G.M., Amiel, A.J. and Schneidermann, N. 1974: Submarine cementation in reefs: example from the Red Sea-J. Sed. Petrol., 44: 816-825.

Gaucher, G., 1981, Les facteurs de la pedogenese: Dison, Belgium, G. Lelotte, 730 pp.

Hanor, J.S. 1978: Precipitation of beach rock cements: Mixing of marine and meteoric waters vs. CO_2 degassing-J. Sed. Petrol. 48: 489-502.

Heckel, P.H. 1972: Recognition of Ancient shallow marine environments-In: Rigby, J.K. (Ed.), Recognition of ancient sedimentary environments-Society of Economic Paleontologists and Mineralogists, Special Publication, 16: 226-286.

Hutchinson, C.S. 1974: Laboratory Handbook of Petrographic Techniques-John Wiley and Sons, New York, 527 P.

Ismail, M. . and Abd El-Razik, T.M., 1969: Stratigraphical microfacies studies in the Idfu-Esna district, Nile Valley, UAR. Bull. Fac. Sci., Alex. v. IX, P. 383-395.

Issawi, B. 1972: Review of Upper Cretaceous-Lower Tertiary stratigraphy in Central and Southern Egypt. Amer. Ass. Petrol. Geol. Bull. 56(8): 1448-1473.

James, N.P. and Ginsburg, R.N., 1976: Facies and fabric specificity of early subsea cements in shallow Beliz (British Handuras) reefs. J. Sed. Petrol., v.46, P. 523-544.

Kenawy, A.I. 1972: Planktonic Foraminifera of the Lower Tertiary succession in the Taramsa section, Qena, Nile Valley, Egypt. Hungary Fram. Mineral. Paleont., 3: 25-100.

Khalifa, H. 1970: Geology of Gabal El Shaghab area, near Esna. M. Sc. Thesis, Geol. Dept., Assiut Univ., Assiut, Egypt.

Krasheninnikov, V.A. & Abd El Razik, T.M. 1968: Zonal stratigraphy of the Paleogene in Qusseir (Red Sea Coast). Third African Micropaleontological Colloquium, Cairo.

Kulbicki, G. and Millot, G. 1963: Diagenesis of clay in sedimentary and petroliferous series. Clay & Clay Min, 329-332.

McIntyre, I.G. 1977: Distribution of sub-marine cements in a modern Caribbean fringing reef, Galeta Point, Panama-J. Sed. Petrol., 47: 503-516.

McIntyre, I.G. and Videtich, P.A. 1979: Pseudostalactites from submarine cave near Columbus Cay, Belize barrier-reef complex-evidence of extensive submarine lithification-(Abs.) A.A.P.G. Bull., 63: P.489.

McHargue, T.P. and Price, B. 1982: Dolomite from clay in argillaceous or shale-associated marine carbonates-J. Sed. Petrol., 52: 873-886.

Metwalli, M.H., Wali, A.M.A. and Abd El-Shafy, A., 1987:Cretaceous petroleum-bearing rock types-their diagenesis and significance in the Gulf of Suez area, Egypt. Sedimentary Geology, V. 53, P. 269-304.

Millot, G., 1970: Geology of clays. Berlin, Springer-Verlag, 499 P.

Moore, C.H., 1989: Carbonate diagenesis and porosity: Developments in Sedimentology 46, El Seveir, Amstrdam, 338 pp.

Nagtegaal, P.J.C. 1980: Clastic reservoir rock-origin, diagenesis and quality-International meeting on petroleum geology, Beijing, China.

Nakkady, S.E. 1958: Stratigraphy and Petroleum Geology of Egypt. Assiut Univ. Press. Monograph Series no. 1, 215 p.

Omara, S., El-Tahlawi, M.R., and Khalifa, H., 1972: Proceedings of the 6 th Arab Science Congress, Damascus, P. 889-901.

Paquet, H., 1970: Evolution geochimique des mineraux argileux dans les alterations et les sols des climats mediterraneens et tropicaux a saisons contrastees, Sci. Geol. Strasb. Mem., 30: 221 PP.

Robert, C. and Kennett, J.P., 1992: Paleocene and Eocene kaolinite distribution in the south Atlantic and southern Ocean: Antarctic climatic and paleoceanographic implications. Marine Geol., V. 102, P. 99-110.

Robert, C. and Kennett, J.P., 1994: Antarctic subtropical humid episode at the Paleocene-Eocene boundary: Clay-mineral evidence. Geology, V. 22, P. 211-214.

Said, R., 1961: Tectonic Framework of Egypt and its influence on distribution of Foraminifera. Amer-Assoc. Petrol. Geol. Bull. 45, p. 188-218.

Said, R., 1962: The Geology of Egypt. 1 st. Ed., El Sevier Publ. Co., Amesterdam, New York, 377 pp.

Said, R., & Sabry, H. 1964: Planktonic foraminifera from the type locality of the Esna Shale in Egypt. Micropaleont., Vol. 10, P. 385-395.

Scoffin, T.P., 1987: An introduction to carbonate sediments and rocks. Blackie & Son Ltd., London, 273 pp.

Shinn, E.A. 1969: Burrowing in Recent lime sediments of Florida and the Bahamas-Jour. Paleont., 42: 879-894.

Soliman, H.A., Ahmed, E.A., Aref, M.M., and Rushdy, M.,1989:Contribution to the stratigraphy and sedimentology of the Upper Cretaceous-Lower Eocene sequences east of Esna, Nile Valley, Egypt. Bull. Fac. Sci., Assiut Univ., V. 18(1-F), P. 41-67.

Sweet, K. 1965: Dolomitization silicification andcalcitization patterns in Cambro-Ordovician oolites from north-west Scotland-J. Sed. Petrol., 35: 928-938.

Tucker, .E., and Wright, V.P., 1990: Carbonate sedimetology, Blackwell Sci. Publ., Oxford, 482 pp.

Walton, W.R. 1964: Recent foraminiferal ecology and paleoecology, In: Imbrie, J. and Newell, N.D. (Eds.), Approaches to paleoecology-Wiley, N.Y., PP. 151-237.

Weaver, C.E. 1958: A discussion on the origin of clay minerals in sedimentary rocks. Clay & Clay Min., no. 566, p. 159-175.

Weaver, C.E., 1989: Clays, muds and shales: Developments in Sedimentology, no. 44:, Elsevier Pub. Co., Amsterdam, 819 pp.

Youssef, M.I., 1949: Stratigraphical studies in Kosseir area. Ph. D. Thesis, Alexandria Univ., 146 pp.

Youssef, M.I. 1954: Stratigraphy of Gabal Oweina section, near Esna, Upper Egypt. Bull. Instit. Desert Egypt., 4, p. 83-93.

Zen, N.A.N., 1959: Clay mineral-carbonate relations in sedimentary rocks. Am. Petr. Soci., 257: 29-43.

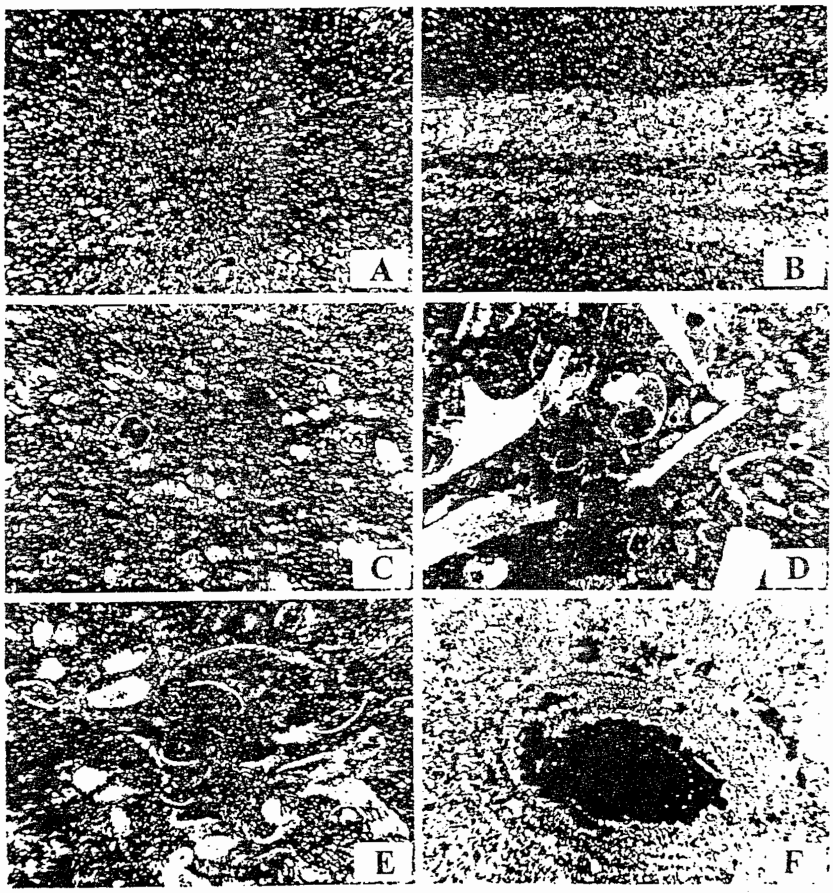

PLATE 1

A. Thin-section photomicrograph showing dolomitized mudstone facies, Sample no. 10, Esna Shale, Duwi section, C.N., X20.

B. Thin - section photomicrograph showing stromatolitic dolomitized mudstone facies, sample no. 24, Thebes Formation, Duwi section, C.N., X 20.

C. Thin-section photomicrograph showing foraminiferal wackestone facies, sample no. 2, Tarawan Chalk, Duwi section, P.P.L., X 20.

D. Thin-section photomicrograph showing bioclastic dolomitized wackestone facies, sample no. 20, Thebes Formation, Duwi section, C.N., X 20.

E. Thin-section photomicrograph showing ostracods wackestone facies, sample no. 26, Thebes Formation, Duwi section, P.P.L., X 20.

F. Thin-section photomicrograph showing alveolinid wackestone facies, sample no. 30, Thebes Formation, Ghanima section, C.N., X 20.

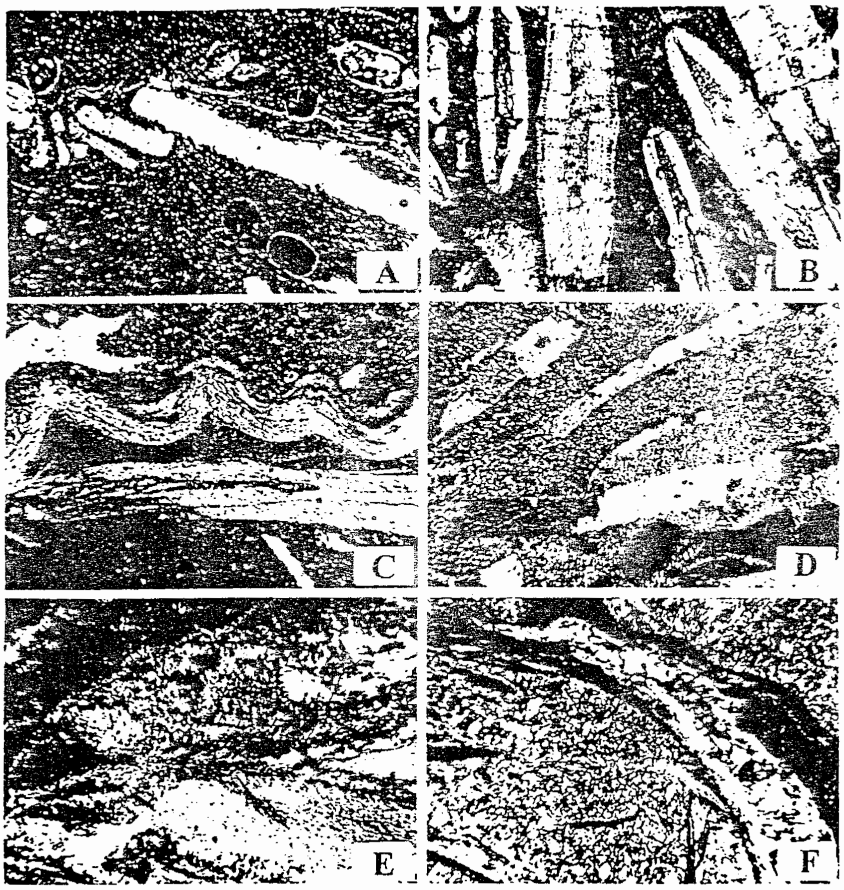

PLATE 2

A. Thin-section photomicrograph showing phosphatic echinoidal wackestone facies, sample no. 18, Thebes Formation, Duwi section, P.P.L., X 20.

B. Thin-section photomicrograph showing operculinid packstone facies, sample no. 14, Thebes Formation, Ghanima section, P.P.L., X 20.

C. Thin-section photomicrograph showing molluscan packstone facies, sample no. 38, Thebes Formation, Duwi section, P.P.L., X 20.

D. Thin-section photomicrograph showing recrystallized molluscan shells to coarse-grained sparry calcite, sample no. 27, Thebes Formation, Duwi section, C.N., X 20.

E. Thin-section photomicrograph showing silicified molluscan packstone facies, sample no. 34, Thebes Formation, Duwi section, C.N., X 20.

F. Thin-section photomicrograph showing dolomitized silicified molluscan packstone facies, sample no. 30, Thebes Formation, Duwi section, C.N., X 20.

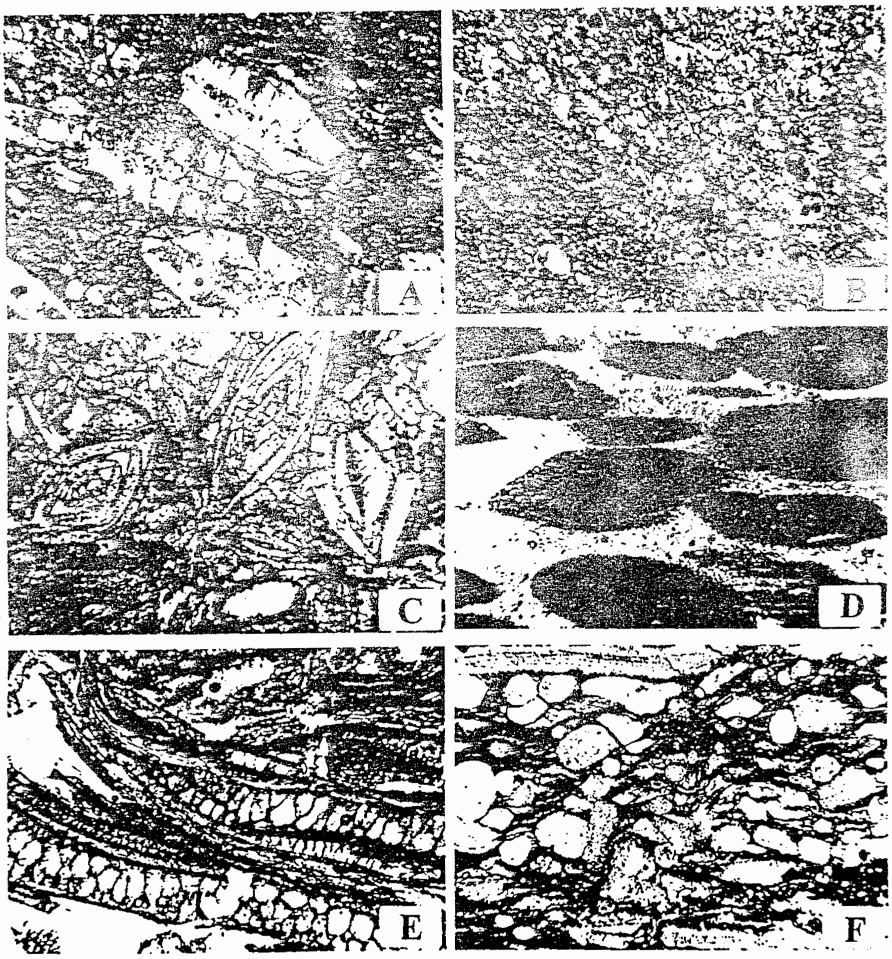

PLATE 3

A. Thin-section photomicrograph showing dolomitized nummulitic packstone facies, sample no. 17, Thebes Formation, Ghanima section, C.N., X 20.
B. Thin-section photomicrograph showing dolomitized foraminiferal grainstone facies, sample no. 3, Tarawan Chalk, Taramsa section, P.P.L., X 20.
C. Thin-section photomicrograph showing nummulitic grainstone facies, sample no. 19, Thebes Formation, Duwi section, P. P. L., X20.
D. Thin-section photomicrograph showing heavily micritized, well oriented nummulite shells cemented by microspar calcite, sample no. 16, Thebes Formation, Duwi section, C.N., X20.
E. Thin-section photomicrograph showing molluscan grainstone facies, sample no. 22, Thebes Formation, Taramsa section, P.P.L., X20.
F. Thin-section photomicrograph showing bioclastic grainstone facies. Note the development of post-depositional flowage due to compaction effects, sample no. 7, Esna Shale, Taramsa section, P.P.L., X20.

التركيب المعدنى والأحداث الرئيسية البعد ترسيبية لبعض الأحجار الرملية للفانيروزوى فى شمال مصر

إعداد

عبد المنعم توفيق عبد الحميد

قسم الجيولوجيا - كلية العلوم - جامعة طنطا

موجز :

أثبت الفحص البتروجرافى لبعض الأحجار الرملية للفانيروزوى فى شمال مصر أنه مفيد فى تحديد التركيب المعدنى وصخور المصدر وتاريخ عمليات مابعد الترسيب لهذه الأحجار الرملية ٠ وتتراوح هذه الأحجار الرملية فى تركيبها مابين المرو النقى الناضج إلى المرو الواكى غير الناضج ونادرا إلى التحت إركوز أو الواكى الصخرى ٠ وقد وجد أن معظم حبيبات المرو أحادية التحبب تتميز بإنطفاء عادى وإنطفاء تموجى تليها فى المرتبه الثانية حبيبات المرو عديدة التحبب ٠ بينما تتواجد غالبية الفلسبارات فى الصخور الحالية على هيئة الفلسبار البوتاسى مع نسبة قليلة من البلاجيوكليز ٠ ومن المعتقد أن نسبة الفلسبارات الأصلية لبعض الصخور كانت مرتفعة عن نسبتها الحالية الأمر الذى يشير إلى إستمرارية ذوبانها تباعا تاركة وراءها فراغات كبيرة الحجم ٠

أوضحت الدراسة أن المواد الرئيسية اللاحمه تتمثل فى السليكا ، الكالسيت ، الدولوميت ، الكاولينيت ونادرا الجبس ٠ وتشير النتائج البعد ترسيبية لهذه الصخورأن المياه الأرضية قد لعبت دورا هاما فى ترسيب معظم السليكا اللاحمة ٠ ويتواجد الكالسيت اللاحم فى صورتين رئيسيتين : النوع الأول كالسيت خشن التبلور من النوع المبرقش أما الثانى فهو الكالسيت دقيق التحبب من النوع الميكريتى ٠ وقد نشأ الكالسيت غالبا نتيجة ذوبان الأصداف الجيرية فى التتابعات الصخرية الأحدث ٠ وتتواجد معادن الحديد اللاحمة فى معظم هذه الصخور أساسا فى صورة الهيماتيت مع نسبة ضئيلة من الجيوثيت ٠ ويعتقد أنها نشأت مبكرا حيث أن الشواهد البتروجرافية تشير إلى أنها ترسبت قبل وبعد ترسيب الكوارتز ٠ كما يعزى وجود الكاوليتيت اللاحم إلى وفرة أكاسيد السليكون والألومنيوم نتيجة ذوبان الفلسبارات الفتاتية بفعل المياه الأرضية ٠