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GEBEL QABELIAT

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Abstract

Gebel Qabeliat lies on the eastern bank of the Gulf of Suez, between Wadi Feiran and El-Tor in the southwestern part of Sinai. It is bounded westward by Wadi Araba, and eastward by El-Qaa plain. Gebel Qabeliat shows a southwest- facing steep slope throughout its extension, and all sedimentary rocks, and those to the west, retain almost complete uniformity of dip and strike. The deposits range in age from Cambrian to Recent.

The few publications found on the geology of the area between Wadi Feiran and El-Tor include the studies of Barron (1907), Moon and Sadek (1921), Bowman (1925) and Perez (1938). Recently, the area has attracted an intense study due to the discovery of petroleum. Unfortunately, most of the data obtained are unpublished, except for some EC-PC and EPEX seminars, and the studies carried out by Garfunkel and Barton (1977), Bunter (1982), Hamza and Abdalla (1984), Moustafa and Khalil (1985) and Allam *etai.* (1986).

The aim of the present study is to interpret the depositional environment of these sandstones and to determine the possible source area. The study was undertaken with the view to disclose origin, agent of transportation and conditions prevailed during the deposition of these sandstone beds.

The studying biostratigraphical subdivisions, based on both planktonic foraminifers and calcareous nannofossils. The samples used in the present study were collected from the Early Eocene beds of Gebel Qabeliat, Gulf of Suez, and Sinai, Egypt.

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Acknowledgement

I wish to express my deepest gratitude to PROF. DR.Hamza Khalil , lecturer of Stratigraphy and Paleontology, Geology Department, Faculty of Science, Tanta University for suggesting the present point of study, Great efforts and guidance, with reference related to the subject and also for her continugement during the preparation of this work providing me.

Chapter ONE

INTRODUCTION

Gebel Qabeliat lies on the eastern bank of the Gulf of Suez, between Wadi Feiran and El-Tor in the southwestern part of Sinai (Fig. 1). It is bounded westward by Wadi Araba, and eastward by El-Qaa plain. Gebel Qabeliat shows a southwest- facing steep slope throughout its extension, and all sedimentary recks, and those to the west, retain almost complete uniformity of dip and strike. The deposits range in age from Cambrian to Recent.

The few publications found on the geology of the area between Wadi Feiran and El-Tor include the studies of Barron (1907), Moon and Sadek (1921), Bowman (1925) and Perez (1938). Recently, the area has attracted an intense study due to the discovery of petroleum. Unfortunately, most of the data obtained are unpublished, except for some EGPC and EPEX seminars, and the studies carried out by Garfunkel and Bartov (1977), Bunter (1982), Hamza and Abdalla (1984), Moustafa and Khalil (1985) and Allam etai. (1986).

The main objective of the present study is to have a better understanding of the geology and stratigraphy of Gebel Qabeliat area. This has been accomplished by:

a) preparation of a photogeological map (scale 1: 40 000) and recording both the stratigraphic and structural field data;

b) identifying the macro- and microfaunal and calcareous nannoiloral assemblages; and

c) Microfacial analysis of each lithostratigraphic unit and interpretation of its paleoenvironment.

The field work has documented the similarity between Gebel Qabeliat section and the current stratigraphic nomenclature of the Gulf of Suez region. Accordingly, the sedimentary sequence in the mapped area may be summarized as follows:

Miocene Ras Malaab Group

Gharandal Group

Khaboba Formation

Darat Formation

Thebes Formation

Upper Esna Shale

Lower Esna Shale

Sudr (Chalk) Formation

Matulla Formation

Wata Formation

Raha Formation

"Nubia Sandstone"

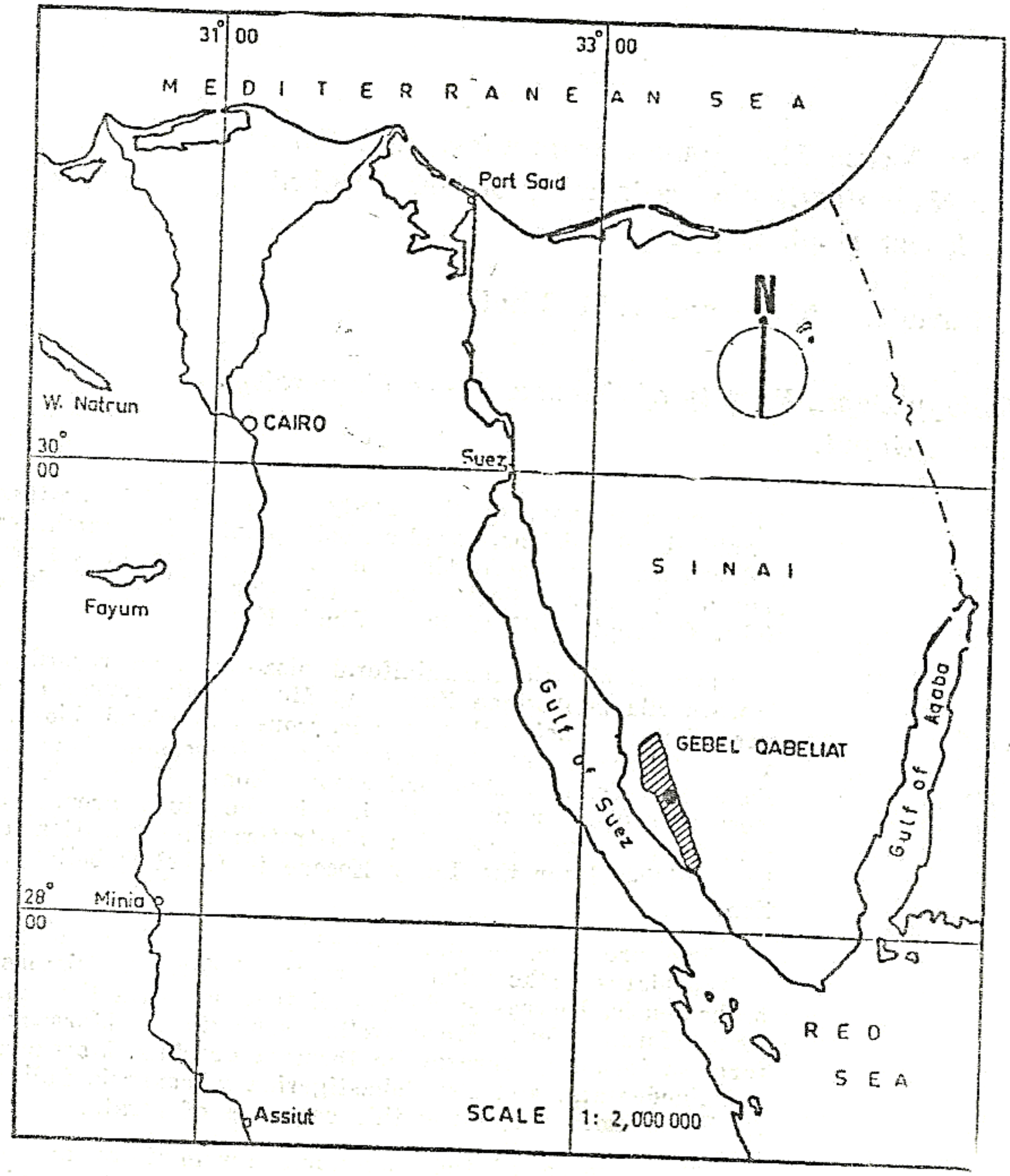


Fig.1: location map of the study section

CHAPTER TWO

STRUCTURES

The mapped area represents a segment of the eastern, onshore, part of the Gulf of Suez rift. It has the form of a long northern-oriented homo- cline that extends from Gebel Nezzazat (outside the present area) to El-Tor. This homocline dips northeastward with an average angle of dip of 25°. It is bounded on its western side by down to the southwest normal faults that trend north-northwest. It is dissected by the following fault blocks, from north to south: Gebel Nezzazat, Gebel Ekma, Gebel Abu Huswa, and Gebel Araba.

Faults

The Fig(2), indicates the presence of five sets of faults which trend as follows: 1) N 35° W to N 65° W with maximum at N 45° W; 2) E-W; 3) N 15° W; 4) N 5° E; and 5) N 35°E. One of these major fault sets (the E-W fault set) includes minor faults. Example of these minor faults is the E-W faults at southern end of Gebel Araba and Gebel Abu Sweira.

The N 35° to 65° W fault set includes two subsets: the N 35° to 45° W subset and the N 45° to 65° W subset. The former represents those parallel to the boundary faults of the Gulf of Suez rift, and represented in the mapped area by the N-W fault in Gebel Ekma and those bounding the western part of Gebel Abu Durba, Gebel Abu Huswa, and Gebel Araba. The latter subset, on the other hand, includes the faults in Gebel Ekma which trend generally N 69° W and dip 59° to the southwest. They juxtapose the Nubia Sandstone of the up thrown side against the Cenomanian rocks of the downthrown side.

The N 15° W and N 5° E fault sets are scattered in the area and represented east of Gebel Abu Durba and the two faults bounding the Miocene rocks west of Gebel Ekma

The N 35° E fault set includes few northeast- trending faults in Gebel Ekma, and the NNE faults which bound the northern parts of Gebel Abu Durba and Gebel Abu Huswa.

Previous studies on the Gulf of Suez indicate the presence of three main fault trends: the N-NW (clysmic) trend, the N-NE (Aqaba) trend, and the N-W fault trend (Robson, 1971; Garfunkel and Bartov, 1977). The N-NW (clysmic) faults are normal faults which surround the rift and many of its fault blocks (Robson, 1971) and have a spoon-like form which have caused tilting of the fault blocks up to 25° (Chenet et al., 1984).

The N-NE (Aqaba) faults are believed to be of strike-slip type (Garfunkel and Bartov, 1977). The mapped N-NE trending fault between Gebel Abu Durba and Gebel Araba is such left-lateral strike slip. Furthermore, the N-W set of faults are strike slip as well. According to Garfunkel and Bartov (1977), the N-W faults are right-lateral strike slip and formed contempomeously with the Aqaba fault set during the early stages of rifting of the Gulf of Suez.

Hence, it seems that the mapped N 45° to 65° W fault subset and the N-NW (Aqaba) fault set are right-lateral and left-lateral strike slip respectively, whereas the N-NW (clysmic) faults are normal faults. All of these faults developed in Oligocene time and are still active till the present time.

Folds

In the studied area, one anticline was mapped at the southern end of Gebel Abu Durba. The fold axis plunges eastwards. Another anticline exists outside the limits of the mapped area in Gebel Nezzazat and its axis plunges northwards. The former anticline affects the Nubia Sandstone, while the latter affects the sequence up to the Miocene beds. The difference in trend of the two fold axis could be explained to be due to different stresses at twp different times. The first fold indicates N-S post-Nubia compression whereas the second fold indicates an E-W Miocene and/or post-Miocene compression.

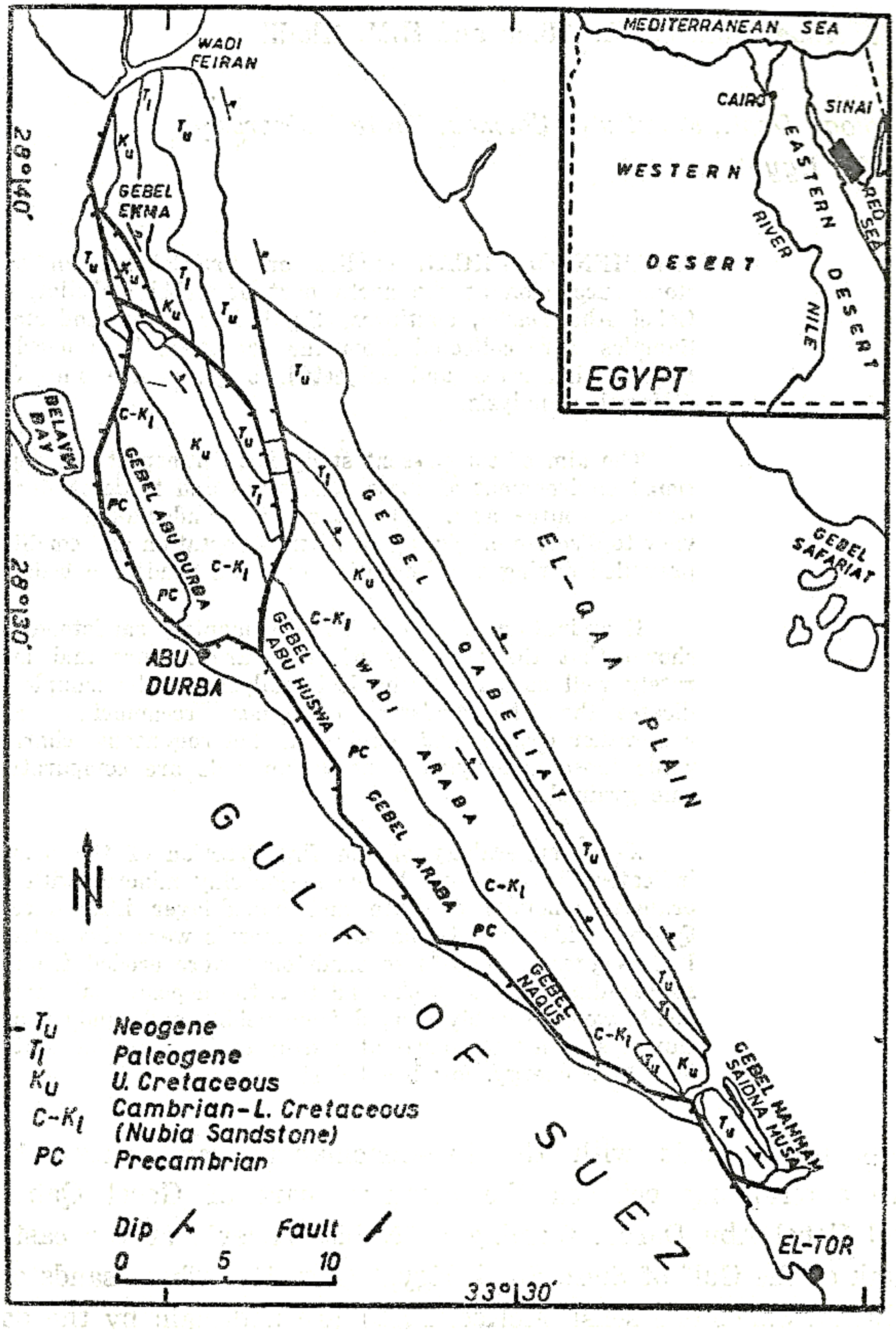

MEDITERRANEAN SEA
CAIRO
SINAI
WESTERN DESERT
EASTERN DESERT
RIVER NILE
RED SEA
EGYPT
WADI FEIRAN
GEBEL EKMA
BELAYIM BAY
GEBEL ABU DURBA
ABU DURBA
GEBEL ABU HUSWA
WADI ARABA
GEBEL ARABA
GEBEL GABELIAT
EL-QAA PLAIN
GEBEL SAFARIAT
GEBEL NAQUS
GEBEL HAMMAM SAIDNA MUSA
EL-TOR
GULF OF SUEZ
28°40'
28°30'
33°30'
N
Tu Neogene
Tl Paleogene
Ku U. Cretaceous
C-Kl Cambrian-L. Cretaceous (Nubia Sandstone)
PC Precambrian
Dip
Fault
0 5 10

Fig. 2: Geological map of the study section

Chapter THREE

SEDIMENTOLOGY

Studies on Precenomanian sandstone succession at the north, part of Gebel Qabeliat, east Gebel Abu Dorba, southwest Sinai, have been undertaken. Samples were collected from the sandstone beds overlying Precambrian rocks and subjected to grain size and X-ray diffraction analysis.

The aim of the present study is to interpret the depositional environment of these sandstones and to determine the possible source area. The study was undertaken with the view to disclose origin, agent of transportation and conditions prevailed during the deposition of these sandstone beds.

Examination of these Precenomanian sandstones has shown that the majority of them are mature and moderately well sorted. Mechanical analysis of the samples indicates that the sandstone overlying Precambrian rocks are rather coarse and exhibit a heterogeneous character while those underlying Cenomanian beds are comparatively fine grained.

X-ray mineralogy of the fine fraction of the samples indicates that kaolinite is the major clay mineral with subordinate amounts of illite and mixed-layer illite/smectite. Quartz, feldspar and iron oxide minerals were also detected. It is suggested that these sandstones were eroded from the surrounding igneous rocks and that the depositional environments were probably ranged from pebbly and sandy braided fluvial systems to marginal and/or shallow marine settings in a high energy, low braided streams.

Study Precenomanian sandstones which are outcropping between the northern part of Gebel Qabeliat and Gebel Abu Dorba, forming a "Nubia Valley", at the eastern bank of the Gulf of Suez, Sinai, Egypt (Fig.2). These sandstones (Nubian Sandstone sensu McKee, 1962) are underlain by the dark colored basement rocks and unconformably overlain by the light colored rock of the marine Cenomanian.

Despite the wide geographical distribution of the Paleozoic and Mesozoic sandstones, however, there have been little interest and much confusion regarding their proper age. The exact age of these sandstones, therefore, is questioned (see the discussion in Omara and Schultz, 1965; Hassan, 1967).

The purpose of the present work (which dealt with by the three authors in cooperation) is to examine these sandstones in terms of their grain-size constituents to understand sediments dispersal pattern in an attempt to identify the factors most influencing their transportation and the processes involved during their deposition. Examination of the clay minerals encountered in the sandstones was made in a trial to investigate the nature of the clay mineral assemblages and to shed light on their possible sources.

Lithology and methodology

The strata displayed in the cliffs are formed mainly of repetitive sequence of multicolored sandstone, siltstone and shale occasionally interbedded by thin-bedded gritty or even pebbly sandstone beds. Fig. 3 gives the stratigraphic succession which was described, measured and sampled. Sandstone succession measures about 735 m in thickness and it is made up mainly of cross-bedded sandstone, silt- stone, sandy shales and gritty sandstone. These sandstones are commonly yellow, white, hematite red, well bedded, rarely calcareous and occasionally cross-bedded. The sandstone beds show every gradation of grain size up to gritty and even to gravel- size pebbles.

The beds of gravel, consisting of small, well rounded quarts pebbles imbedded in a. sandy matrix are also common especially in the upper part of the succession. The sandstones are stratified and sometimes show variable dipping. The cross-stratification, ripple marks, lamination and intraformational conglomerates are prominent primary structures which characterize these sandstones.

Grain-size analysis of the samples and the clay mineralogy of the less than 2 micron fraction of the sediment were carried out. Disaggregation of samples and removal of carbonate and iron oxides were done using stannous chloride and HC1 (Folk, 1974).

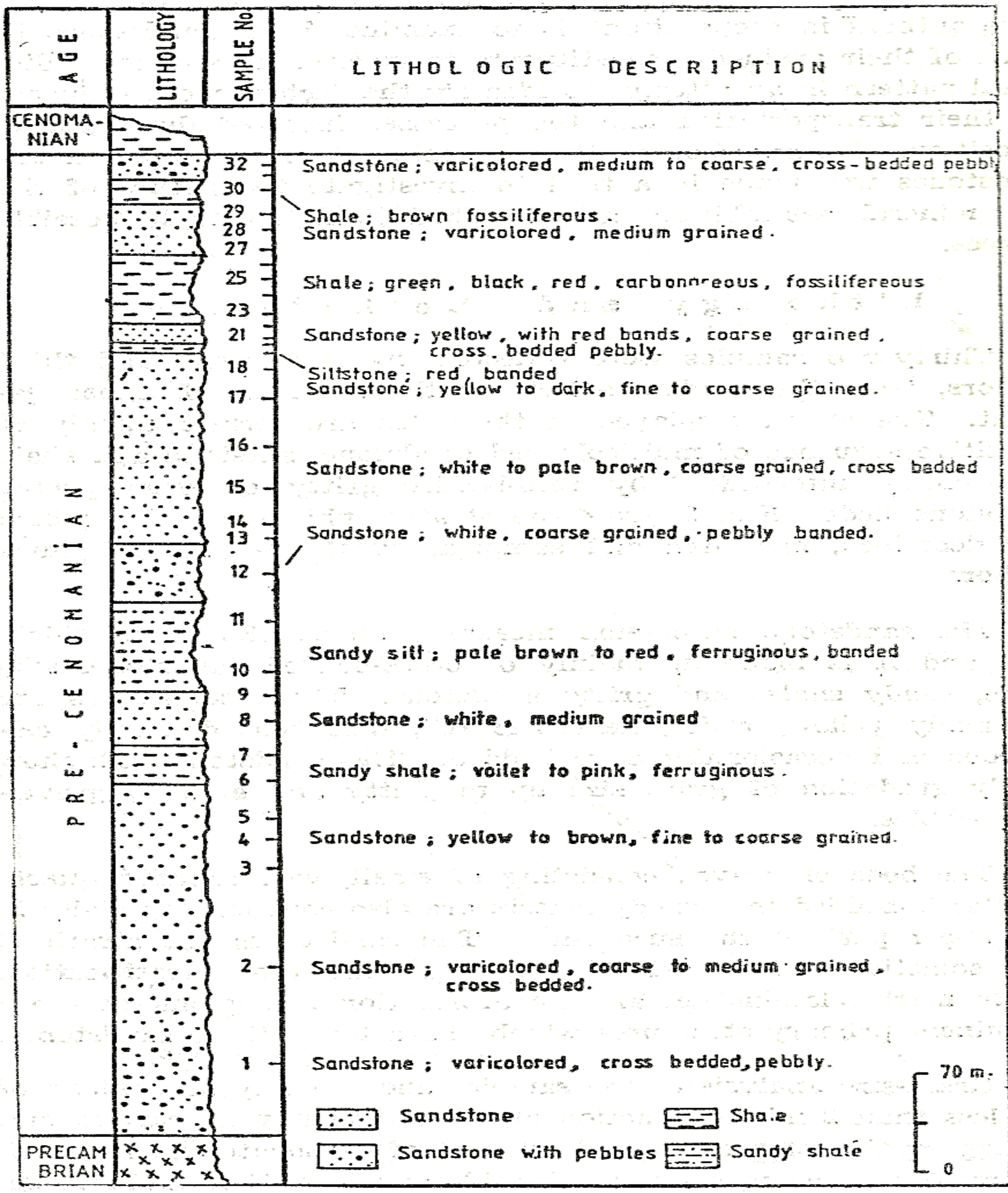

AGE
LITHOLOGY
SAMPLE No
LITHOLOGIC DESCRIPTION
CENOMA-NIAN
PRE - CENOMANIAN
PRECAMBRIAN
32 30 29 28 27 25 23 21 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
Sandstone ; varicolored, medium to coarse, cross-bedded pebbl
Shale ; brown fossiliferous .
Sandstone ; varicolored, medium grained .
Shale ; green, black, red, carbonnreous, fossilifereous
Sandstone ; yellow, with red bands, coarse grained, cross bedded pebbly.
Siltstone ; red, banded
Sandstone ; yellow to dark, fine to coarse grained.
Sandstone ; white to pale brown, coarse grained, cross bedded
Sandstone ; white, coarse grained, pebbly banded.
Sandy silt ; pale brown to red, ferruginous, banded
Sandstone ; white, medium grained
Sandy shale ; voilet to pink, ferruginous .
Sandstone ; yellow to brown, fine to coarse grained.
Sandstone ; varicolored, coarse to medium grained, cross bedded.
Sandstone ; varicolored, cross bedded, pebbly.
Sandstone
Sandstone with pebbles
Shale
Sandy shale
70 m.
0

Fig3: Measured section of the pre-cenomanian sandstones, Gebal Qabeliat.

Mechanical analysis of the samples and the statistical parameters of grain-size data (Folk and Ward, 1957) were calculated in Table (1) and plotted against litho logy in Fig. 4 (a, b, c and d). The inter-relationships between various parameters are presented on Figs. 7, 8, 9 and 10.

They clay mineralogy of the fine fraction of the present sandstone was examined by the X-ray diffraction technique. The less than 2 micron fraction was separated and mounted on glass slides. The X-ray diffract meter (Philips P.W. 1050/20) was operated at 30 KV, 30 am, range C.P.S, 1-2 K, width 5, time constant 5, Nickel-filtered Cu-K radiation was used. Samples were run at a scanning rate of 4°/min, with a chart speed of 1 cm/min. Three traces were run for each sample: untreated (air-dried) glycolated (ethylene glycol) and heated (55°C) and a semi quantitative determination of the clay mineral groups are estimated (Biscay,1965).

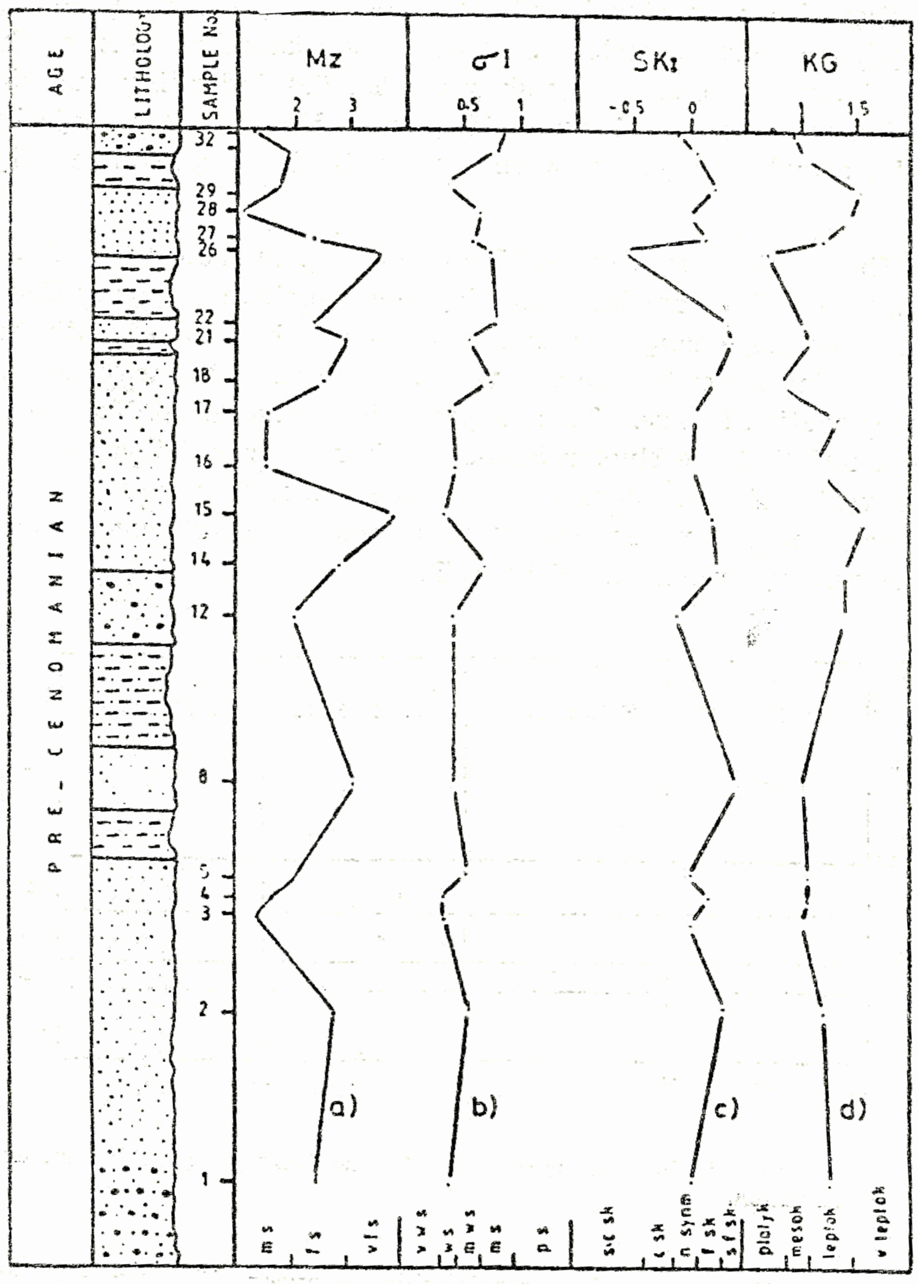


Fig4: stratigraphic distribution of a) the mean size (mz) ,b) inclusive graphic standard deviation c) inclusive graphic skewness (SKI) and d) graphic kurtosis .

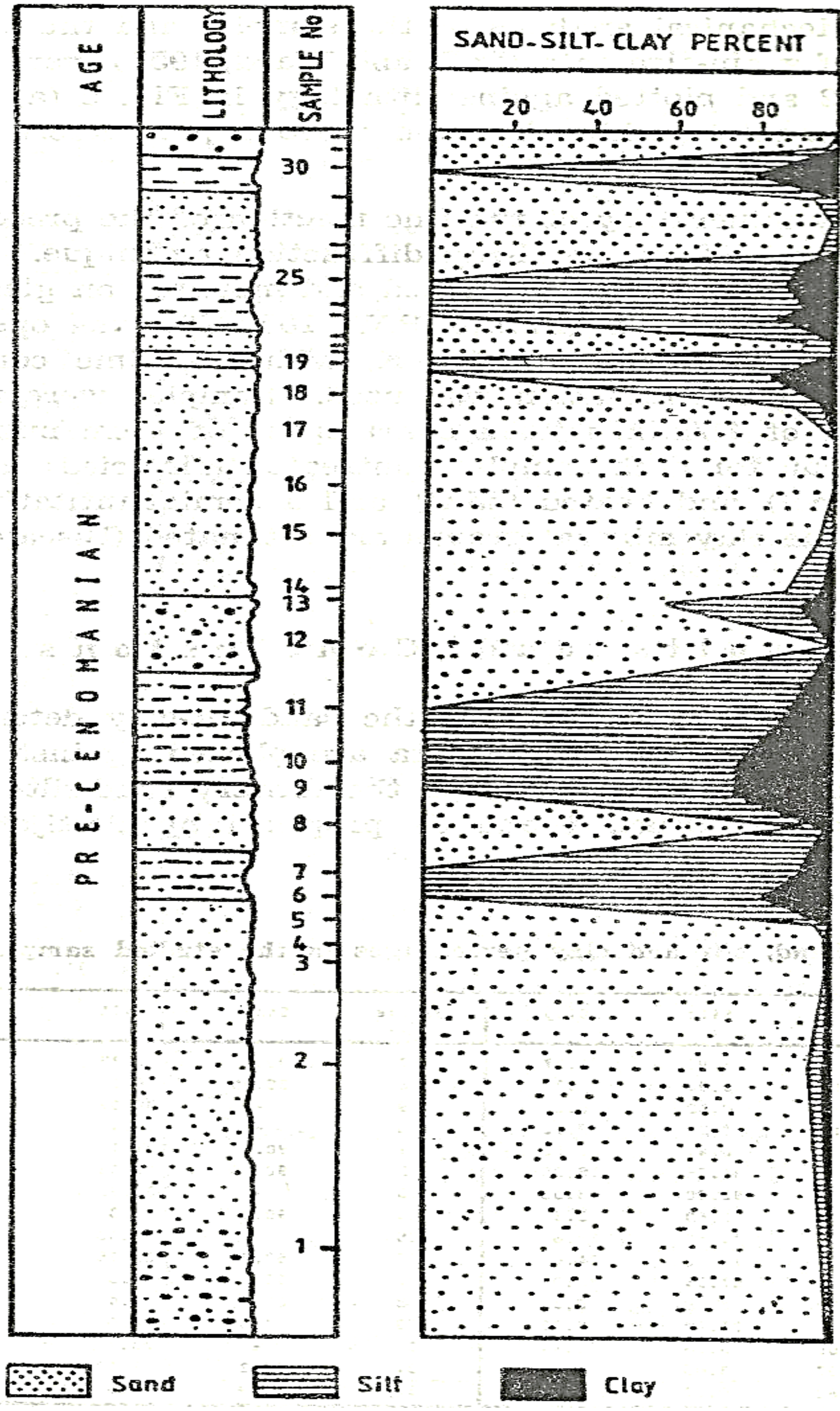

AGE
LITHOLOGY
SAMPLE No
SAND-SILT-CLAY PERCENT
20
40
60
80
PRE-CENOMANIAN
30
25
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Sand
Silt
Clay

Fig 5: Stratigraphic distribution of sand, silt and clay in the studies section.

Examination of fig 3, 5 shows that the sand fraction is the dominant constituent in the lower part of the succession near the Precambrian rocks. In the middle part (samples 12-18) and in the

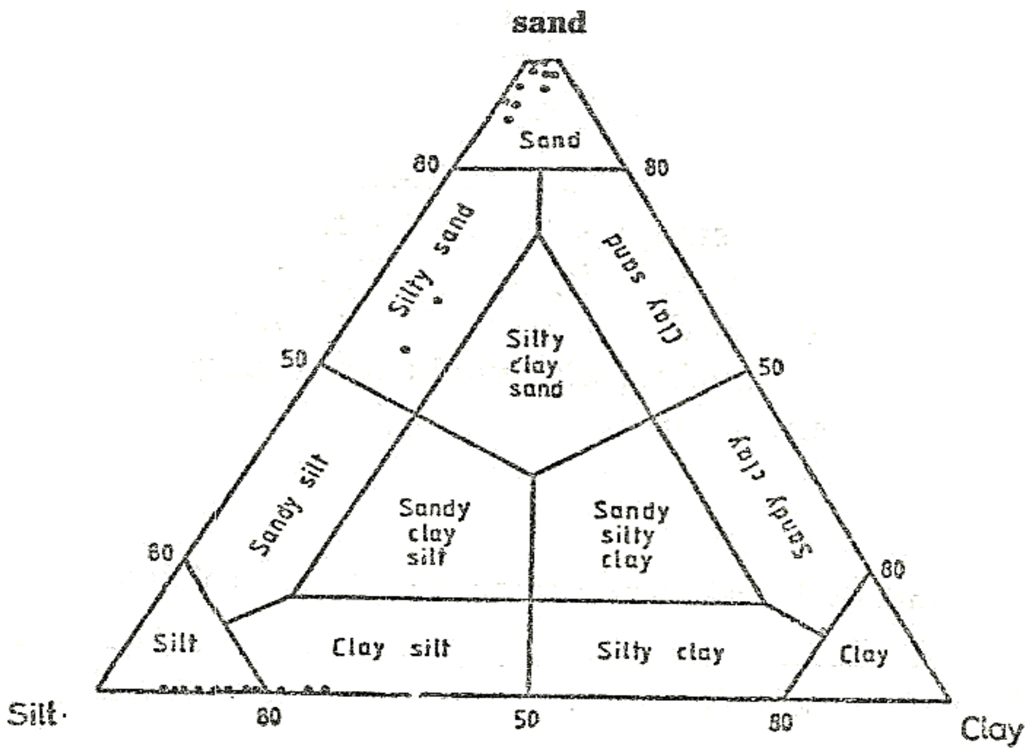
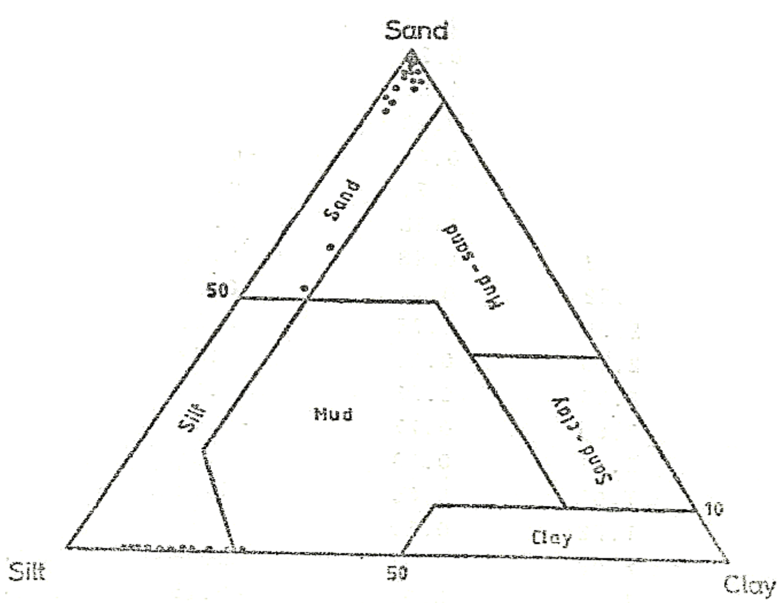


Fig 6: ternary sand –silt –clay diagram of the studies sandstones. Symmetrical scheme after pettijohn et al. 1972

Fig 7: ternary sand-silt-clay diagram of the studied sandstone. Asymmetrical scheme after pettijohn et al... 1972.

Upper part of the succession that underlying the Cenomanian shales, the silt and clay fractions dominate in the sediments. Figs. 6 and 7 further illustrate that the majority of sediments have rather heterogeneous texture pointing to quick accumulation. Strictly, marine environment of deposition is provisionally doubtful. However, some samples have rather homogeneous texture, better sorting and are probably of marine origin.



Statistical parameters of the grain-size data have shown that the Mz value for most sample fall within the range of medium to very fine-sands (Fig. 4a). Fig. 6b indicates that the inclusive graphic standard deviation (4i) of most samples ranges from well sorted to moderately well-sorted suggesting the prevailing of beach environment.

Table: 1Statistical grain size parameters of the samples

Sample No	MZ	I	SK_1	KG
1	2.42	0.44	0.08	1.27
2	2.80	0.61	0.35	1.23
3	1.37	0.38	0.05	1.02
4	1.63	0.38	0.19	1.07
5	2.10	0.59	0.04	1.07
8	3.15	0.48	0.46	1.01
12	2.07	0.46	-0.11	1.41
14	2.88	0.71	0.26	1.40
15	3.88	0.38	0.24	1.59
16	1.58	0.48	0.03	1.13
17	1.52	0.44	0.08	1.35
18	2.58	0.76	0.23	0.84
21	2.90	0.60	0.37	1.09
22	2.35	0.83	0.33	1.04
26	2.60	0.77	-0.63	0.70
27	2.63	0.63	0.14	1.20
28	1.07	0.66	-0.01	1.45
29	1.72	0.39	0.21	1.53
31	2.02	0.87	0.04	1.04
32	1.3	0.9	-0.15	0.92

Statistical parameters of the grain-size data have shown that the MHz value for most samples (Table 1) fall within the range of medium to very fine-sands (Fig. 4a).(Fig. 4b) indicates that the inclusive graphic standard deviation (4i) of most samples ranges from well sorted to moderately well-sorted suggesting the prevailing of beach environment.

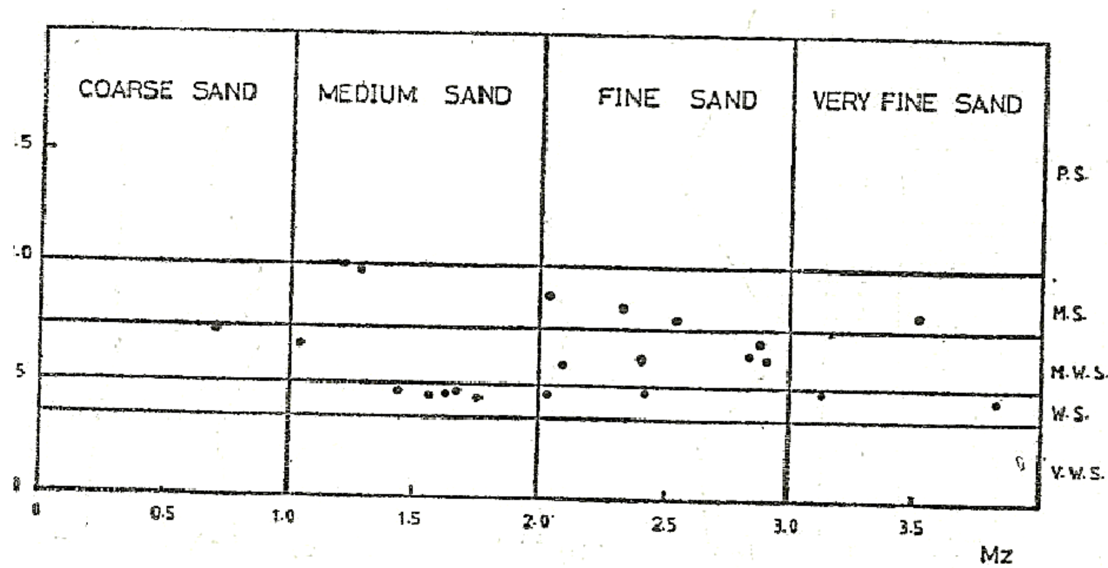


Fig 8: relationship between mean size MHz and inclusive graphic standard deviation.

Fig 9: illustrates the relationship between MHz and SK_X and shows that samples are generally near symmetrical to strong fine- skewed. This suggests the prevailing beach environment of deposition. The tendency of some samples overlying Precambrian rocks to be more near symmetrical than the overlying samples could be attributed to the physiographic features along the contact with the basement complex.

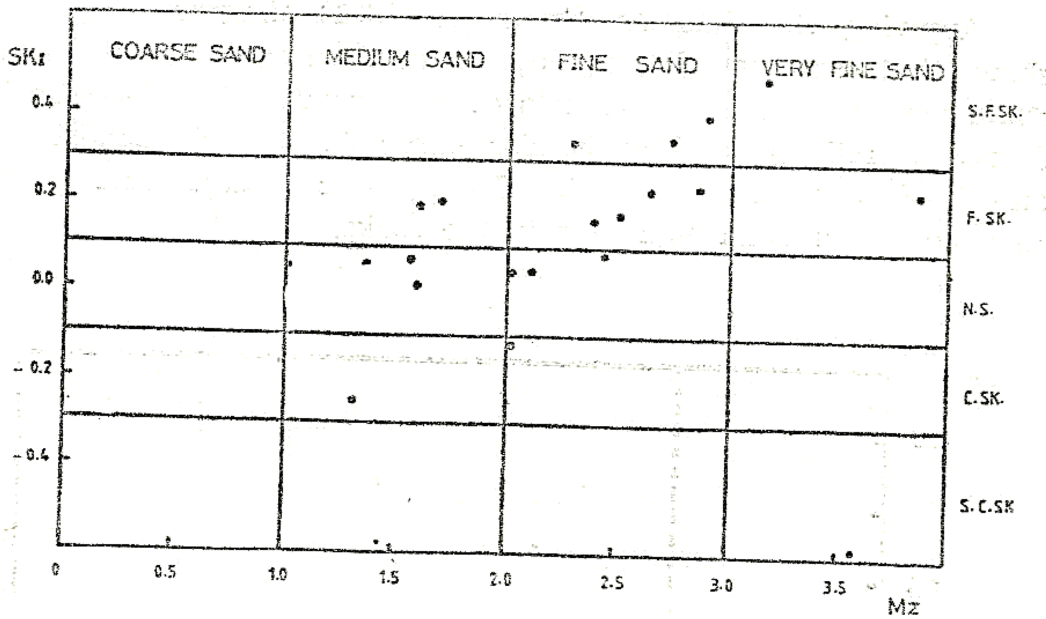


Fig 9: Relationship between mean size Mz and skewness SKI

The relationship between Mz and KG (Fig. 10) indicates that the samples near the contact are generally to leptokurtic indicating typical beach environment. The overlying samples vary from platykurtic and leptokurtic. This leptokurtic character points to what Mason and Folk (1958) termed "Aeolian flat" sediments. However, El Hinnawi et al. (1973) concluded that this term is not meant to indicate that the sediments originated by aeolian action but merely signifies that the present clay skin of sediments over this flat area is being influenced by wind action.

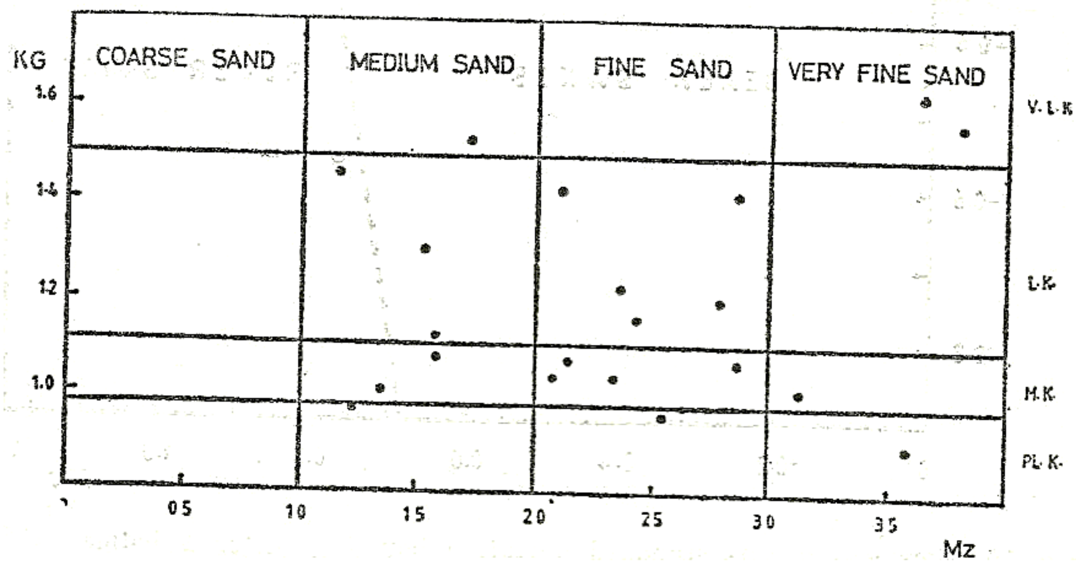


Fig 10: Relationship between mean size Mz and kurtosis KG.

Applying the data on Friedman (1961) diagram (Fig. 11) shows that some samples are located in the field of beach sands while the rest cluster in the field of river sands. The decrease in degree of reliability of grain size parameters in old sandstones may be attributed to the role of digenetic change which has changed the original character in the rocks.

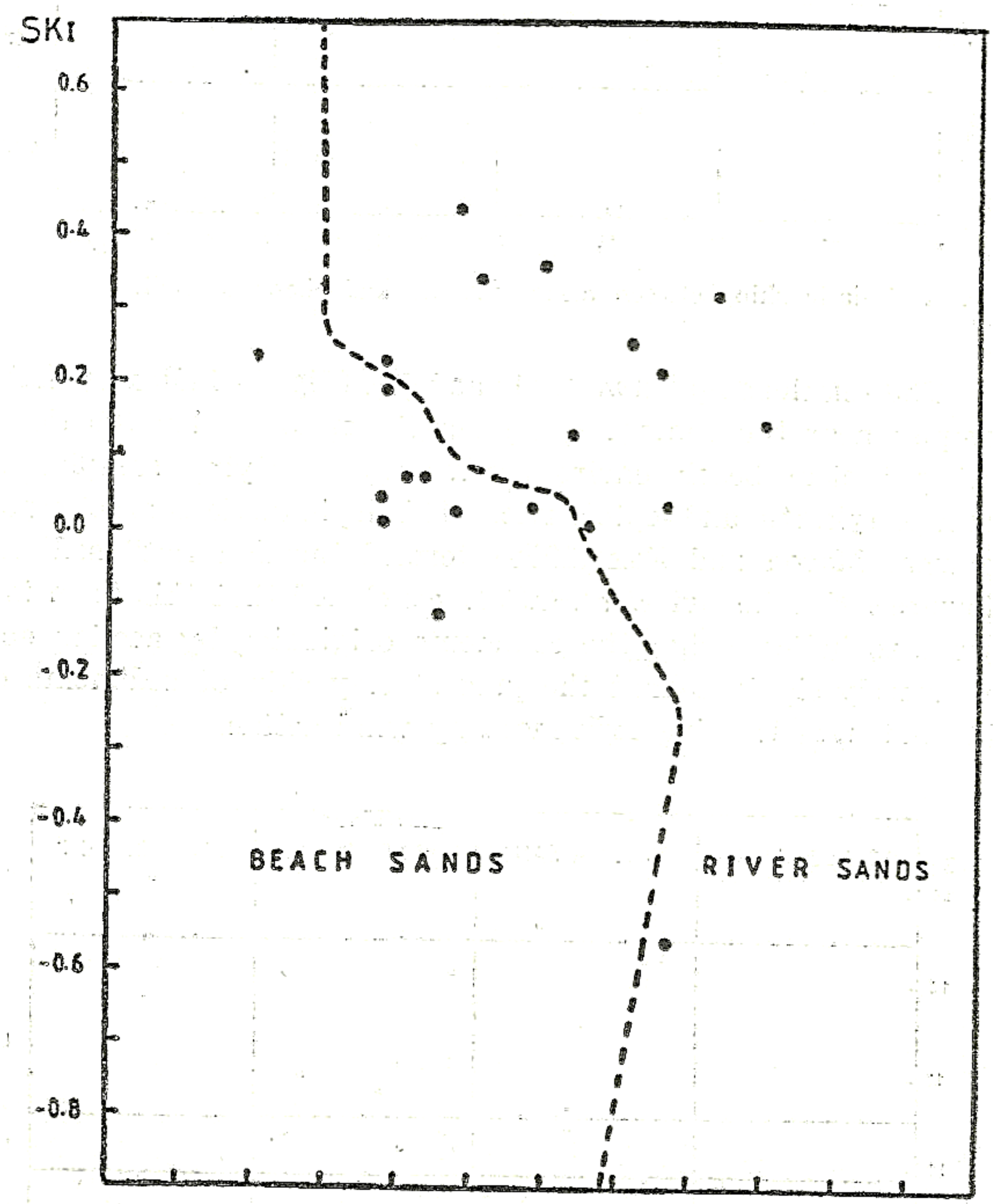


Fig 11: Skewness versus standard deviation boundary after Friedman (1961).

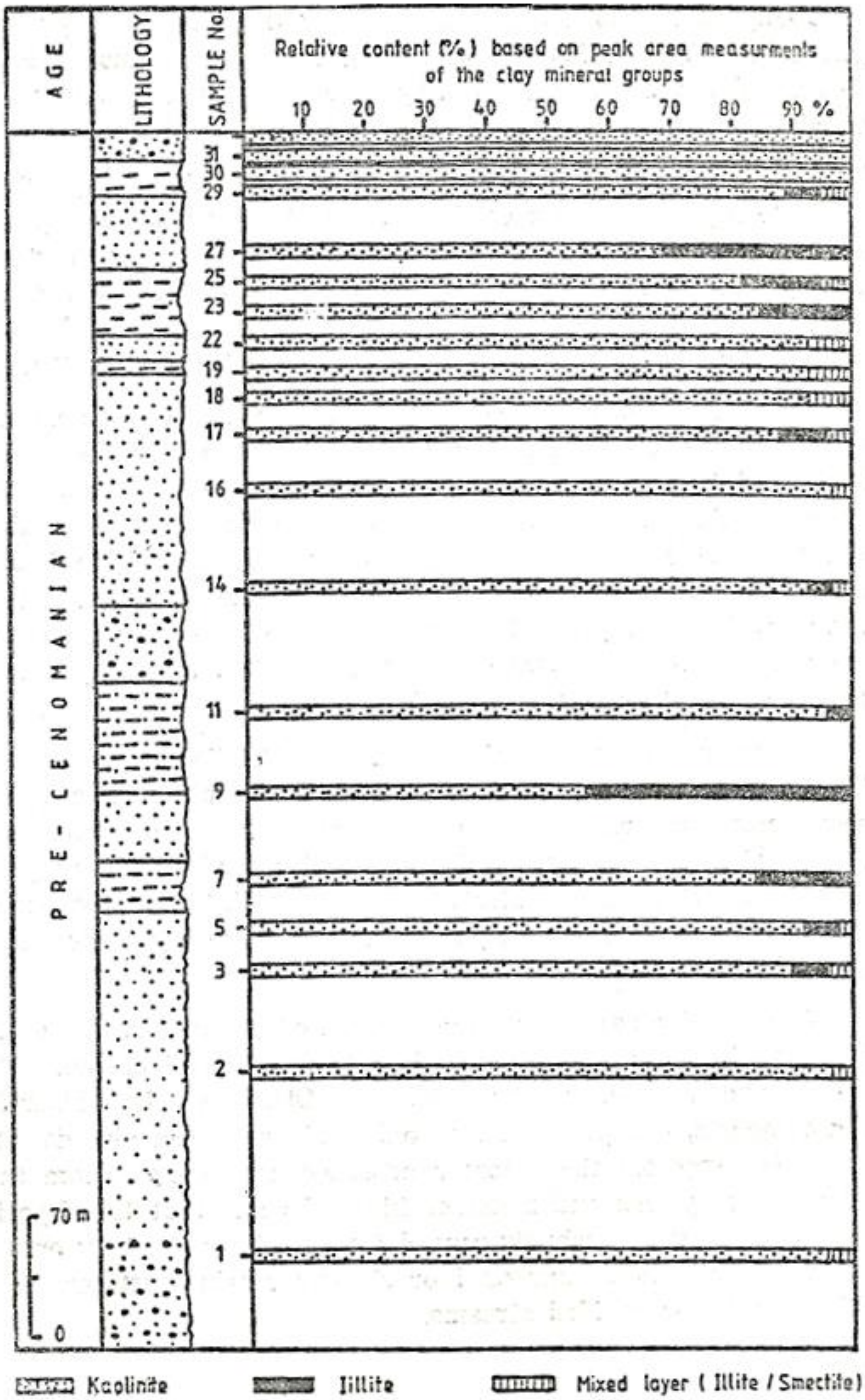

AGE
LITHOLOGY
SAMPLE No.
Relative content (%) based on peak area measurments of the clay mineral groups
10 20 30 40 50 60 70 80 90 %
PRE-CENOMANIAN
31
30
29
27
25
23
22
19
18
17
16
14
11
9
7
5
3
2
1
70 m
0
Kaolinite
Jillite
Mixed layer (Illite / Smectite)

Fig12: Variation distribution of the clay mineral groups in the analyzed samples

X-ray diffraction analysis of the clay fraction of the present sandstones (Fig. 12) lies shown that kaolinite is the most widely distributed clay mineral followed by illite and expanded clay (mostly mixed-layer illite/smectite). Kaolinite values range between 55% and 100% in the samples with an average value of 89%.

Elite represents the second most abundant clay mineral group and it varies in content from 0.0% to 44.5% with a mean value of 7.6%. Mixed-layer illite/smectite clay minerals constitute small proportion of the fine fraction of the present sandstone and reach no more than 7.7% with a mean value of 2.7% (see Fig. 12).

Kaolinite is likely to be formed as a result of chemical decomposition of feldspars and micas. However, its formation from Al-rich solutions infiltrated from the overlying rocks cannot be excluded. The presence of a considerable amount of illitezation of kaolinite since the latter can be destroyed during digenesis due to its instability under deep burial (Dunoyer de Segonsac. 1970). However, the presence of illite/smectite mixed-laver clay minerals suggests that this sandstone have not suffered very deep burial but was subject to intermediate depth.

In conclusion, the examination of the Pre-Cenomanian sandstones northern of Gebel Qabeliat has shown that the majority of these sandstones are mature and moderately well sorted. Mechanical analysis of the samples indicates that the sandstones overlying Precambrian rocks are rather coarse and exhibit a heterogeneous character while those underlying Cenomanian beds are comparatively fine grained.

X-ray mineralogy of the fine fraction of the samples indicates that kaolinite is the major clay mineral with subordinate amounts of illite and mixed-layer clay minerals. Other non-clay minerals such as quartz, feldspars and iron oxide minerals were also detected. It is suggested that these sandstones were eroded from the surrounding igneous and metamorphic rocks and that the depositional environments probably ranged from pebbly and sandy braided fluvial systems to marginal or shallow marine settings in a high energy, low braided, streams.

CHAPTER FOUR

STRATIGRAPHY

The exposed sedimentary rocks of the present area include the Cambrian-Lower Cretaceous Nubia Sandstone; Upper Cretaceous, Paleocene, and Eocene limestones; Miocene marls, shales and evapomes; and Pliocene-Pleistocene sands and gravels.

1. Nubia Sandstone

These rocks represent the oldest exposed sedimentary deposits in the mapped area. This term (sensu Russeger, 1837) has been used here to include all the sediments which range in age from Cambrian to Early

Cretaceous. It is beyond the scope of this study to contribute to the Nubia Sandstone nomenclature and its age controversy.

The Nubia Sandstones are exposed in the mapped area at the base of the steep west-facing slope of Gebel Qabeliat, in Gebel Negus, Gebel Abu Sweira, Gebel Hammam Saidna Musa, and Gebel Ekma. They cover the eastern floor of Wadi Araba along the entire length of Gebel Abu Huswa; then the outcrop is offset to the west and extends until Abu Durba oil field. These rocks also appear as a narrow strip at the base of the western slope of Gebel Ekma and strike to the northwest for few kilometres until they are downthrown beneath the surface.

a. Lower Nubian Sandstone (N1), 430 m thick, mainly near-shore marine to deltaic and fluvio continental sandstones. They are fine-, medium- to coarse-grained and sometimes conglomeratic and have white to brown color. The rocks are friable, partly kaolinitic and have cross-bedding which show a direction of transportation from south to north and east to west. They are probably of Cambrian age. Omara (1974) reported on a limestone bed underlying the Cambria-Ordovician sandstones near the Abu Durba granite, which contains stromatolites and small archeocyatids of an Early Cambrian age.

b. Middle Nubia Sandstone (N2), 250 m thick, consists of marine shales of grey to green color and bioturbat thin sandstone interbeds. These sand-stones are fine to medium grained, silty to clayey, fossiliferous and probably of Permo-Carboniferous age.

c. Upper Nubia Sandstone (N3), 260 m thick, consists of shales, marls, limestones and sandstones. These fluviatile sandstones are massive and vary in size from fine to coarse grained, sometimes conglomeratic. It shows cross-bedding which embrace a direction of transport from south to north. In some places it is interbedded with fossil soils such as mudstones, varicolored, well-stratified, with root structures. These sandstones are probably of Early Cretaceous age.

2-Cenomanian:

The Cenomanian beds (Raha Formation of Ghorab, 1961) are uniform throughout the mapped area (Fig. 1). They lie uncomfortably above the Nubia Sandstone. At the southern flanks of Gebel Qabeliat, the beds strike NNW and their exposures form a narrow strip which extends as far as Wadi Feiran. The rapid thickening of these beds towards the north (from 79 to 217 m), is probably due to the deepening of the Cenomanian sea when the sediments were deposited.

Lithologically, the Cenomanian beds consist mainly of limestones, marls and shales, with 10 m thick gravel and pebble deposits at the base. The limestones are grey, fine-grained, hard and compact. They are weathered into small chunks with rounded edges. The marls are greenish-grey and compact. The shales are also massive and greenish-grey but sometimes dull brown, and break with conchoidal fractures. Moreover, different lithofacies can be identified microscopically. The most important of them are:

a.Biomicrite: this rock-type consists of about 30 vol. % pelecypods and gastropod shell fragments scattering in a micritic carbonate groundmass. The shell fragments are filled with calcite crystals. Some rhombohedra dolomite crystals fill the pores or scattered in the groundmass.

b.Dolostone: this consists of more than 90 vol. % dolomite crystals, which are microcrystalline and rhombohedra in shape. The rhombs (0.1 to 0.01 mm) are reddish brown due to the presence of Fe-oxides. The dolomite components are packed together with ferruginous cement. A cryptocrystalline carbonate matrix is also present. The few pelecypods and gastropod shell fragments are filled with very fine calcite crystals.

c.Marl: this contains pelecypods and gastropod shell fragments (20 vol. %). Quartz grains and gypsum veins are also present. Most of the quartz grains lie within the size of medium sand (0.5 -to 0.25 mm).

d.Shale: this is characterized by the presence of very fine-grained, argillaceous components (<0.06 mm). It is highly fossiliferous with abundant foraminifers. Very fine to fine quartz grains are scattered within the matrix, having sub angular to rounded shape.

Paleontological, the Cenomanian rocks are rich in micro and mega fossils. The following foraminiferal species have been recognized: Thomasinella Punic Schlumberger, T. *rugosa Schlumberger*, T aegyptioca Omara, Nezzazata *simplex* Omara, *Cribrostamoides* sinaica Omara, C.*paralens* Omara, *Haplophrcigmoides eggeri* Cushman, and H. *gigas* Cushman: in addition to the following mega fossils: *Exogyru* africana Lamark, E.flabellata Coldfuss,E.oliponesis Sharp,E. Overweg be rich, E.

suoliponensis Sharp, E. borbiculcita Lamarck, E. conica Sowerby, Plicatulaauressensis Coquand, P. reynesiCoquand.

Dosinia fragemoli (Coquand), *Lima* (P.) tihensis Abbass, L. (R.) *cenomanensis* Abbass, Nerineama- gharensis Abbass, N. faidensis Abbass, *Pterodontagigantica* Abbass, and *Hemiaster* sp.

3-Turonian:

The Turonian beds (Wata Formation of Ghorab, 1961) consist of a succession of limestones, sandstones, and shales. They lie conformably over the Cenomanian Raha Formation and below the lime-stones and shales of the Lower Senonian Matulla Formation. In Gebel Qabeliat the Turonian section strikes NNW, forming a narrow belt (75 - 95 m thick) extending northward few places throughout this belt, the outcrop is until Wadi Feiran. In offset to the east and west (Fig. 2).

Litho logically, the Turonian succession consists of green and brown thin beds of shales, soft brown sandstones and limestones. This limestone is hard, brittle and brownish yellow and sometimes carries shark teeth and thin oyster-beds.

The entireTuronian section has a brown ferruginous appearance Turonian section has a brown ferruginous appearance which easily distinguishes it from the under- lying greenish grey Ceremonial rocks. Under the microscope the following rock types can be recognized:

a) Biomicrite: this consists of abundant pelecypods and gastropod shell fragments (50 vol. %). The fossil shell fragments are filled with calcite crystals, and are packed in a cryptocrystalline, highly ferruginous, carbonate groundmass. The few glauconitic grains have a rounded to sub rounded shape.

b) Pelmicrite: this rock type consists of oval to rounded calcareous fecal pellets (70 vol. %) and pelecypods shell fragments (25 vol. %). The shell fragments are filled with coarse crystalline calcite crystals. The components are packed in a micritic carbonate groundmass.

c) Calcareous sandstone: this consists of sub- angular to sub rounded quartz grains (75 vol. %) scattered in a ferruginous carbonate groundmass (25 vol. %). The quartz grains have an average size of about 1 mm.

d) Shale: this is nanofossiliferous and characterized by the presence of high amount of argillaceous materials and few detrital grains (< 0.06 mm).

Paleontological, the Turonian beds contain abundant and well-preserved mega faunal assemblage, but they are poor in microfossils. Among the recognized species are the following: *Cucullaea schweinfurthi* Quash, Astarte (T.) *tenuicostata* Saguenay, Roudaireia blanckenhoni (Fourtau), CorbulaperoniFourtau. Ostrea semi plane Sowerby, Brachycomes jordani (Quaas), *Pyrgulifera* hadhirensis Abbass, *Tylostoma gaderisis* Abbass, Archilectonica Faris Abbass, Anculosa sinaiensis Abbass, Plicatula sp., and Lucina sp.

4) Lower Senonian

The Lower Senonian beds (Matulla Formation of Ghorab, 1961) consist of sandstones, shales, and limestones which are well exposed throughout the mapped area (Fig. 2). The entire succession strikes to the NNW In continuous exposure extending northward until Wadi Feiran, and dips steeply to the northeast.

Lithologically, the Lower Senonian section is composed of 124 m of brown, medium-grained sandstones; grey, brown to yellow sandy shales, and brown ferruginous sandy dolomitic limestone. Different lithofacies can be identified and differentiated microscopically as follows :

a) Biomicrite is rich in fossil shell fragments made up mainly of pelecypods, gastropods and echinoderms (30 vol. %). The shell fragments are filled with coarse calcite crystals and packed in a micritic ferruginous carbonate groundmass. Some fossil cavities are filled with silica and/or calcite crystals.

b) Calcareous sandstone consists of angular detrital quartz grains ranging between 0.5-0.12 mm in size (70 vol. %). Few fragments of pelecypods are present and consist of fibrous calcite (5 vol. %). The matrix consists of microcrystalline ferruginous carbonates.

c) Sandy dolostone consists of zoned, rhombic, euhedral to subhedral dolomite crystals (75 vol. %), together with angular fine-grained quartz (20 vol. %) and packed in a cryptocrystalline ferruginous carbonate groundmass. The rock contains very few fossil shells which have cavities filled with coarse calcite crystals.

d) Shale composed of very fine detrital grains (<0.06 mm). It is also highly ferruginous and non fossiliferous.

Paleontologically, the following fauna were recognized in the Lower Senonian succession: Plicatulaferryi Coquand, P. numidia Coquand, P.

paacicostata Seguenza, Ostrea bourgingnati Coquand, O. niacaisi Coquand, O. boucheroni (Coquand), O. costae Coquand, Proterocardita hillana (Sowerby); in addition to *Acteonellasinaien*- sis Abbass, Acteonella roashensis Abbass, Aporrhais *themedensis Abbass*, and *Libycerithium themedensis* Abbass.

5. Upper Senonian

The Upper Senonian section (Sudr Formation of Kostandi, 1959) comprises 181 m thick deposits of chalk which occur below the grey shales of Paleocene age (Esna Shale) and lies unconformably over the Lower Senonian brown sandstones and green shales (Matulla Formation). The base of the chalk is well marked by a "Gryrphaea bed' carrying Pycnodonta vesicularis (Lamarck). The chalk is exposed throughout the mapped area forming a narrow strip of characteristic snow white limestone, which strikes NW (Fig. 2).

Litho logically, the chalk forms a distinct unit which contrasts with the underlying and overlying dark layers. It is formed of well-bedded, fine grained and pure limestones. However, the upper part is interbedded with some flints, similar to the overlying sequences. Microscopic study showed that only one rock type can be recognized : the foraminiferal biomicrite which consists mainly of micritic limestone (calcite) with abundant foraminifers. The microfossil tests were partly filled with microcrystalline calcite. The foraminifers represent about 40 % of the total rock components.

Paleontologically, the chalk includes Pycnodonta vesicularis (Lamarck) and abundant planktonic foraminifers, such as: Heterohelix globusa (Ehrenberg), H. pulchra (Brotzen), H. globrans (Cushman), Pseudotextularia deforms (Kikoine), Globigerinelloides multispina (Lalicker), Hedbergella sp., H. monmouthensis (Olsson), *Globotruncana* aegyptiaca Duwi Nakkady, G. gagnebini Tilev, *Globotruncanella* havanensis (Voorwijk), *Rugoglobigerin* rotunda Brorninsrin, R. pustulata Brownian.

6. Paleocene

The Paleocene section in the mapped area (Lower Esna Shale sensu Beadnell, 1905) lies above the Upper Senonian chalk (Sudr Formation). The base of the Paleocene shales is well marked by the abrupt change in lithology from carbonates to clastic sediments. The shales are exposed throughout the mapped area forming a narrow strip which extends from the southern end of Gebel Qabeliat to the north of Wadi Feiran with a variable thickness ranging from about 10 to 30 m.

Lithologically, the entire succession is composed of greenish-grey shales with persistent white chalky limestone interbeds. Microscopic and microfacial studies revealed the presence of the following rock types:

a) Shale consists of very fine-grained (<0.06 mm) argillaceous materials, with a small amount of very- fine-grained clastics.

b) Foraminiferal biomicrite is composed of micritic calcite crystals with abundant foraminifers and nannoplankton.

Paleontologically, the deposits are rich in the foraminifers Morozovella angulata White, M. *pseudobulloides* Plummer, M.tirinidadensis (Bolli), M. unicata Bolli, M. *praecursoria* Morozova, *Globigerina triloculinoides* Plummer, *Planorotalites compressa* Plummer, P.*pustillapusilla*(Bolli), and P. *chapmani* Parr; in addition to the following calcareous nannoplankton:

Markalius *inversus* Deflandre, Cyclococcolithus formosus Kamptner. *Chiasmolithus danicus* (Brotzen), C. consuetus Bramlette and Sullivan, *Coccolithus pelagicus* (Wallich), *Neochlastozygus* sp., Ellipsolithus macellus Bramlette and Sullivan, *Thoracosphaera* operculata Bramlette and Martini, Fasciculithus sp., F.janiiPerch-Nielsen, F. bobbii Perch-Nielsen.

F. *tympanijormis* Hay and Mohler, F. *alanii* Perch-Nielsen, F. ulli Perch-Nielsen, Sphenolithus radians Deflandre, S. moriformis Bronnimann and Stradner, Toweius craiiculus Hay and Mohler, *Pontosphaera multipora* Kamptner, *Tranversopon-* tis pulcher Deflandre, Ellipsolithus distichus Bramlette and Sullivan, *Zygodiscus adams* Bramlette and Sullivan Placozygos sp., Ericsonia ovalis Black, and *Neococcolithus protenus* Bramlette and Sullivan.

7) Lower Eocene

The Lower Eocene beds (Upper Esna Shale of Beadnell, 1905; and Thebes Formation of Hume, 1911) are found throughout the mapped area and form a distinct mappable unit which could be traced in the field over long distances, and form cliffs of characteristic appearance. The Lower

Eocene section lies unconformably on the Paleocene rocks. However, this unconformity is usually not well marked, sometimes it is even difficult to locate the contact due to the fact that the Paleocene chalks often cany flint interbeds similar to those of Eocene. Therefore, the first appearance of flint above the Paleocene shales was taken as the Paleocene/Eocene boundary, Hence, the uppermost Esna Shale and the entire Thebes Formation are of Lower Eocene age (Allam et aL, 1986).

Lithologically, the Lower Eocene succession consists of limestones, chalky limestones with flint bands and gypsiferous clay. The section has an average thickness between 110 m in the southern part and 210 m in the northern part of the mapped area. Microfacial study showed that only one rock type canbe described; the foraminiferal biomicrite. It consists of micritic carbonate crystals with abundant foraminifers and nannoflora.

Paleontologically, the following foraminifers and calcareous nannoplankton species were recognized from the Lower Eocene beds: Acarinia quetra (Bolli), A. wilcoxensis (Cushman and Ronton), A. esnaensis (LeRoy), A. makannai(White), A. primitiva (Finaly), Subbotina linaperta (Finaly), Morozovella marginodentata (Subbotina), M. subbotinae (Morozova), M. aequa (Cushman and Renz), M. fonnosagracilis (Bolli), M.formosaformosa(Bolli), M. aragonensis (Nuttal), and Pseudohastigerina wilcoxensis (Cushman and Renz); in addition to Tribrachiatus nunnii Romein, T. contortus (Stradner), Placozygos sigmoides (Bramlette and Sullivan), Fusciculiulus janii jerch-Nielsen, Coccolithus pelagicus (Wallich), C. crassus Bramlette and Sullivan, Chiasmolithas danicus (Brotzen), C.

eograndis Perch-Nielsen, C. solitus Bramlette and Sullivan, CyclococcolithiLS formosus Kamptner. *Zygrhablithus* bijugatus Deflandre.

Sphenolithus moriformis Bronnimann and Stradner, S. radians Deflandr, Pontosphaera multipora (Kamptner), *Neochlastozygus* protenus (Bramlette and Sullivan), Thoracosphaera operculata Bramlette and Martini, Transversopontis pulchera Deflandre, Zygodiscus plectopons Bramlette and Sullivan, Discoaster sp., D. barbadiensis Tan Sin Hok, D. dejlandrei Bramlette and Riedel, D. binodosus Martini, D. robust us Haq, D. lodoensis Bramlette and Riedel, D. saipanensis Bramlette and Riedel, Ellipsolithus distichus (Bramlette and Sullivan), *Neococcolithes* dubius (Deflandre), Toweius craticulus Hay and Mohler, Rhabdosphaera perlonga (Deflandre), and Micrantolithus vesper Deflandre.

8) Middle Eocene

The Middle Eocene beds (Darat and Khaboba Formations of Viotti and Eldemerdash, 1968) are exposed in the mapped area above the cherty strata of Early Eocene age (Thebes Formation) and unconformably below the Miocene Gharandal Group. The thickness of the Middle Eocene section was measured at the north end of Gebel Qabeliat and ranged between 90 and 104 m. In the southern parts of the area, the Middle Eocene limestones are represented by thin beds capping the high ridges.

The Middle Eocene succession consists litho logically of two rock units which belong to the Lower and Upper Lutetian. The Lower Lutetian Darat Formation is composed of chalky and crystalline limestones of predominant white color with some shale and chert interbeds. The Upper Lutetian Khaboba Formation is composed of massive nummulitic limestones carrying some echinoids, oysters and abundant benthonic foraminifers. These nummulitic limestones are not very different from those exposed to the east of Cairo (Mokattam Formation of Said, 1962). Micro facial study gave two rock types:

a. Biomicrite consists of pelecypods and gastropod fragments with very few angular quartz grains (1 mm). It represents about 5% of the total rock components. The components are packed in a micritic carbonate groundmass.

b. Nummulitic biomicrite consists of abundant Nummulites sp. and Operculina sp. in a micritic carbonate groundmass. The fossils represent about 60 % of the total rock components.

Paleontologically, the Middle Eocene is highly fossiliferous, and therefore needs further investigations. However, some of the observed species are: Nummulites gizehensis (Forskal). N.

Discorbinus Schlotheim, N. somaliensis Nuttal and Brighton, N. Beaumont Darchiac and Haime, *Operculina schwageri* Silvesteri, and O. parva Douville.

9) Miocene

The Miocene succession (Gharandal and Ras Malaab Groups of the EGPC, 1964) consists of 240 m thickness of limestones, chalky limestones, marls, shales, gypsum and conglomerates. The Miocene rocks unconformably overly the Eocene and/or older beds. In the area between Gebel Hammam Saidna Musa to Gebel Abu Sweira, the Miocene beds are found capping the hills and unconformably overlie the Nubia Sandstone and Cretaceous beds. Along Gebel Qabeliat, in the area between Gebel Ekma and Gebel Abu Huswa, the Miocene has been affected by faulting. The beds, which lie unconformably over the Eocene section, form a small synclinal fold and two distinct ridges due to faulting. Near Wadi Feiran, Miocene gypsum is found overlying the Eocene beds; whereas to the west of Gebel Ekma, the gypsum is found in faulted contact against the Nubia Sandstones. The sedimentary section can be divided into two main rock units, the Lower Miocene clastics (Gharandal Group) and the Middle-Upper Miocene evaporites (Ras Malaab Group).

The Gharandal Group comprises: a) the basal rock unit (Nukhul Formation), which is composed mainly of limestones and shales overlying a thin conglomeratic bed; b) the middle rock unit (Rudeis Formation) which is composed mainly of shales and sandstones; c) the upper rock unit (Kareem Formation) which is composed mainly of sandstones and shales with thin evaporitic beds at the base.

The Ras Malaab Group consists mainly of:

a) interbedded shales and sandstones with anhydrite and salt in the lower part (Belayim Formation);
b) thick salt deposits in the middle part (South Gharib Formation).
c) interbedded shales and anhydrite in the upper part (Zeit Formation).

Under the microscope, the following lithofacies can be differentiated:

a. Sandy shale made up of very fine grains (<0.06 mm) with rounded quartz grains (1 mm) which form about 20 % of the total components. Gypsum veins are also present.

b. Sandstone made up of angular to sub rounded quartz grains form about 90 % of the total rock components. It ranges in size between 0.25-1 mm, and embedded in fine grained detrital matrix.

c. Sandy biomicrite contains shell fragments of pelecypods. Gastropods and corals (40 vol. %) scattered in micritic carbonate groundmass. Angular quartz grains range in size between 0.5 to 1 mm and represent about 20 vol. % of the rock.

d. Gypsum with fibrous crystals and a small amount of argillaceous matter and carbonates.

The identified fauna from the Miocene rocks areas follows: Sphenolithus moriformis (Bronnimann and Martini), Thoracosphaera operculata Bramlette and Martini, Coccolithus eopelagicus (Bramlette and Riedel), Prediscosphaera grandis Perch-Nielsen, Micrantholithus vesper Deflandre, Watznaueria bamesae (Black), Micula mores (Martini), Quadrumnitidum(Stradner), Helicopon tosphaera carteri (Wallich), Cyclicargolithus Jloridanus (Roth and Hay), Sphenolithus conicus Bukry, Helicopontosphaera kamptneri Hay and Mohler, Pontosphaera multispora Roth, and Coccolithuspelagicus (Wallich).

10) Pliocene – Pleistocene:

The Pliocene-Pleistocene (Tor Group of Webster and Ritson, 1982) is composed of a thick sand dominant stratigraphic unit above the Miocene Ras Malaab Group. The sand deposits are arkosic and appear to be derived predominantly from the Precambrian basement and younger rocks. Beds of coralline limestones occur near the top of the unit and sometimes with anhydrite. Adepositional environment similar to that prevailing at present is expected with coalescing subaerial coastal fans with occasional aeolian, sabkha and reef deposits (Allam, 1986).

The Pliocene-Pleistocene deposits, in the mapped area, have not been subdivided. They are widely scattered throughout the area especially along the wadis and plains. In El-Qaa plain, where several wadis empty into the plain, extensive deposits of sands and gravels are sometimes found standing as steep to vertical walls (15 - 20 m) and form the banks of the main drainage lines. These banks are usually composed of cross-bedded, cemented sands interbedded with conglomerates. To the east of El-Tor, there are several low hills which are covered by gravels but show small boulders of calcareous sandstones along their western slopes. Along the western slopes of Gebel Abu Huswa and Gebel Abu Durba, scattered deposits of40 - 50 m thick cemented sands and gravels are found fringed against the hill front. The plain of Wadi Feiran is well filled by sands and gravels of the main drainage lines. Generally, the surface of the Pliocene-Pleistocene clastic deposits is covered by poorly sorted boulders and pebbles, which have been derived from the surrounding older rocks.

DEPOSITIONAL HISTORY:

It is well known that a granitic Precambrian shield forms the highland of Sinai. The Cambrian and younger sub aerial erosion of this Precambrian shield has led to the deposition of thick and widespread Nubia Sandstone. The absence of any basal conglomerates in the lower Nubia Sandstone in the mapped area and the presence of bioturbations in the lower sands suggest that the lower Nubia Sandstone was deposited in a shallow marine platform with low relief. A hinterland to the south and a basin to the north are also inferred. The widespread and uniform nature of the lower Nubia Sandstone implies a Paleozoic epicontinental to shallow marine shelf of large dimensions. It is suggested that this shelf may have extended far northward in Sinai throughout the Paleozoic Era.

During the Permo-Carboniferous times there is a north to south widespread marine transgression in the mapped area. The geologic record of this transgression is represented by clastic sediments with dateable fossils. The depositional environment in that time implies a submarine relief of some magnitude. It ranges from inner sublittoral, outer sublittoral to bathyal marine conditions. Earth- movements during the Permo-Carboniferous time are suspected. At the end of the Paleozoic Era the sea withdrew from the mapped area.

The characteristics of the Early Mesozoic Nubia Sandstones which are interbedded with fossil soils with root structures and fossil trees, indicate a fluviatile to deltaic depositional environment. The sandstones were probably eroded from the surrounding igneous and metamorphic rocks, so that it would be possible that the depositional environment ranged from braided fluviatile systems to marginal or shallow marine settings in a high energy low braided streams.

The Cenomanian begins with the first appearance of marine beds above the Nubia Sandstone. The transition from clastic to an entirely marine section occurs over few metres. The facies characters of the Cenomanian rocks indicate a fairly shallow transgressing sea. The upper part of the succession shows alternating shallow and comparatively deep marine facies. This phenomenon would suggests an oscillating shallow sea, especially during the Late Cenomanian when this sea became gradually deeper at the beginning of the Turonian.

The Late Cretaceous sea continued its transgression during the Turonian, where compratively deeper marine conditions prevailed. This was evidenced by predominance of limestones and dolostones and low clastic ratio. The presence of dolomite indicates a stable sea-margin-environment. However, this Turonian sea was receiving, at intervals, subordinate amounts of terrigenous material from a neighboring southern landmass (Lewy, 1975 and Ismail and Dakkak. 1976).

The abundance of detrital grains and the pelletal nature of the Lower Senonian rocks indicate a predominant shallow marine condition of the neritic zone. This shallowing of the Late Cretaceous sea would suggest a crustal uplift of the sea floor about the end of Turonian time (Ismail and Dakkak, 1976).

The clastic sediments of Lower Senonian age is followed by a chalky sequence of Upper Senonian age, which indicate deposition under deeper marine conditions far from any terrigenous material. It means, the shallowing of the Lower Senonian sea was followed by a reversal in the secular oscillation of the sea floor (Vail et aL, 1977). However, the orogenic movements which affected the northern parts of Egypt along the NW-SE Syrian arcs (Shukri, 1954), were not active at the mapped area because the. Paleocene deposits conformably follow the topmost Upper Senonian beds. The Paleocene sediments show open marine outer neritic facies environment. It seems that the marine conditions during the Paleocene time were, more or less, similar to that obtained during the Late Senonian.

The beginning of Early Eocene was the time when the transgression of the sea was either halted or had a slight regression. The crustal stability has produced a deposition of uniform open-sea facies of the limestone with flint. By upper Lower Eocene time a regression of the sea started, and the reefal alveolinid limestone facies was formed under shallow marine conditions. According to Said (1962) the Late Eocene regression of the sea must have continued probably to the end of Oligocene time. Therefore, the Middle Eocene Sea was gradually regressing, due to the appearance of larger foraminifers above the Lower Eocene beds.

The Oligocene in Sinai was marked by general uplift accompanied by igneous activity. The igneous activity was represented by the Early Tertiary basalt flows which was generally interpreted as related to initial faulting in the Suez rift (Garfunkel and Bartov, 1977; and Webster and Ritson, 1982).

The onset of rifting is defined in the present map by an unconformity. The erosion which occurred appears to be restricted to the Upper Eocene limestone. A shallow proto-rift depocentre was first formed in which the lower part of the Gharandal Group was deposited. As the sea- level rose through the Aquitania and Early Burdigalian (Vail et al., 1977), successive formations on lapped the margins of the developing depocentre. The subsequent deposition of the upper part of the Gharandel Group, comprise lagoonal and subsequent marginal and shallow marine sequence, and reflects major sea-level changes. The Lower Miocene deposits were succeeded during Middle Eocene (Serravallian) time by prolonged sedimentation of reef building carbonates in the mapped area. These reefs, which constitute the Belayim Formation marks the last occurrence of marine fauna in the Miocene. The reefal conditions were gradually changed to progressive aridity, leading to the prolonged formation of evaporates.

Malaab Group during Turtonian and .sinian times. The evaporitic deposits were aclulated under very shallow epicontinental sea. Nelly, at the close of Miocene time, aridity seed and gave way, during Pliocene-Pleistocene as, to the sedimentation of clastic materials in the western Sinai. The Pliocene-Pleistocene deits, in the mapped area, have mainly terrestrial. They are mostly composed of gravels and glomerates with some anhydrite interbeds. This ms to indicate that occasional marine transients covered the area.

Chapter five

Biostratigraphy

The main purpose of this study is to establish biostratigraphical subdivisions, based on both planktonic foraminifers and calcareous nannofossils. The samples used in the present study were collected from the Early Eocene beds of Gebel Qabeliat, Gulf of Suez, Sinai, Egypt.

Two planktonic foraminiferal biozones were recorded : Morozovella subbotinae Zone and Morozovella Formosa Formosa Zone. Their relevant calcareous nannofossil biozones are: Tribrachiatus contortus Zone, Biscoaster binodosus Zone and Tribrachiatus orthostylus Zone. These biozones were recorded for the first time in the study area. Furthermore, a high resolution biostratigraphic zonation can be established for the Early Eocene in Gebel Qabeliat section.

The presence, in the studied samples, of nannofossils Tribrachiatus orthostylus, Discoaster lodoensis, Discoaster harbadiensis, Discoaster deflandrei together with the planktonic foraminifers Morozovella subbotinae, *Morozovella* Formosa Formosa, Morozovella Formosa gracillis, *Morozovella* marginodentata, and Pseiidohastigerina wilcoxensis indicates an Early Eocene age for this sequence of strata.

The absence of the planktonic foraminifers and calcareous nannofossils at the Early/Middle Eocene boundary in the section of Gebel Qabeliat points but to a change in the paleoecoiogical conditions in the area during that time. Eesumption of shallow marine environment is evidenced by the upsequence appearance of larger foraminifers Num- muities spp. and Assilina spp.

Paleontologically, works dealing with the Eocene at the east coast of the Gulf of Suez in general includes: Robson (1943), Pooley (1944), Farag and Shata (1955), Ansary el al. (1961), Bishay (1981), Abdelmalik (1967), Viotti and El Demerdash (1968), Ker- dany and Abdel Salam (1970), Kerdany el al. (1974), Abdelmalik el al. (1974), El Heiny and Enani (1984) and many others. None of these papers delt especially with the planktonic foraminifera and calcareous nonnofossil biostratigraphy of Gebel Qabeliat.

The purpose of this study is to establish biostratigraphic subdivisions based on both planktonic foraminifera and calcareous nannofossils and to record a high resolution biostratigraphic zonation as proposed by Hay and Mohler (1969). The study samples were collected from the Early Eocene sediments, near the north of Gebel Qabeliat, opposite Gebel Abu Durba.

Planktonic foraminifers and calcareous nannoflora have proved to be useful in stratigraphic zonation as well as for worldwide correlation.

In general calcareous nannofossil zonation was first established in land sections. Martini (1971) and Martini and Worsley (1970) presented a simplified summary of Tertiary and Quarternary calcareous nannofossil zonation. Martini and Worsley (1970) define the boundaries of their zones only by the highest or lowest occurrence of a single species. Bukry and Bramlette (1970) and Bukry (1970) used many closely-spaced first and last occurrence of species and the composition of the assemblages to define their zones.

In the present work, the planktonic foraminifera! zonation was essentially established following the same subdivisions introduced by BolIi (1957, 1966) for the Early Eocene. The scheme proposed by Martini (1971) was adopted for the Early Eocene calcareous nanoplankton. The recognized calcareous nannofossil biozones and their relevant planktonic foraminifera! Zones in the studied section are presented in Fig. 13. The distribution of planktonic foraminifera and calcareous nannofossils are tabulated in Figs. 14 and 15. Fig. 16 illustrates biozonation based on planktonic foraminifers and calcareous nannofossil marker species utilized for the definition of zones. Fig. 17 shows a comparison of the calcareous nannofossil zonation used in this study by Martini (1971) to those adopted by Okada and Bukry (1980).

a. Planktonic foraminiferal zonation

Based on the planktonic foraminifers identified, two Biozenes are recognized. The Early Eocene planktonic foraminifers founded in Gebel Qabeliat section are broadly similar to those recorded in southern Israel (Benjamini, pers. com.)

1. Morozovella subbotinae Zone

This zone is characterized by the presence of: *Morozovella* subbotinae (Morozova), M. *formosa gracilis* (Billi). *Psendohasti*- gerina *wilcoxensis*

(Cushman and Ponton) have their first occurrence here. The assemblage also includes: *Acarinina quetra* (Bolii) A. *wilcoxensis* (Cushman and Ponton). A. *esnaensis* (Le Roy), A. Primitiva (Finaly), A. makannai (White), Subbotina lina- perta (Finaly), *Morozovella* aequa (Cushman and Renz), M. *mar- ginodentata* (Subbotina).

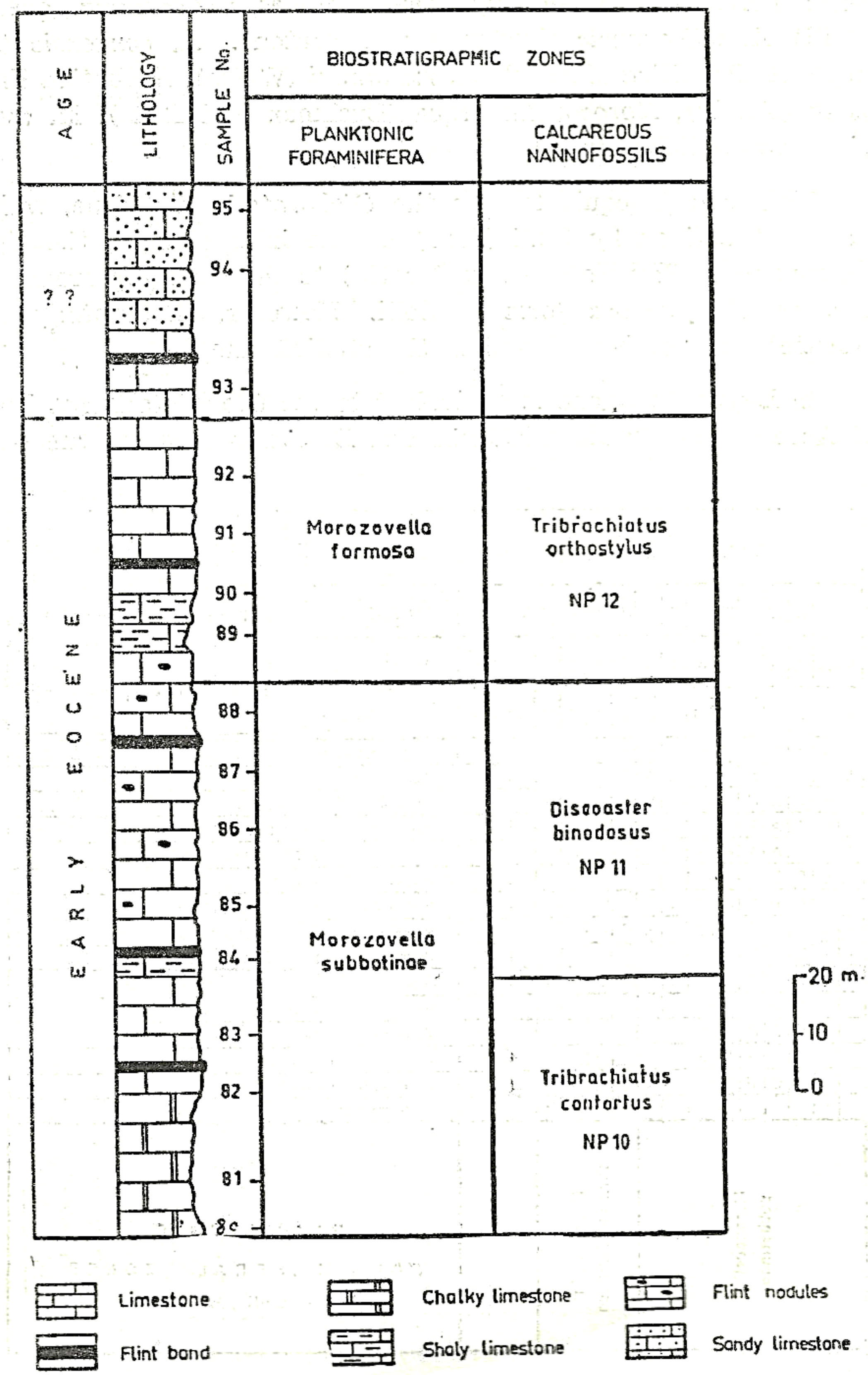

AGE
LITHOLOGY
SAMPLE No.
BIOSTRATIGRAPHIC ZONES
PLANKTONIC FORAMINIFERA
CALCAREOUS NANNOFOSSILS
? ?
EARLY EOCENE
95
94
93
92
91
90
89
88
87
86
85
84
83
82
81
80
Morozovella formosa
Morozovella subbotinae
Tribrachiatus orthostylus
NP 12
Discoaster binodosus
NP 11
Tribrachiatus contortus
NP 10
20 m.
10
0
Limestone
Flint band
Chalky limestone
Shaly limestone
Flint nodules
Sandy limestone

Fig13: litho, bio, and chronostratigraphy of early Eocene sediment in G.Qabeliat section.

This zone is equivalent to the *Globorotalia rex* Zone, which was first defined by Bolli (1957) as the interval from the first occurrence of Globorotalia Rex (Martin) to the first appearance of *Globorotalia Formosa Formosa* Bolii. However, *Globorotalia rex* (Martin) has not been found in the studied samples.

In Egypt, this zone is equivalent to the *Globorotalia* rex Zone of Ansary and Tewfik (1988) in Ezz El Orban area, on the west coast of the Gulf of Suez; to the *Globorotalia wilcoxensis* Zone of El Naggar (1966) in the Nile Valley ; to the *Globorotalia* subbotinae Zone of Fahmy et al. (1968) in Gebel Shehab, Eastern Desert, very near the Nile Valley ; to the *Globorotalia* subbotinae Zone of Krasheninnikov and Abdel Razik (1968) in Qusseir area, on the Red Sea coast; to the *Globorotalia* subbotinae Zone of Faris (1974) in Central Egypt ; to the *Globorotalia* rex Zone of Kerdany et al. (1974) in Abu Zenima area, on the east coast of the Gulf of Suez ; to the *Globorotalia* subbotinae *Nummulites* deserti Zone of Allam (1983) in the Nile Delta.

AGE	EARLY EOCENE													?		
SAMPLE No.	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
ABUNDANCE	A	A	A	A	A	A	A	A	A	R	R	C	A	B	B	B
PRESERVATION	G	G	G	G	G	M	M	M	M	P	P	P	M	-	-	-
Acarinina quetra	A	A	A	A	A	A	R	R	R	R						
Acarinina wilcoxensis	A	A	A	A	A	A	R	R	A	R		R	R			
Subbotina linaperta	F	F	C	R	R				F	R		R	R			
Morozovella marginodentata •	C	C	A	A	F			R								
Morozovella subbotinae •	C	C	A	A	A	R	R	R								
Morozovella aequa	C	C	C	C	R			R								
Morozovella formosa gracilis	C	C	C	R	A	A	C	R								
Pseudohastigerina wilcoxensis •	R	R	R	R	F	R	C	C	R	R			R			
Acarinina esnaensis	R	R	R	R	R	R	R									
Morozovella formosa formosa •			C	R	F	R	R			R	R	R	R			
Morozovella gracilis			C	R	R	R	R									
Acarinina sp.			F	C	R	C	R									
Acarinina mckannai			F	C	F	R	R		R							
Acarinina primativa			F	C	F	R	R		R			R	R			
Morozovella aragonensis •										R		R	R			
PLANKTONIC FORAMINIFERAL ZONES (After Bolli, 1957, 1966)	*Morozovella subbotinae*									*Morozovella formosa formosa*						

ABUNDANCE: B: Barren, R: Rare, C: Common, F: Frequent, A: Abundant

PRESERVATION: P: Poor, M: Moderate, G: Good

• Important species

Fig14: distribution of early Eocene planktonic foraminiferal zones in area.

80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	
EARLY EOCENE													[illegible]			AGE
80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	SAMPLE No.
A	A	A	A	A	C	A	A	C	A	C	C	A	B	B	B	ABUNDANCE
M	M	M	G	G	M	M	M	P	M	G	G	G	–	–	–	PRESERVATION
R	R	R	R													Tribrachiatus nunnii •
R																Placozygus sigmoides
R																Fasciculithus janii
C	F	C	C	C	C	C	C	C	C	C	C	C				Coccolithus pelagicus
R	R	R														Chiasmolithus danicus
C	R	R	R	R	C		C	C	C	C	C	C				Cyclococcolithus formosus
R	R	R	R				F	R		R		R				Zygrhablithus bijugatus
R	R	R	R			R	R	R	R	R						Sphenolithus moriformis
C	R	R	R	R	R	R	C	C								Pontosphaera multipora
R	R	R	R													Neochiastozygus protenus
F	R	R	C	R	R	C	C		R	R						Thoracosphaera operculata
F	R	R	R	R		R	C									Transversopontis pulcher
R	R	R	R	R	R	R	R									Chiasmolithus eograndis
R				R			R	R	R			R				Zygodiscus plectopons
R				R	R				R			R				Discoaster barbadiensis •
R								R	R		R					Discoaster deflandrei •
R	R	R														Tribrachiatus contortus •
C																Coccolithus crassus
	R	R		F	R	R	R	R	R	R	R	R				Tribrachiatus orthostylus •
	R	R	R			R		R		R	R	F				Sphenolithus radians
	R	R														Ellipsolithus distichus
	R					R	R	R								Discoaster binodosus •
	R	R	R		R	R	R	R								Chiasmolithus solitus •
		R					R	R				R				Neococcolithus dubicus
			R			R	R									Toweius craticulus
				R	R				R							Discoaster robustus
							R					R				Rhabdosphaera perlonga
								R	R		R					Discoaster lodoensis •
											R					Micrantholithus vesper
												R				Discoaster saipanensis •
												R				Cruciplacolithus delus
												R				Cruciplacolithus cribellus
																Discoaster sp.
												R				Reticulofenestra reticulata
												R				Braarudosphaera bigelowii
NP10			NP11					NP12								NP
Tribrachiatus contortus			Discoaster binodosus					Tribrachiatus orthostylus								CALCAREOUS NANNOFOSSIL ZONES (After Martini, 1971)

ABUNDANCE: R: Rare; C: Common; F: Frequent; A: Abundant

PRESERVATION: P: Poor; M: Moderate; G: Good

• Important species

Fig15: distribution of early Eocene calcareous nannofossils zones

According to Allam (1983: 440) this zone points on the beginning of the Early Eocene age.

2. *Morozovella Formosa Formosa* Zone:

This zone is characterized by the common occurrence of the following species: *Acarinina quetra* (Bolli), A. wilcoxensis (Cushman and Ponton), A. *primitiva* (Finlay), *Psedohastigerina wilcoxensis* (Cushman and Ponton), *Morozovella aragonensis* (Nuttall) and M. Formosa Formosa (Bolli).

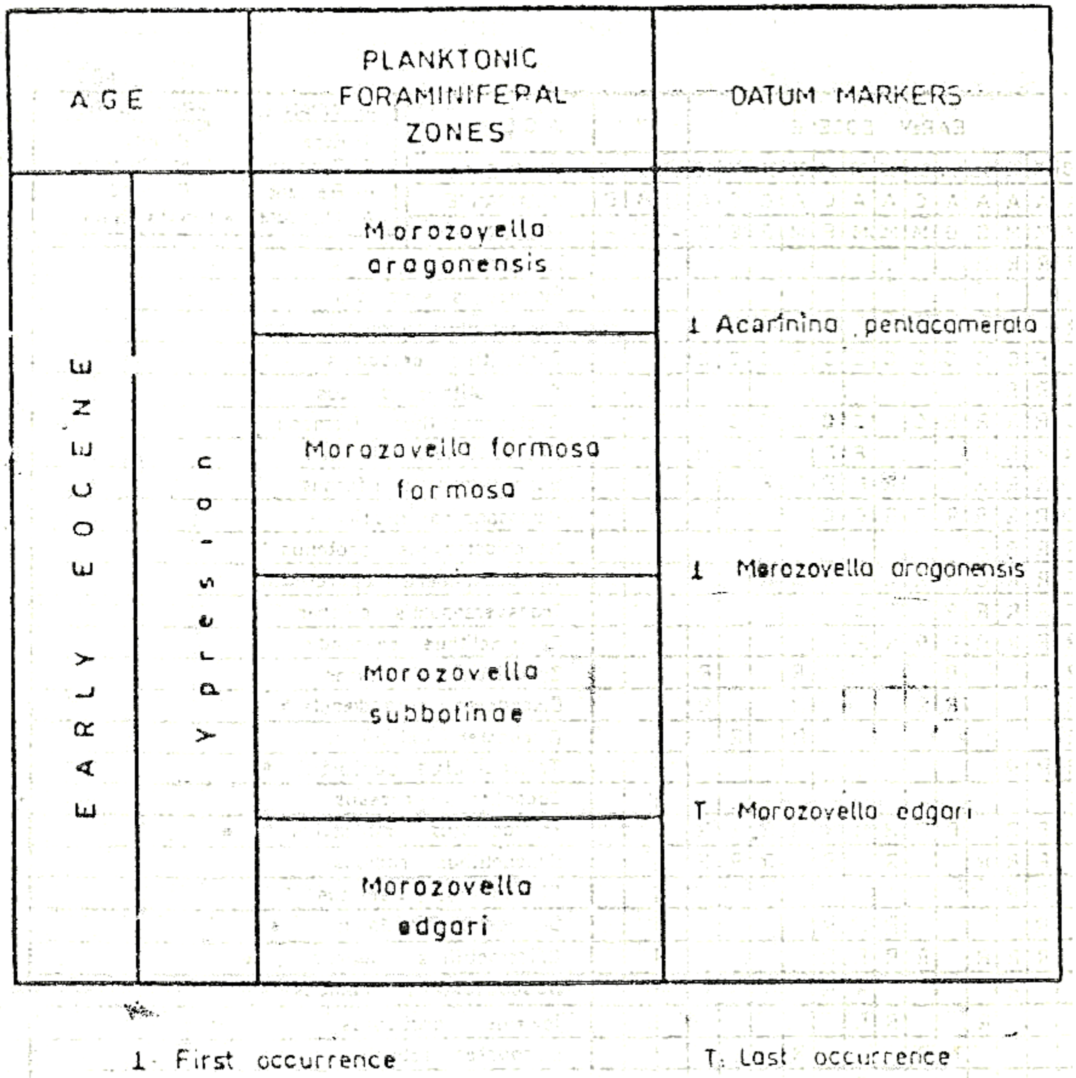


Fig16: biozonation based on planktonic foraminifers and marks species.

This zone was first defined by Bolli (1957). In Egypt it is equivalent to the *Globorotalia aragonesis Acarinina pentacame- rata* Zone of Fahmy et al. (1968) in Gebel Gurnah near Luxor to the *Globorotalia aragonensis* Zone of Viotti and El-Demerdash (1968) in Wadi Nukhul,.SW Sinai ; to the Globorotalia aragonensis_ Acarinina pentacamerata Zone of Krasheninnikov and Abdel Razik (1968), in Qusseir region, Red Sea coast;

to the Globorotalia aragonensis Globorotalia Formosa. Zone of Allam (1983) in the Nile Delta.

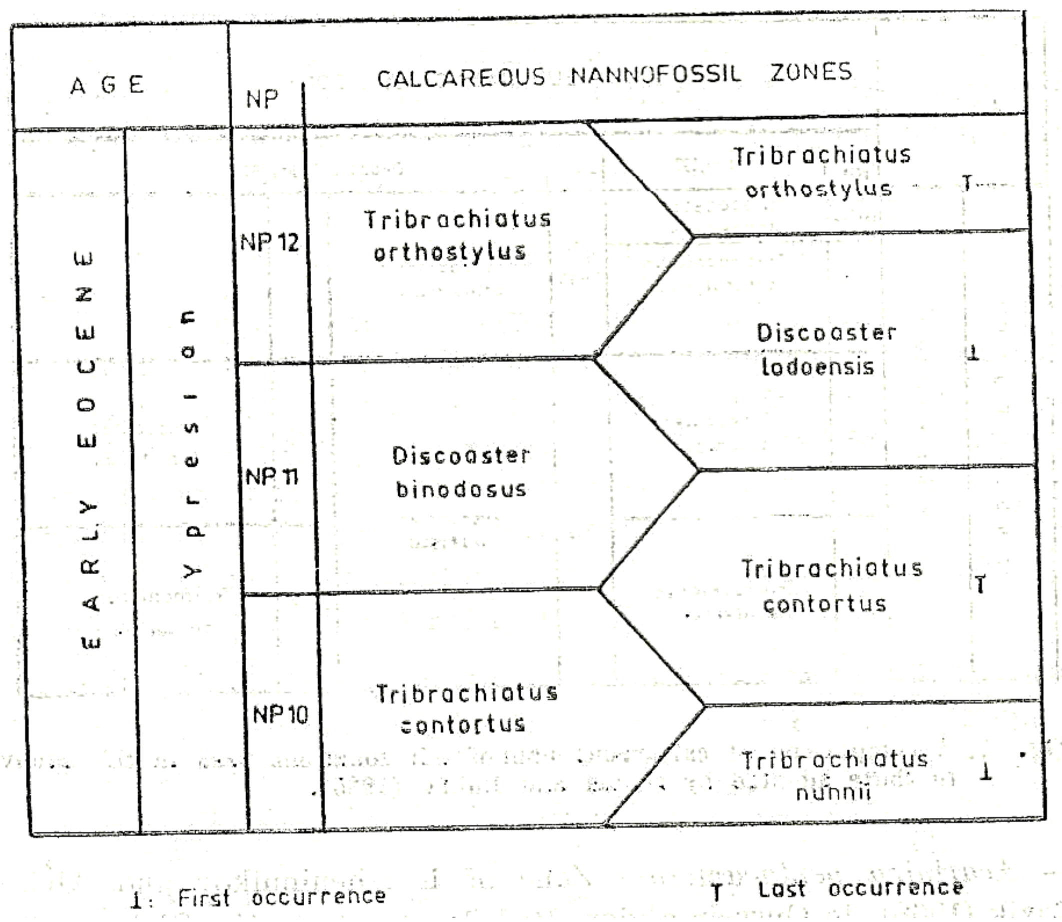


Fig17: calcareous nannfossil zonation adopted in this study.

According to Allam (1983: 441.) this zone is considered .to indicate the end of the Early Eocene age.

b.*Calcareous nannofloral zonation*

The identified nannofossil *association* belongs entirely to the Early Eocene, precisely to the *Tribrachiatus* contortus Zone (NP 1.0), Discoaster binodosus Zone (NP 11) and *Tribrachiatus ortho stylus* Zone (NP 12). The recognized calcareous nannofossil zones, which are recorded for the first time in Gebel Qabeliat, are briefly described below in ascending order :

1. *Tribrachiatus contorts* Zone (NP 10):

This zone includes the interval from the first occurrence of *Tribrachiatus nannii* (Bronnimann)

This zone was originally defined by Hay (1964). The *Tribrachiatus contortus* Zone corresponds to the *Tribrachiatus contortus* subzone (CP 9a) of Okada and Bukry (1980). This zone was described from Central Egypt from the Early Eocene sediments by Faris (1982) and Marzouk (1985).

2. Discoaster binodosus Zone (NP 11):

This zone was defined originally by Mohler and Hay (1967) to include the interval from the last occurrence of *Tribrachiatus contortus* (Stradner) to the first occurrence of Discoaster lodoensis Bramlette and Riedel. Where T. *contortus* (Stradner) is absent, T. *orthostylus* Shamrai is often used as the marker for the lower boundary of this zone (Pereh-Nielsen et al. 1974). Discoaster binodosus Zone is equivalent to D. *binodosus* subzone (CP 9b) introduced by Okada and Bukry (1980).

Kerdany (1970) recognized this zone in Egypt. Shafik and Stradner (1971) found the *Discoaster binodosus* Zone in the upper part of the Esna shale in Gebel Tarbouli as well as in the uppermost part of the same formation of the Hamrawein and Gebel Duwi sections. Marzouk (1985) described this zone in Gebel Abu Had, El Sarai and Taramsa sections near Qena.

3. *Tribrachiatus orthostylus* Zone (NP 12):

Interval zone from the first occurrence of *Discoaster* lodoensis Bramlette and Riedel to the last occurrence of Tribrachiatus *orthostylus* Shamrai.

This zone was originally defined by Bronnimann and Stradner (1960), as *Marthasterites tribrachiatus* Zone from the Capdevilla Formation in Cuba. T. *orthostylus* Zone corresponds to the T. *orthostylus* subzone (CP 10) of Okada and Bukry (1980).

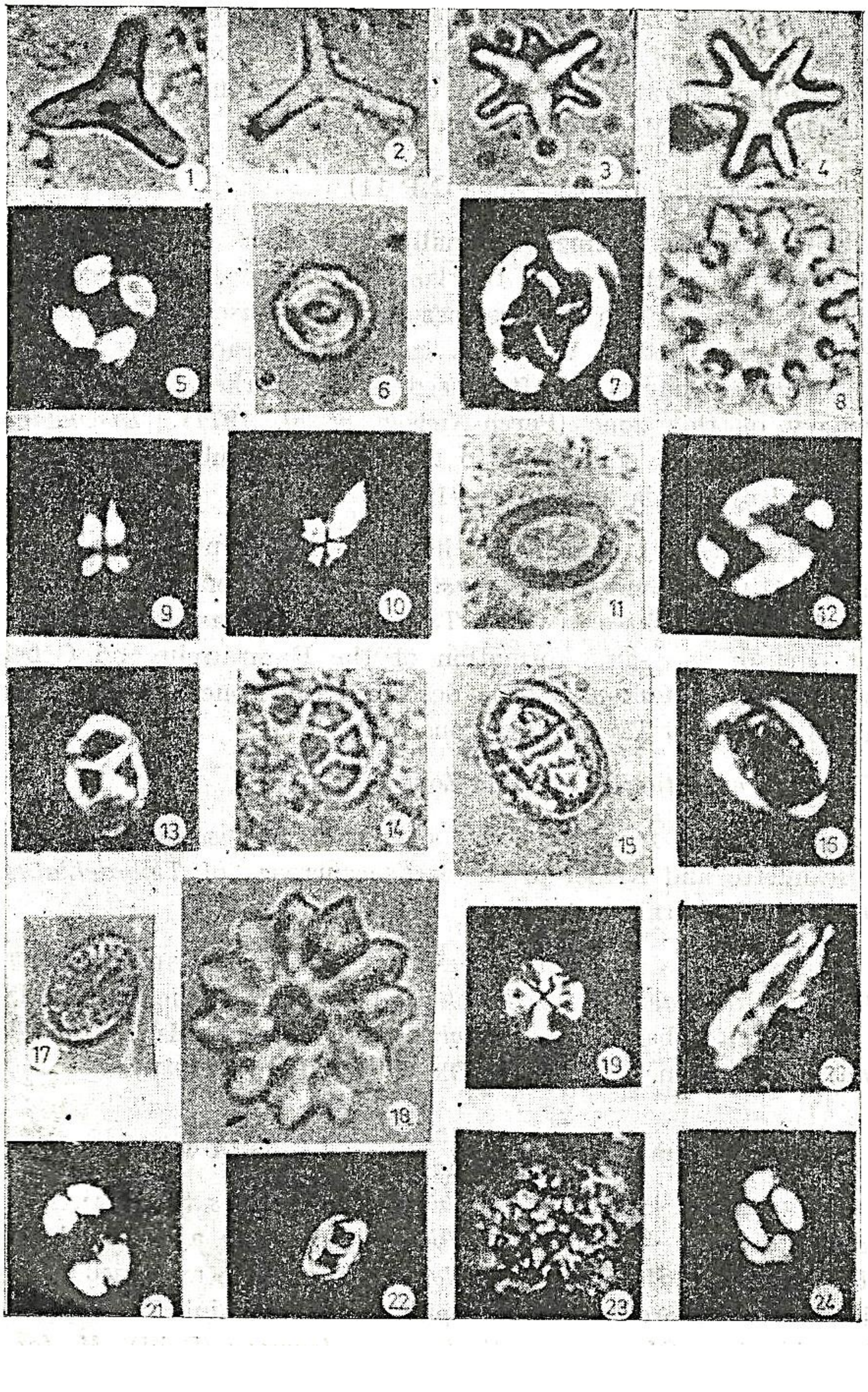

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Fig: 18 Tribrachiatus orthostylus Shamrai Sample No. 89, *Tribrachiatus* orthostylus Zone (NP 12).

3: *Tribrachiatus* nunii (Bronnimann and Stradner)

Sample No. 82, *Tribrachiatus* contorts Zone (NP 10)

4: *Tribrachiatus* contorts (Stradner)

Sample No. 81, *Tribrachiatus* contorts Zone (NP 10)

5, 6: *Cyclococolithus* formosus Kempten

Sample No. 87, Discoaster binodosus Zone (NP 11)

7: *Chiasm olithus* eograndis (Bramlette and Sullivan)

Sample No. 80, *Tribrachiatus* contortus Zone (NP 10)

8: Discoaster binodosus Martini

Sample No. 86, Discoaster binodosus Zone (NP 11)

9, 10: Sphenolithus radians Deflandre

Sample No. 92, *Tribrachiatus* orthostylus Zone (NP 12))

11, 12: Transversopontis pulcher (Deflandre)

Sample No. 87, Discoaster binodosus Zone (NP 11)

13, 14: *Neococcolithus* dubicus (Deflandre)

Sample No. 92, *Tribrachiatus* orthostylus Zone (NP 12)

16: Zygodiscus plectopons Bramlette and Sullivan

Sample No. 85, Discoaster binodosus Zone (NP 11)

17, 21: *Pontosphaera multipora* (Kamptner)

Sample No. 88, Discoastcr binodosus Zone (NP 11)

18: Discoaster barbadiensis Sample No. 94, Discoaster binodosus Zone (NP 11).

15, 19: Sphinolithus moriformis (Bronnimann and Stradner)
Sample No. 90, Tribrachiatus orthostylus Zone (NP 12)

20: Zygrhablitnus bijugatus (Deflandre)
Sample No. 81, Tribrachiatus contortus Zone (NP 10)

22: Placozygus sigmoidcs (Bramlette and Sullivan)
Sample No. 80, Tribrachiatus contortus Zone (NP 10)

23: Thoracosphaera operculata Bramlette and Martini
Sample No. 85, Discoaster binodosus Zone (NP 11)

24: Coccolithus pelagicus (Wallich)
Sample No. 91, Tribrachiatus orthostylus Zone (NP 12)

The co-occurrence of *Tribrachiatus orthostylus* Shamrai, Discoaster binodosus Martini, D. lodoensis Bramlette and Riedel, D. barbadiensis Tan Sin Hok, D. Deflandrei Bramlette and Riedel, to- gether with the presence of the planktonic foraminifers, Morozovella subbotinae (*Morozova*), M. Formosa Formosa (Bolli), M. formosa gracilis (Bolli), M. *marginodentata* (Subbotina) .

Dohastigerina wilcoxensis (Cushman and Ponton) in the studied samples (Fig. 14) indicates an Early Eocene age for the Gebel Qabeliat section. This conclusion is based on documented data presented by many authors working on material from various parts of the world.

In the study area a high resolution biostratigraphic zonation can be demonstrated. The high resolution biostratigraphic zone, as defined by Hay and Mohler (1969), is a combined zone with a binominal name. The former part of the name indicates the planktonic foraminiferal zone established by Bolli (1966) and the second refers to the calcareous nannoplankton zone suggested by Hay and Mohler (1967). Therefore, for Gebel Qabeliat section (Fig. 13), the combined planktonic foraminiferal - calcareous nannoplanktonic zonation can be summarized as follows:

Lower Eocene

d) *Morozovella formosa formosa* — Tribrachiatus orthostylus Zone

2. *Morozovella subbotinae* — *Discoaster* binodosus Zone

1. *Morozovella subbotinae* — *Tribrachiatus contortus* Zone

It is considered here that the proposed high resolution biostratigraphic zonation based on the two different planktonic fossils is much more accurate than any of the zones based only upon one of these involved faunal elements.

The total absence of planktonic foraminifers and calcareous nannofossils in the Middle Eocene samples is significant clue to indicate a change in the paleoecological conditions prevailed at the end of the Lower Eocene and/or in basal Middle Eocene. Resumption of shallow marine conditions is evidenced by the up-sequence appearance of larger foraminifers *Nummilites* spp. and *Assilina* spp.

Chapter six

Summary and Conclusions

Gebel Qabeliat lies in the southwestern of Sinai on the east bank of the Gulf of Suez, about 220 km south of Suez. It is situated between latitudes 28° 41' and 28° 14' N and between longitudes 33° 15' and 33° 37' E. It stretches in a northwest direction, occupying the area between the Araba range and El-Qaa plain. It is bounded to the north by Wadi Feiran and to the south by Gebel Hammering Saidna Musa which borders the plain in which lies El Tor.

Gebel Qabeliat is an excellent stratigraphic outcrop ranging in age from probable Permo-Carboniferous sandstones through Cretaceous, Paleocene and Eocene lime stones to Miocene beds. The dip of these beds is regularly eastward where the beds disappear under the alluvial deposits filling El Qaa plain.

The geology of the Gulf of Suez region attracted the attention of a large number of geologists, because of the occurrence of petroleum along its shores. Barron (1907) in his "Topography and Geology of the Peninsula of Sinai (Western portion)" has written the most complete account of the investigated area which has been published. The small area around Gebel Abu Durba (Western Gebel Qabeliat) has been described in "Preliminary Geological Report on Abu Durba (Western Sinai) "written by Hume et al. (1921). A short description of the geology of the studied area is given in "Report on Boring for Oil in Egypt" by Bowmann (1952). A detailed work on "El-Qaa plain and adjacent areas" was followed by Perez (1838), who mapped the area in scale 1:100,000.

The exposed sedimentary rocks of the present area include the Cambrian-Lower Cretaceous Nubia Sandstone; Upper Cretaceous,

Paleocene, and Eocene limestones; Miocene marls, shales and evapomes; and Pliocene-Pleistocene sands and gravels. The
sedimentary succession follows

Studies on Pre-Cenomanian sandstone succession at the north, part of Gebel Qabeliat, east Gebel Abu Darba, southwest Sinai, have been undertaken. Samples were collected from the sandstone beds overlying Precambrian rocks and subjected to grain size and X-ray diffraction analysis.

The studying biostratigraphical subdivisions, based on both planktonic foraminifers and calcareous nannofossils. The samples used in the present study were collected from the Early Eocene beds of Gebel Qabeliat, Gulf of Suez, and Sinai, Egypt.

Two planktonic foraminiferal biozones were recorded: Morozovella subbotinae Zone and Morozovella Formosa Formosa Zone. Their relevant calcareous nannofossil biozones are : Tribrachiatus contortus Zone, Biscoaster binodosus Zone and Tribrachiatus orthostylus Zone. These biozones were recorded for the first time in the study area. Furthermore, a high resolution biostratigraphic zonation can be established for the Early Eocene in Gebel Qabeliat section.

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الملخص العربي

يقع جبل قابليات على الاتجاه الشرقيِ لخليجِ السويس، بين وادى فيران في الجزءِ الجنوبي في جبل قابليات الغربيِ لسيناء. هو يُحاطُ من ناحيه الغرب بوادي عربةِ، وشرقاً بسهل المنطقة الجنوبية الغربية التى تُواجهُ منحدراً حادّاً في كافة أنحاء إمتدادِه.

الغرض الاساسي من دراسه الصخور الرمليه في المنطقه المذكوره اعلاه هو معرفه نوعيه تكوين هذه الصخور ومصدرالرسوبيات ونوعيتها وطريقه انتقال الرسوبيات والعوامل التى سادت فى ذلك الحين اثناء عمليه الترسيب .

المعادن الفتاتيه المكونه للصخور الرمليه وجد انها من معدن المرو والفلسبار اضافه الى كميه قليله من اكسيد الحديد اما بالنسبه للمعادن الطينيه فان معدنى الكاولينيت والاليت وكذلك الاليت _والسمكتيت هى المعادن الرئيسيه في طبقات القطاع المدروس .

من العلاقه الموجبه بين معدن الاليت وكل من المرو والفلسبار امكن التكهن بان معدن الاليت هو من اصل قاري وانه حمل بواسطه الانهار او الرياح من المناطق القريبه الى مكان الترسيب ومن العلاقه السالبه بين هذين المعدنين ومعدن الكاولينيت امكن الاستنتاج بات معدنى المرو والفلسبار هما من اصل فتاتى اى انها نواتج تعريه الصخور الناريه القريبه وانها نقلت بعد ذلك الى مكان الترسيب في بيئات نهريه او شاطئيه او بحريه.

يتناول هذا البحث دراسه التقسيمات البيواستراتيجرافيه لكل من الفورامينفرا الهائمه والفانوبلانكتون الجيريه كما يشمل مقارنه بين النطاقات الحيويه المستنبطه من القطاع المدروس لصخور الايوسين المبكر من جبل قابليات جنوب غرب سيناء بالنطاقات المعروفه فى مناطق مختلفه من العالم .

وتعتبر الفورامينفرا الهائمه والفلانكتون الجيريه من الدلائل القويه لتحديد عمر الصخور وقد تم التعرف على صحبه الفانوبلانكتون الجيريه وكذلك افورامينفرا الهائمه بما يؤكد ان عمر القطاع سالف الذكر هو الايوسين المبكر وقد استند هذا الى اراء كثير من المؤلفين .وقد تم تمييز نطاقين للفورامينفرا الهائمه وكذلك 3 نطاقات للفانوبلانكتون الجيريه. ويرجع عدم وجود الفانوبلانكتون الجيريه والفورامينفرا الهائمه في الجزء العلوى من القطاع الي تغير الظروف المناخيه في نهايه الايوسين المبكر او بدايه الايوسين المتوسط ويرجع ذلك الى ان الاجزاء العليا قد ترسبت فى بيئه بحريه ضحله ويستدل على ذلك الفورامينفرا الكبيره.