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Textural, Mineralogical and Microfacies Characteristics of the Lower Paleogene Succession at the Nile Valley and Kharga Oasis Regions, Central Egypt

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Abstract

Four lithostratigraphic successions covering the Early Paleogene time have been measured and sampled at the Nile Valley and Kharga Oasis areas in central Egypt. They include the Early-Late Paleocene upper Dakhla Shale and the Tarawan Chalk, and the Late Paleocene-Early Eocene Esna Shale. There is no marked variation between the grain size distribution of the Dakhla and Esna shales. They are generally composed of medium and coarse silts with small amounts of sand and clay. XRD analysis revealed the dominance of smectite with relatively low contents of kaolinite and illite and sporadic occurrence of palygorskite. Smectite was formed under warm semi-arid climatic conditions. Kaolinite, on the other hand, was formed under tropical to subtropical humid conditions. The relative proportions of smectite to kaolinite are controlled by the hydraulic sorting which concentrates kaolinite in the nearshore and shallow areas and drifts the smectite to deeper settings. The non-clay minerals are dominant by calcite with lower contents of quartz and local occurrences of feldspars. The high calcite content is consistent with the abundant calcareous fossils in the studied sediments. Dakhla Shale contains high carbonate contents and this is attributed to the high carbonate productivity and reduction of the detritus influx during a period of sea level highstand. On the other hand, low carbonate contents of the Esna Shale was attributed to the dilution by high terrigenous influx during sea level lowstand. Petrographic examination of the Tarawan Chalk sediments and the interbedded limestones within the Dakhla Shale has led to the identification of four carbonate microfacies. These microfacies are: mudstone/wackestone, wackestone, wackestone/packstone and packstone. Dissolution of skeletal grains and infilling with iron oxides and neomorphic calcite are the dominant diagenetic features.

Key-words : Dakhla Shale, Esna Shale, Tarawan Chalk, Nile Valley Facies, clay minerals.

Introduction

Lower Paleogene sediments were deposited over large areas of Egypt as far south as the border of Sudan. They are widely distributed in the Eastern and Western Deserts, Nile Valley, Gulf of Suez area and Sinai. Among these areas, the lower Paleogene sediments at the Central Nile Valley and the Kharga Oasis display gross lithologic similarities and they belong to the same facies type (Nile Valley Facies) (Issawi, 1972).

The lower Paleogene succession of the Nile Valley facies has attracted the attention of several geologists. Most of the previous studies were interested in the litho- and biostratigraphic aspects (Said, 1962; 1990; Strougo, 1986; Speijer and Schmitz, 1998; Faris et al., 1999 and others) and the mineralogical characteristics of the succession (Marzouk, 1985; Soliman et al., 1989; Tantawy et al., 2001). However, no previous studies have been done on the textural characteristics and the carbonate contents of the lower Paleogene sediments in this area.

The present study aims at discriminating the lower Paleogene shales on the basis of their textural and mineralogical attributes, identifying the different microfacies of the carbonate rocks, shedding light on the paleoproductivity and paleoclimatic conditions that prevailed during Early Paleogene time and their influence on the sediment composition.

Background and Lithologic Subdivisions

Said (1962) subdivided Egypt into two major tectonic provinces, the tectonically deformed Unstable Shelf to the north (approximately to the North of latitude 28°) and the nearly horizontal and less deformed Stable Shelf to the south. Intracratonic sedimentary basins were developed on the southern Stable Shelf, whereas pericratonic or rift basins were formed on the northern Unstable Shelf (El-Hawat, 1997)

In the Stable Shelf of Egypt, thick Phanerozoic succession was deposited in two broad intracratonic depocenteres, the Upper Nile and the Dakhla basins. They are separated from each other by the Kharga and Dakhla basements, which are aligned in N-S and WNW-ESE directions, respectively. These basins have evolved as a result of structural differentiation and subsidence of the rigid cratonic plate (El-Hawat, 1997). Precambrian crystalline basement highs surround these basins from the southern and eastern sides and they were the main source for terrigenous sediments during Phanerozoic time. During Late Cretaceous, the Dakhla and Upper Nile basins were joined as a result of relief inversion and subsidence of the Kharga high (El-Hawat, 1997).

The lower Paleogene sediments in the Upper Nile basin disconformably overlie the Cretaceous sediments and are separated from it by thin intraformational conglomerate carrying reworked Cretaceous fossils (Said, 1990). Strougo (1986) related the stratigraphic relationships in the south and central Western Desert and in other areas to a large scale syndepositional tectonic disturbance, including faulting, which had led to marked changes of depositional pattern and he named this as *Velascoensis* Event.

The Paleogene was ushered in by a transgression, which pushed its way across the southern borders of Egypt into north Sudan. The maximum transgression occurred during the Late Paleocene. After the Paleocene, the sea kept retreating towards the north almost continuously except for short intervals (Said, 1990).

The lower Paleogene succession of the Nile Valley facies forms a tripartite subdivision arranged in ascending order as the upper Dakhla Shale (Said, 1962), the Tarawan Chalk (Awad and Ghobrial, 1965) and the Esna Shale (Zittel, 1883) (Fig. 1). These sediments were deposited in inner to middle shelf settings.

The Dakhla Shale was first described by Said (1962) to describe the 130 m of shale succession overlying the upper Cretaceous phosphate bearing the Duwi Formation and underlying the Tarawan Chalk at the Mut location, Dakhla Oasis. Generally, the age assigned to the Dakhla Shale is Late Cretaceous-Paleocene (Said, 1962; Faris et al., 1999). The basal part of the Dakhla Shale (Upper Cretaceous-lowermost Paleocene) is not represented herein. The studied upper part of the Dakhla Shale consists of 32-46 m of offshore fossiliferous greenish grey, calcareous shale, marl and argillaceous limestones. The studied interval of the Dakhla Shale ranges from Early Paleocene (NP2) to Late Paleocene (NP7/8) (Faris et al., 1999).

The Tarawan Chalk (Awad and Ghobrial, 1965) consists of fossiliferous, partly marly or chalky, yellowish white limestone of an outer shelf facies. The boundary between the Tarawan Chalk and the underlying Dakhla Shale forms a significant regional disconformity recognized throughout southern and central Egypt. It corresponds to the boundary between the planktonic foraminiferal zones P3 and P5, and is referred to as the "*Velascoensis* Event" (Strougo, 1986; Hermina, 1990). The Tarawan Chalk varies in thickness from 13 to 36 m. It is of Late Paleocene age (NP5-NP7/8 Zones) (Faris et al., 1999).

The Esna Shale (Zittel, 1883) is a thick succession of green shale, enclosing marl and limestone intercalations and lies between the two carbonate units, the Tarawan Chalk at the base and the Thebes Formation at the top. Like the Dakhla Shale, the Esna Shale is inferred to be accumulated mostly in inner to middle shelf environments (Said, 1990). The age of the Esna Shale is Late Paleocene-Earl Eocene (NP7/8-NP11) (Faris et al., 1999).

Materials and Analytical Techniques

The materials of the present study were collected from two different areas in Central Egypt; the Qena-Esna stretch on the eastern border of the Nile Valley and the Kharga Oasis. Four lithostratigraphic sections (Fig. 1) were measured and sampled at G. El-Sheikh Eisa (Qena region), G; El-Shaghab (Esna region), G.

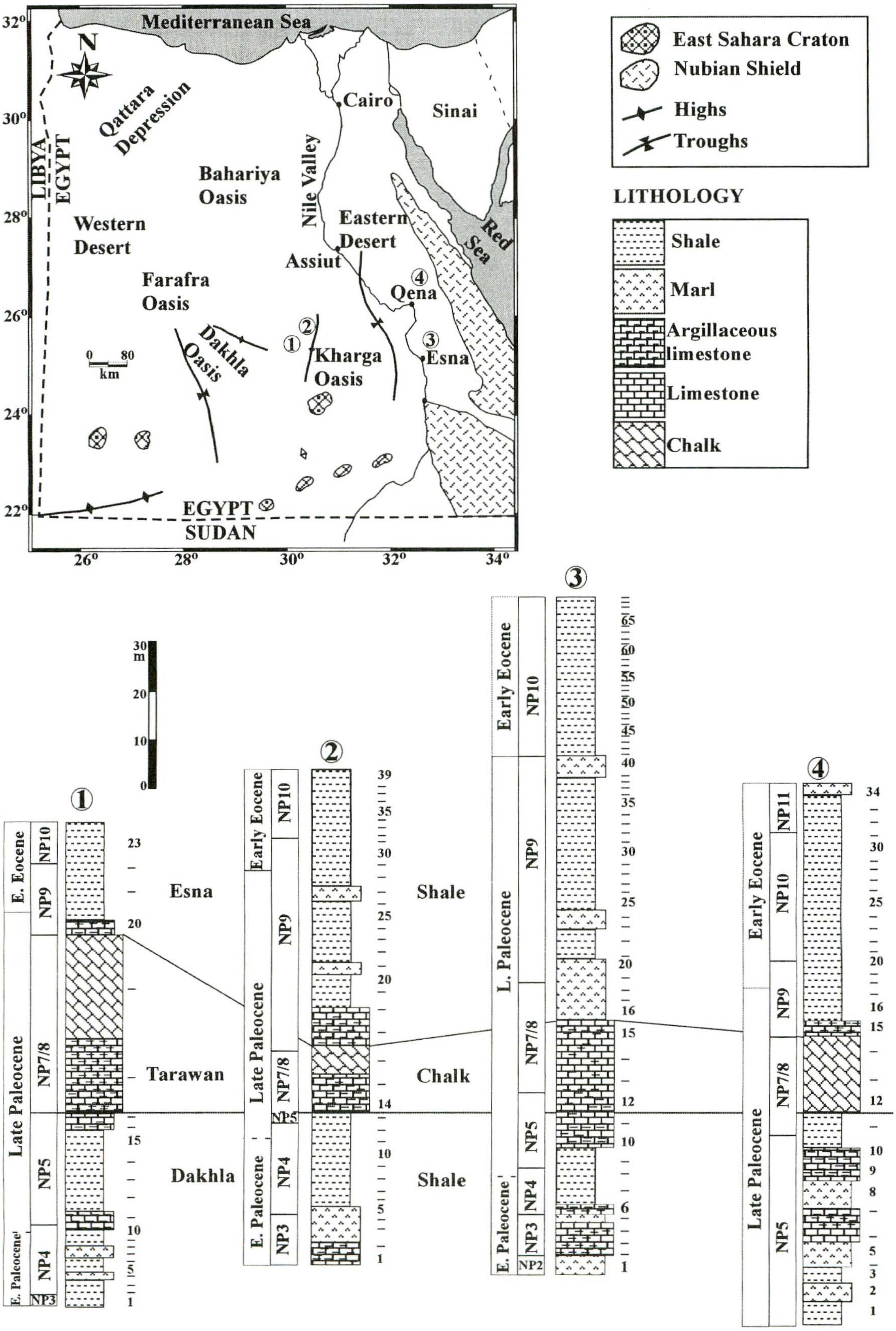

Fig. 1 Location map and the lithostratigraphic sections at the studied locations. 1) G. Teir/Tarawan, 2) G. Um El-Ghanayum, 3) G. El-Shaghab and 4) G. El-Sheikh Eisa. The relative age and calcareous nannofossil zones are modified after Faris et al. (1999). The numbers at the right of the stratigraphic sections indicate sample numbers.

Um El-Ghanayum and G. Teir/Tarawan (Kharga Oasis). A Total of 165 samples were collected for the present work. The lithology, the number of samples and their locations in each section are shown in Fig. 1. The studied sediments were analyzed for their textural (42 samples), mineralogical (18 samples) and carbonate microfacies characteristics (13 samples). In addition, the carbonate contents of the studied sediments were also determined.

The pipette method (Galehouse, 1971; Lewis and McConchie, 1994) is used here to determine the sand, silt and clay contents of the Dakhla and Esna shales. The sediments were easily disintegrated when soaked in water. They were covered by 15% of H_2O_2 to remove the organic matter and act as a dispersant agent. The sand fraction is determined by 63 μm wet sieving, dried and weighed. The mud fraction (silt and clay) was then placed in 1000 ml cylinder and the distilled water was added until the volume was exactly 1000 ml. After checking the temperature, several withdrawals at specific times were taken (Folk, 1968).

The XRD analyses were carried out using a RIGAKU RAD-I X-ray powdered Diffractometer with Cu Kα radiation and energy of 30 kV and 10 mA. Small pieces (30 gm) of shale samples were dried and finely powdered with agate mortar and pestle. The mineralogical investigation was carried out on the bulk rock and on the clay sized (<2 μm) fractions. For the bulk rock mineralogy, the powdered samples were packed into a cavity bearing glass slide (Hardy and Tucker,

Table 1 Results of the textural analysis.

Location	Fm	S. No	Sand wt %	Silt wt %							Clay wt %
			<4Φ	4Φ	4.5Φ	5Φ	5.5Φ	6Φ	7Φ	8Φ	>8Φ
G.Teir/ Tarawan	Esna Shale	T-21	10	3	7	20	10	16	17	0	17
		T-15	1	3	19	64	6	1	1	0	6
	Dakhla Shale	T-13	4	15	45	20	3	3	0	2	7
		T-6	3	27	22	38	2	1	2	2	3
		T-3	3	6	20	33	16	11	1	1	8
G. Um El-Ghanayum	Esna Shale	G-37	0	1	11	76	5	1	0	0	5
		G-35	0	12	13	63	4	2	1	0	6
		G-34	0	2	5	30	55	3	1	0	4
		G-30	1	1	10	79	3	1	0	1	4
		G-28	1	5	3	78	4	2	2	1	5
		G-26	7	2	6	11	68	1	1	0	4
		G-25	3	4	9	30	48	1	1	0	4
		G-24	1	3	7	22	59	2	0	1	6
		G-22	3	2	7	20	58	1	0	2	6
	D. Sh	G-12	1	1	6	14	67	4	0	2	5
G. El-Shaghab	Esna Shale	S-67	10	7	7	53	14	1	1	2	6
		S-66	2	9	17	51	7	5	1	0	7
		S-64	2	4	16	58	2	9	0	0	8
		S-62	1	8	5	46	22	8	2	1	7
		S-59	2	5	9	68	3	6	0	2	6
		S-54	1	5	5	20	5	18	11	21	16
		S-52	1	4	8	19	12	14	12	11	20
		S-51	1	4	5	12	16	17	17	15	14
		S-49	1	2	9	11	16	14	11	19	18
		S-47	1	1	0	12	6	32	35	0	12
		S-45	1	2	11	12	16	13	13	6	25
		S-44	4	6	10	13	14	18	19	9	8
		S-42	2	3	16	16	9	14	9	15	17
		S-37	1	3	3	1	8	39	34	1	9
		S-36	0	3	7	81	0	3	0	0	6
		S-33	5	4	7	75	3	0	0	0	6
		S-32	2	4	2	14	37	28	1	4	7
		S-25	7	3	2	75	4	1	0	0	7
G. El-Sheikh Eisa	Esna Shale	E-31	1	6	15	35	37	0	0	1	6
		E-28	3	3	8	21	62	0	0	0	4
		E-26	1	3	8	35	44	0	0	0	7
		E-24	1	2	15	21	55	0	0	0	1
		E-22	1	4	9	41	36	0	0	0	7
		E-20	8	3	10	46	21	1	1	0	9
		E-19	6	3	9	67	5	1	2	0	7
		E-16	2	0	26	65	0	1	0	0	5
	D. Sh.	E-11	5	11	69	6	0	0	0	1	8

D. Sh.: Dakhla Shale

1988). The slides are then scanned by XRD at a rate of 1°/minute from 2° to 40° 2θ. For clay (<2 μm) minerals analysis, X-ray diffraction was undertaken on oriented aggregates. Samples were completely dispersed in diluted solution of *calgon* to avoid flocculation. The clay fractions (<2 μm) were separated by centrifugation. Oriented samples of the clay (<2 μm) fractions were prepared by carefully pipetting the clay suspension on a glass slide allowing the fractions to be homogeneously distributed. For determination of the clay mineral composition, the oriented samples were X-ray scanned under four separate conditions: air-dried, after saturation with ethylene glycol, after treatment with warm 6N HCl and after heating to 550℃. All slides were scanned at a rate of 1°/minute at a range from 2° to 30° 2θ. Minerals were identified by their characteristic reflections as discussed by Moore and Reynolds (1989). The basic (001) reflection of glycolated smectite is 17 Å and the (001) and (002) reflections of kaolinite are 7.16 Å and 3.58 Å, respectively. Illite was identified at 10 Å and palygorskite at 10.5 Å. The following peaks identify non-clay minerals: quartz, 4.26 Å, K-feldspar, 3.25 Å, and calcite 3.04 Å. Because the intensity of a diffraction pattern (generally expressed as peak height or peak area) of a mineral in a mixture is proportional to its concentration, the relative proportions (semiquan-

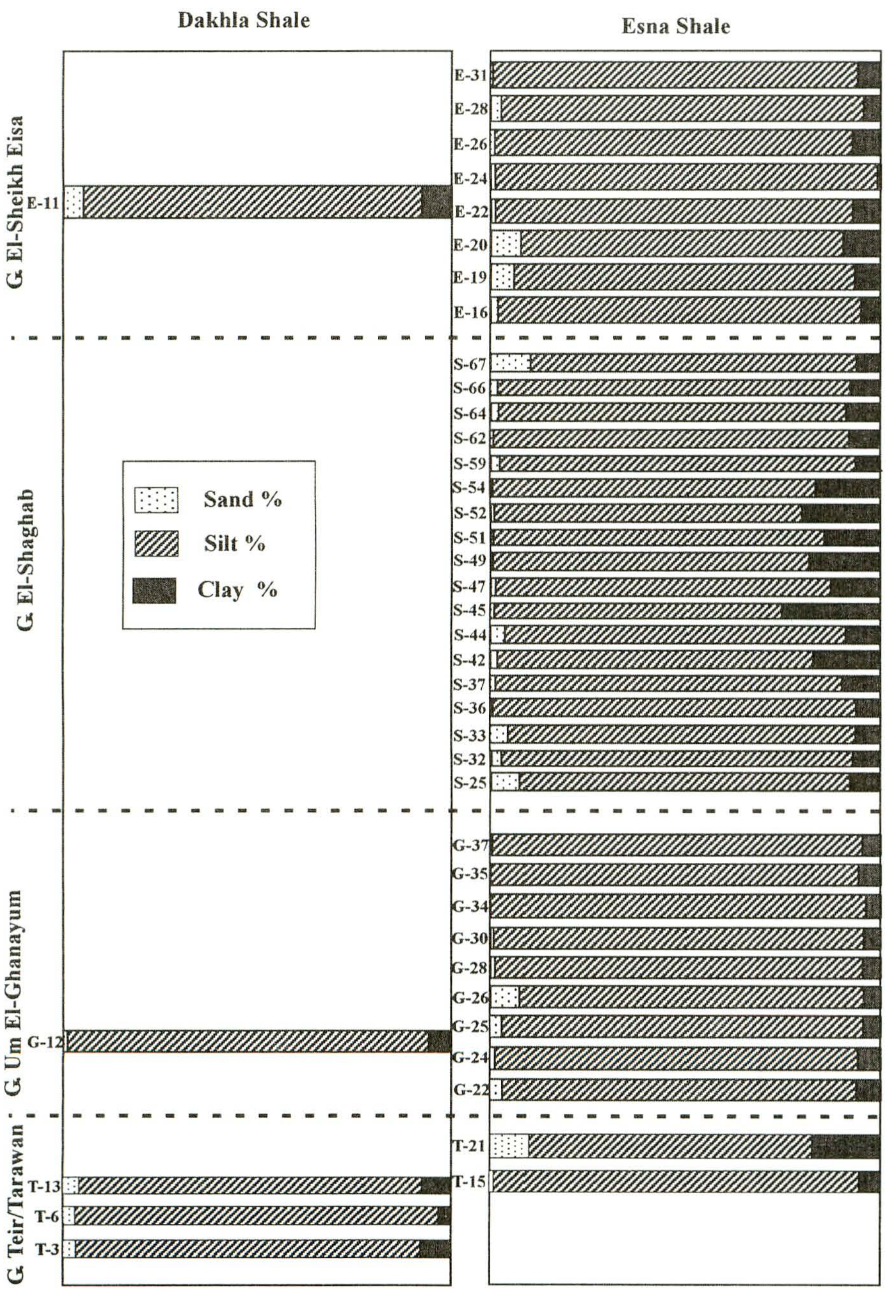

Fig. 2 Sand, silt and clay percentages identified from the grain size analysis of the studied shales.

titative in nature expressed as vol %) of the identified minerals are roughly determined using their peak intensities using the Mac Diff 4.2.5 software. In the case of bulk rock mineralogy, mineral abundances were determined using peak heights, whereas the integrated peak areas of glycolated samples were used to determine the relative abundances of the <2 μm m fractions. The clay fractions were measured using a formula: kaolinite/2.5 + smectite + illite + palygorskite = 100% (Hardy and Tucker, 1988).

The microfacies analysis were carried out on stained (Alizarin Red S) carbonate rocks of the lower Dakhla Shale and the Tarawan Chalk. The petrographic classification of Folk (1959) and the depositional textures of Dunham (1962) are followed herein.

In addition, the carbonate contents of the studied sediments were also determined following the method described in Lewis and McConchie (1994), which is based on the digestion of carbonates using 1M HCl and the back titration of the unused acid by 1M NaOH using phenolphthalein indicator.

Results

Grain-size distribution

The sand, silt and clay percentages determined by

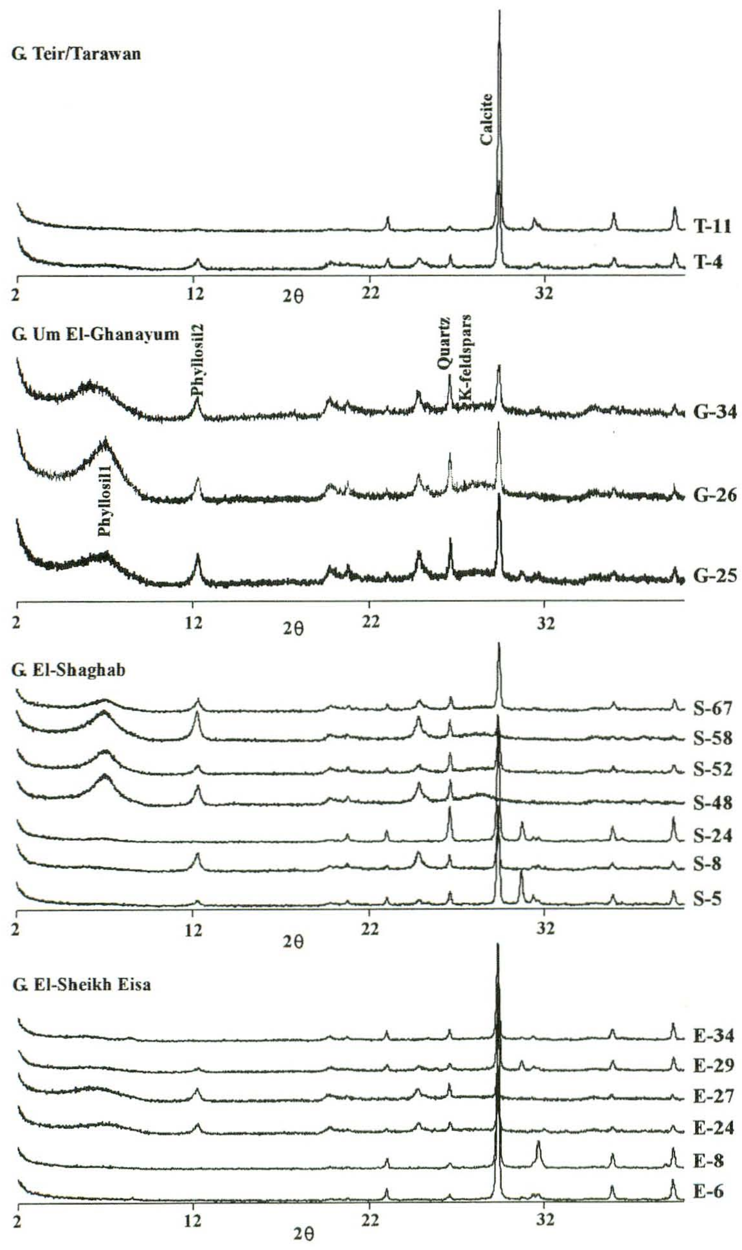

Fig. 3 Representative X-ray diffractograms of the lower Paleogene sediments. (A) bulk rock mineralogy and (B) clay size (<2 μm) fraction.

pipette analysis are shown in Table 1 and Fig. 2. The results of the textural analysis exhibit no marked textural difference between the Dakhla and Esna formations. The Dakhla and Esna shales are composed mainly of coarse to medium silts with subordinate quantities of sand and clays. Sand fraction is recorded with relatively lower values and never exceeds 10%. It fluctuates vertically without definite trend. The highest sand peak (10%) was obtained from the upper Esna Shale at G. El-Shaghab and G. Teir Tarawan.

Silt is the dominant size fraction. The Dakhla Shale has relatively higher silt contents than the Esna Shale. The upper Dakhla Shale at G. Um El-Ghanayum has the highest silt contents (94%), whereas the lowest

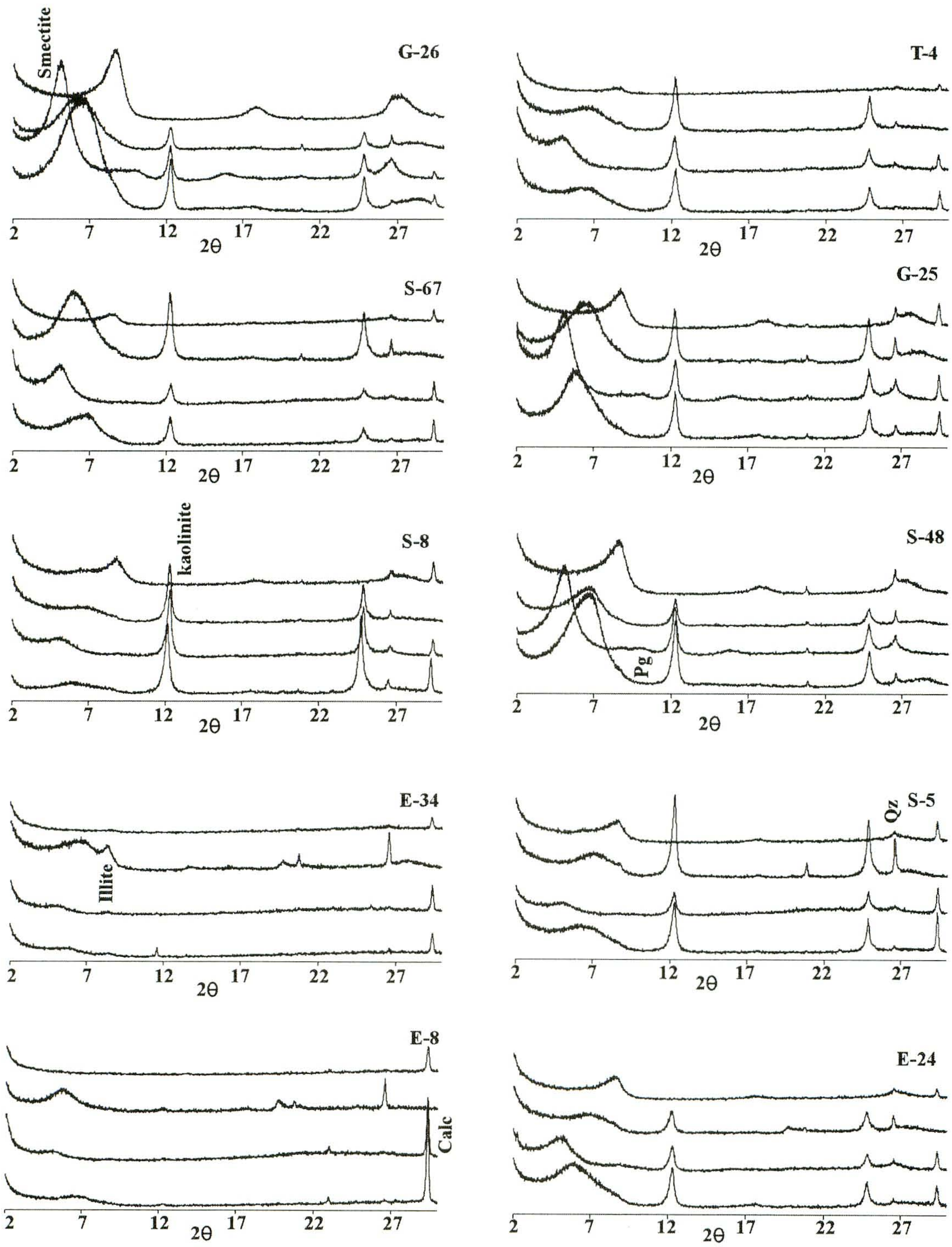

Fig. 3 Continued.

value (73%) was obtained from the upper Esna Shale at G. Teir/Tarawan. The silt contents determined from the Esna Shale sediments vary from 73 to 96%. A wide spectrum of different size classes ranging from very fine silt to coarse silt was observed from the studied sediments. Among silt-size classes, 5$\phi$and 5.5ϕ are the dominant. The values of the 5ϕ vary from 1 to 81%, whereas the 5.5ϕ was recorded with values ranging from 0 to 68%. The clay contents are generally low if compared with silt. However, they recorded relatively higher abundances than the sand-fraction contents. The Esna Shale at G. El-Shaghab yields the highest average clay values (ranging from 6% to 25% and averaging, 11%), whereas the Dakhla and Esna shales at G. Um El-Ghanayum have the lowest average values (5%).

XRD data

The results of the XRD analysis are illustrated in Fig. 3 and summarized in Table 2. The bulk rock mineralogy indicates the presence of phyllosilicates with abundant calcite, and common occurrence of detrital quartz and few and locally low feldspars contents.

Calcite is the most abundant non-clay minerals in the studied sediments. It is recorded with high abundance in the bulk and clay-size mineralogy. It ranges from 16 to 97 % of the bulk rock mineralogy. Generally, the lower Paleogene sediments at G. El-Sheikh Eisa contain higher calcite contents than the other locations. However, the upper Dakhla Shale sediments contain higher calcite contents than the sediments of the Esna Shale. The Dakhla Shale sediments yield calcite with values ranging from 58%-97%, whereas the calcite contents in the Esna Shale sediments range from 16% to 88%. Quartz contents are recorded with relatively low to moderate abundance. It varies from 2% to 32%. The relatively higher quartz abundances were obtained from the Esna Shale sediments at the G. Um El-Ghanayum and the G. El-Shaghab. Feldspars were recorded with very low abundance, less than 4%.

The clay mineral (<2 μm) distribution of the lower Paleogene sediments displays a fairly constant composition. Smectite constitutes the most abundant mineral (35% to 93% of the total clay minerals). The Esna Shale sediments contain relatively higher smectite contents than those of the Dakhla Shale.

Kaolinite is the second abundant clay mineral. It varies from 3% to 58%. The sediments of the Esna area (G. El-Shaghab) have relatively higher kaolinite contents. Illite is recorded sporadically with relatively lower abundances. It ranges from 3% to 34%. Subordinate amounts of palygorskite (less than 10%) were obtained from the Esna Shale sediments at the G. El-Shaghab and the G. Um El-Ghanayum.

Carbonate microfacies

Based on the textural classification of carbonate

Table 2 Results of the XRD analysis.

Location	Fm	S. No	Bulk Rock Mineralogy				Clay-size (<2 μm) Mineralogy					
			Phyll v%	Qz v%	Fels v%	Cal v%	Sm v%	Ilt v%	Palg v%	Kao v%	Qz v%	Cal v%
G.Teir/ Tarawan	D. Sh.	T-11	-	3	-	97	59	17	-	24	F	A
		T-4	11	10	-	79	60	9	-	31	R	F
G. Um El-Ghanayum	Esna Shale	G-34	30	27	3	40	86	-	-	14	R	R
		G-26	32	22	3	43	84	-	7	9	R	R
		G-25	25	21	-	54	80	3	4	13	F	F
G. El-Shaghab	Esna Shale	S-67	20	12	-	68	83	-	-	17	R	F
		S-58	63	21	-	16	73	3	-	24	F	R
		S-52	26	20	-	54	86	-	5	9	R	R
		S-48	68	32	-	-	46	5	10	39	C	-
		S-24	-	23	-	77	93	-	4	3	A	A
	D. Sh.	S-8	24	16	2	58	35	7	-	58	F	C
		S-5	5	11	-	85	46	18	-	36	A	A
G. El-Sheikh Eisa	Esna Shale	E-34	4	9	-	88	66	34	-	-	R	A
		E-29	6	7	-	87	71	10	-	19	R	A
		E-27	30	24	2	44	-	-	-	-	-	A
		E-24	20	12	2	66	67	11	-	22	F	C
	D. Sh.	E-8	-	3	-	97	86	-	-	14	F	A
		E-6	2	3	-	95	73	15	-	12	F	A

A: Abundant, C: Common, F: Frequent, R: Rare, (-) not detected
D. Sh: Dakhla Shale
Phyll.: Phyllosilicates, Qz: Quartz, Fels.: Feldspars, Cal. Calcite, Sm.: Smectite, Ilt.: Illite, Kao.: Kaolinite

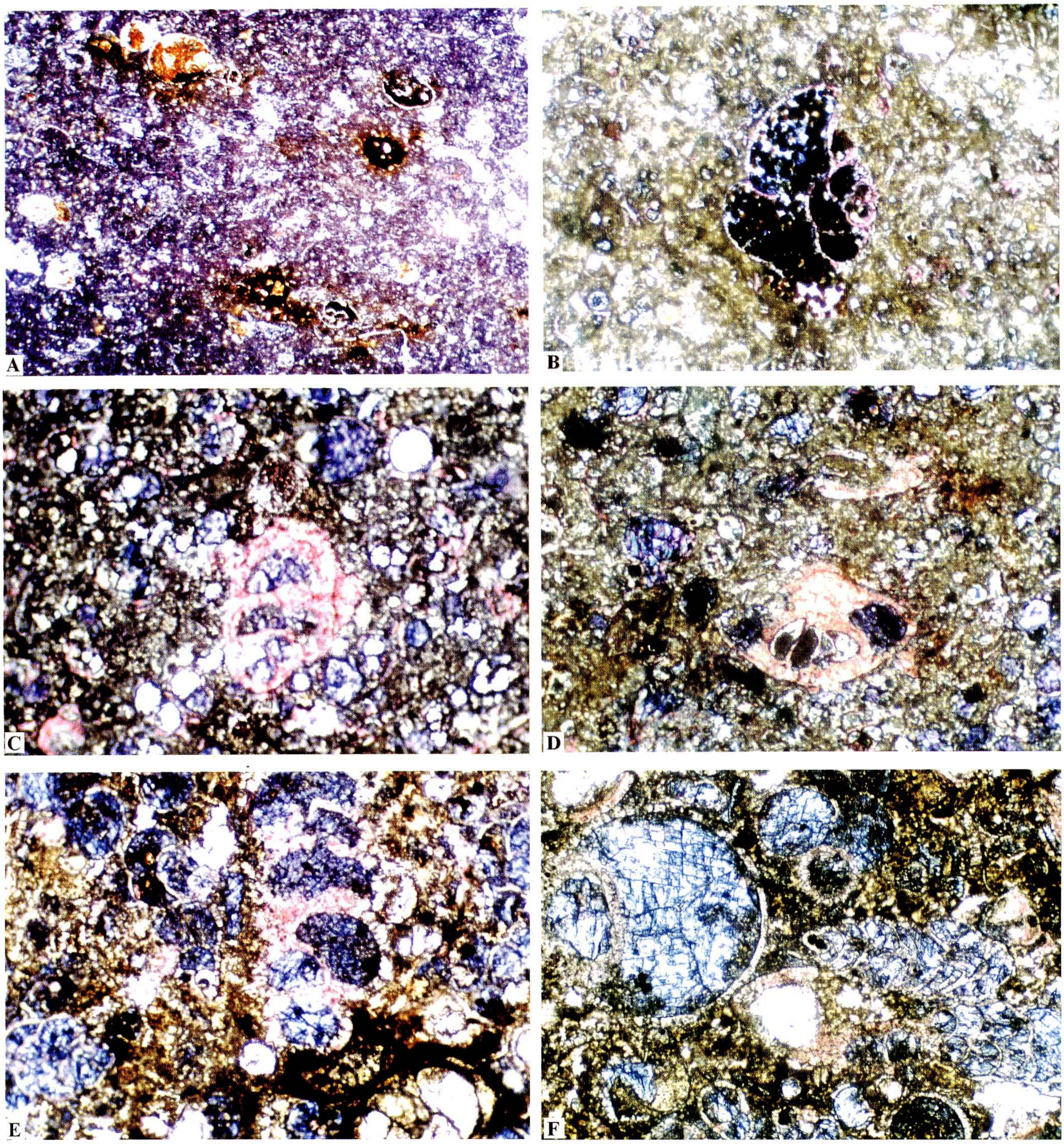

Fig. 4 Photomicrographs of the identified microfacies. (A) Wackestone microfacies, lower Tarawan Chalk at G. El-Shaghab. The broken planktonic foraminiferal tests are embedded within micrite. Note the iron oxide infilling and patches.X-50. (B) Wackestone microfacies, lower Tarawan Chalk at G. Um El-Ghanayum, the benthic foraminiferal test is completely filled with iron oxides. X-125. (C & D) Wackestone/packstone microfacies, upper Tarawan Chalk, G. Um El-Ghanayum. X-125. Notice the micritized wall of benthic foraminiferal tests and the infilling by sparry calcite. (E & F) Packstone microfacies, upper Dakhla Shale, G. El-Shaghab, X-125. Most of the foraminiferal tests are filled with ferroan sparry calcite.

rocks (Dunham, 1962), four microfacies were identified. They are: mudstone/wackestone, wackestone, wackestone/packstone and packstone. Photomicrographs of the different microfacies are shown in Fig. 4.

The mudstone/wackestone microfacies (Fig. 4A) is recorded from the upper part of the Tarawan Chalk at G. El-Shaghab. This facies is made up of dense and cloudy cryptocrystalline non-ferroan calcite containing some skeletal fragments (<10%) dominated by fragments of foraminiferal tests. Foraminiferal chambers are partially filled with iron oxides. Few iron oxide patches and dark ferruginous spots are scattered randomly.

The wackestone microfacies (Fig. 4A and B) is the common microfacies of the middle part of Tarawan Chalk at G. El-Shaghab, G. Um El-Ghanayum and G. El-Sheikh Eisa. Microscopically, the framework of this microfacies is composed of moderately sorted skeletal particles (25%) randomly scattered throughout the micrite. The skeletal particles include planktonic and benthic foraminifera. Most foraminiferal tests are partially or completely filled or replaced with recrystallized

Table 3 The carbonate contents of the studied sediments.

Location	G.Teir /Tarawan		G. Um El-Ghanayum		G. El-Shaghab				G. El-Sheikh Eisa	
Formation	S. No.	Car. wt%	S. No.	Car. wt%	S. No.	Car. wt%	S. No.	Car. wt%	S. No.	Car. wt%
Esna Shale	T-23	15	G-39	9	S-67	26	S-40	60	E-34	65
	T-22	21	G-38	12	S-66	17	S-39	53	E-33	42
	T-21	24	G-37	8	S-65	16	S-38	7	E-32	37
	T-20	99	G-36	7	S-64	17	S-37	8	E-31	24
			G-35	38	S-63	9	S-36	42	E-30	33
			G-34	12	S-62	14	S-35	42	E-29	47
			G-33	6	S-61	4	S-41	5	E-28	12
			G-32	19	S-60	10	S-34	49	E-27	10
			G-31	14	S-59	22	S-33	34	E-26	10
			G-30	17	S-58	7	S-32	5	E-25	16
			G-29	16	S-57	13	S-31	14	E-24	13
			G-28	21	S-56	11	S-29	54	E-23	21
			G-27	54	S-54	4	S-28	30	E-22	31
			G-26	35	S-53	22	S-27	18	E-21	21
			G-25	20	S-52	23	S-26	18	E-20	12
			G-24	17	S-51	6	S-25	28	E-19	34
			G23	21	S-50	10	S-24	73	E-18	36
			G-22	24	S-49	8	S-23	55	E-17	50
			G-21	51	S-48	6	S-22	49	E-16	43
			G-18	56	S-47	1	S-21	49	E-15	82
					S-46	14	S-20	64		
					S-45	18	S-19	66		
					S-44	28	S-18	79		
					S-43	5	S-17	76		
					S-42	6	S-16	73		
Tarawan Chalk	T-19	96	G-16	98	S-13	90			E-14	91
	T-18	84	G15	89	S-12	93			E-13	95
			G-14	88					E-12	96
Dakhla Shale	T-17	77	G-13	16	S-10	85			E-11	66
	T-16	92	G-12	11	S-9	19			E-10	87
	T-15	30	G-11	22	S-8	28			E-9	84
	T-14	23	G-10	23	S-6	70			E-8	70
	T-13	27	G-9	26	S-5	68			E-7	86
	T-12	29	G-8	13	S-4	80			E-6	86
	T-11	85	G-7	43	S-3	69			E-5	75
	T-10	19	G-6	34	S-1	64			E-4	74
	T-9	23	G-5	49					E-3	65
	T-8	35	G-4	57					E-2	60
	T-7	57	G-3	54					E-1	55
	T-6	34	G-2	77						
	T-5	37	G-1	79						
	T-4	48								
	T-3	29								
	T-2	52								

Car.: Carbonate content.

sparry calcite or iron oxides. The walls of many tests are micritized. Porosity is generally low to moderate and represented by small vuggy pores.

The wackestone/packstone microfacies (Fig. 4C and D) is recognized from the lower Tarawan Chalk at G. El-Shaghab and the upper Esna Shale at G. El-Sheikh Eisa. It is made up of skeletal particles (45-50%) of planktonic foraminiferal tests packed in micrite. The foraminiferal chambers are generally filled with sparry calcite and in some cases with iron oxides. Micritization is a common phenomenon that affected some test walls. Large neomorphic ferroan and non-ferroan sparry calcite is observed filling some fractures. Porosity ranges from low to moderate as evidenced by the presence of small irregular vuggy pores.

The packstone microfacies (Fig. 4E and F) is recorded from the limestone intercalations within the Dakhla Shale at G. El-Shaghab. This microfacies is mainly composed of moderately sorted and well packed planktonic and benthic foraminiferal tests showing point and grain-contact. Infilling with sparry calcite and iron oxide as well as the test wall micritization are the common features affecting the skeletal particles. The ferroan calcite is the dominant calcite type. Porosity is generally moderate and represented by irregular vugs and large intragranular pores.

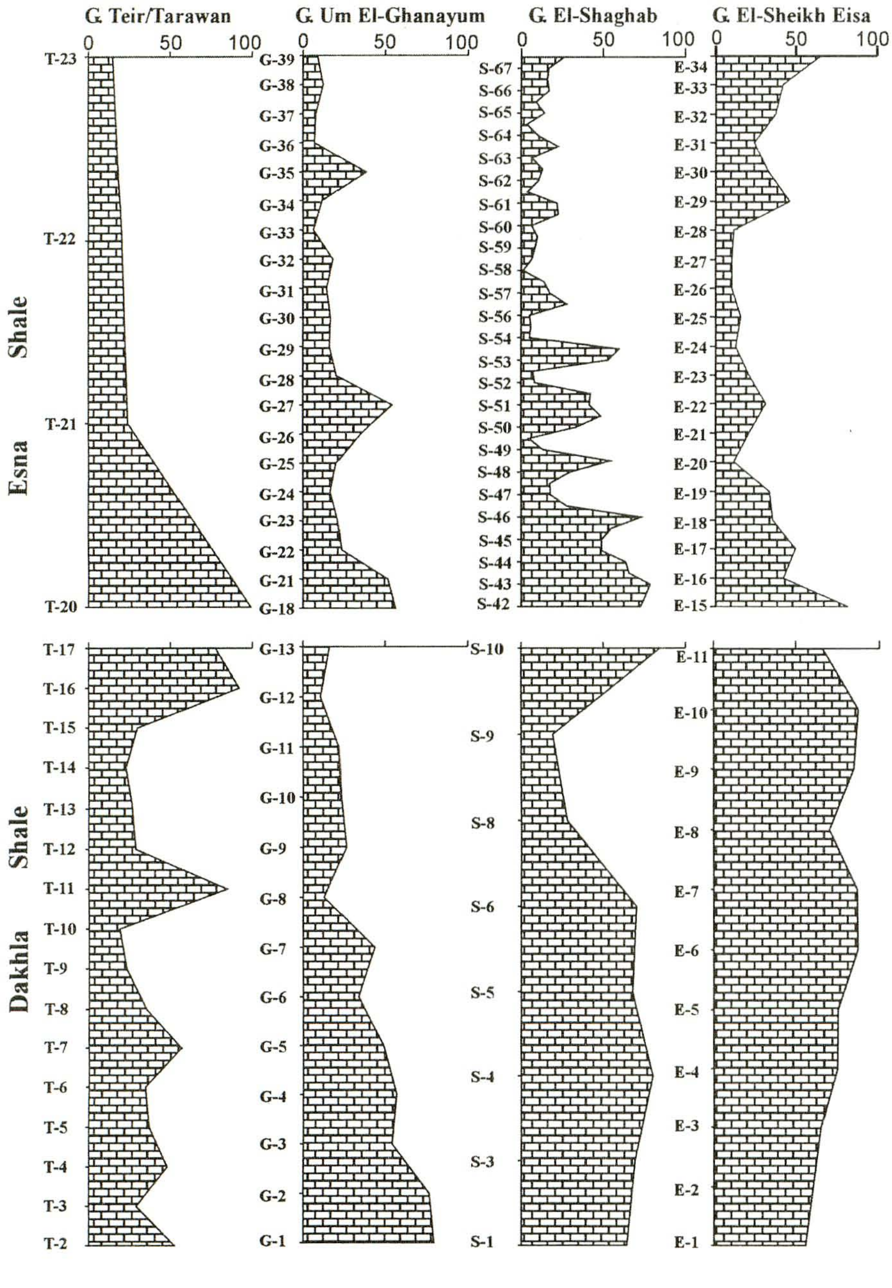

Fig. 5 Vertical variations of the carbonate contents in the Dakhla and Esna shales at the different localities. Note the higher carbonate content of Dakhla Shale relative to the Esna Shale.

Carbonate contents

The proportions of the carbonate content have a wide spectrum of values ranging from 0 to 98 % (Table 3 and Fig. 5). Generally, the Dakhla Shale sediments have higher carbonate contents than those of the Esna Shale. The average values of carbonate content recorded from the Dakhla Shale are 39% (range 11-79%) at G. Um El-Ghanayum, 43% (19-92%) at G. Teir/Tarawan, 60% (19-85%) at G. El-Shaghab, and 74% (55-87%) at G. El-Sheikh Eisa.

The Esna Shale sediments have relatively lower carbonate contents. They range from 10-82% (averaging 32%) at G. El-Sheikh Eisa, from 1-79% (averaging, 27%) at G. El-Shaghab, from 6-56% (averaging, 23%) at G. Um El-Ghanayum, and from 15-99% (averaging, 40%) at G. Teir/Tarawan.

The acid insoluble residue determined for the Tarawan Chalk varies from 4% to 9% (averaging 6%) at G. El-Sheikh Eisa, from 7% to 10% (averaging 9%) at G. El-Shaghab, from 2% to 12% (averaging 8%) at G. Um El-Ghanayum, and from 4% to 16% (averaging, 10%) at G. Teir/Tarawan. Microscopic examination of the acid insoluble residues revealed the presence of detrital and fine sand- and silt-sized quartz grains, clays, few pyritized fossils, few iron oxides, and rare agglutinated foraminifera.

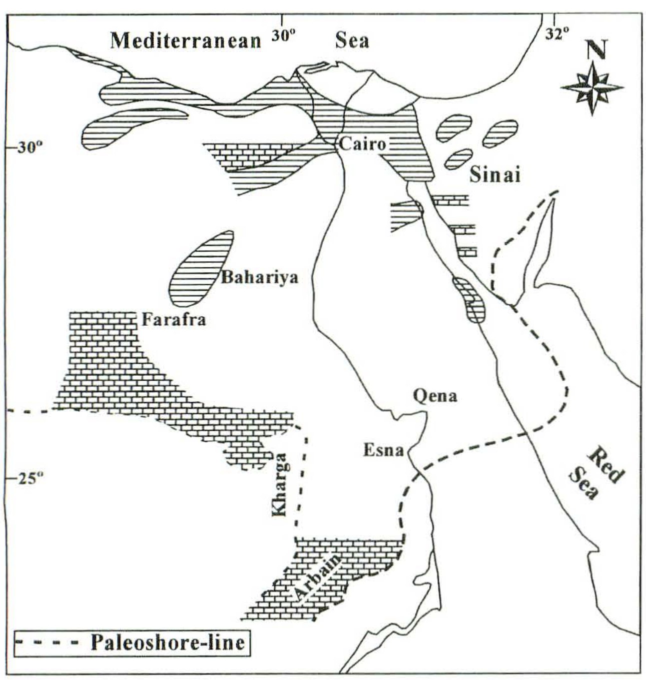

Fig. 6 Early Paleogene paleoshoreline (Said, 1990). Note that the Qena area was relatively deeper than the Esna and Kharga during Early Paleogene.

Discussion

The lower Paleogene sediments in central Egypt contain abundant and highly diversified planktonic foraminifera and calcareous nannoplanktons (Faris et al., 1999), suggesting deposition in open marine inner to middle shelf environments. Sea level fluctuations, climate, paleogeography, basin physiography and sediment supply have significant signatures on the lower Paleogene sediment characteristics in central Egypt.

Depositional processes

The studied sediments are exclusively enriched in silts with subordinate quantities of clays and sands. The high percentages of silts and clays would suggest a deposition from suspension. The present study shows the independence of fine grain size distribution on the water depths. The lower Paleogene sediments at the Esna area (G. El-Shaghab) were deposited under relatively shallower conditions than other areas (Said, 1990), (Fig. 6). However, there is no difference between the grain size distributions in all of the studied sediments. Generally, siliciclastic sediments are delivered to the basin from the nearby land areas. The coarse sediments are concentrated in the nearshore areas and the fines are drifted to the deeper sites. Unlike sands, deposition of muds is not primarily governed only by particle size, water depths and flow velocities. There is no need to assume that muds were necessarily deposited under conditions of lower current velocity, lower wave activity or greater water depth. Those substantial amounts of mud can indeed be deposited in energetic environments when suspensions are concentrated enough (McCave, 1984). McCave (1984) distinguished three main processes for the deposition of fine grained sediments: 1) re-sedimentation processes including all processes that move sediments downslope over the sea floor; 2) normal bottom currents (contourites) that erode, transport and deposit sediments on the sea floor and 3) pelagic settling through the water column. However, in the sea water, muds are easily flocculated and behave as aggregates rather than individual particles. Therefore, flocculation played the main role in the deposition of Dakhla and Esna shales.

Carbonate paleoproductivity

The studied lower Paleogene sediments were deposited under different phases of carbonate productivities. Most of calcareous materials include remains of calcareous fossils and calcite. The abundance of carbonate in the Dakhla Shale sediments is attributed to the high carbonate productivity during periods of reduced terrigenous influx. The Dakhla Shale sediments were deposited during sea level highstand (Luning et al., 1998), which led to the reduction of terrigenous influx, allowed calcareous organisms to flourish and resulted in increasing carbonate production. On the other hand, the relatively low carbonate contents obtained from the Upper Paleocene-Lower Eocene Esna Shale were related to high terrigenous influxes and to the syn- and post-depositional dissolution of readily dissolved planktonic organisms. The Esna Shale was deposited during sea level lowstand (Said, 1990), during which high amounts of terrigenous sediments were delivered to the basin.

The lower Paleogene sediments were laid down in inner to middle shelf environments. These sites are tolerated by varieties of calcareous fauna which contributed well in the carbonate composition of the studied sediments. The productivity of the calcareous microinvertebrates is influenced by numerous water-mass properties such as temperature, pressure, density, nutrients, salinity, light penetration, oxygen and other physical, chemical and biological factors (Luning et al., 1998). Most of calcareous nannoplanktons and planktonic foraminifera have their highest abundance in areas of ocean upwelling (Soutar et al., 1981). Upwelling process is important for planktonic organisms as it brings the nutrient-rich subsurface water to the photosynthetic layer. Upwelling process also controls the bottom environment through enhanced downward flux of organic matter. The Dakhla Shale sediments were deposited in environments with enhanced upwelling processes, whereas reduced upwelling intensities had dominated during the deposition of the Esna Shale.

Factors controlling mineralogical composition

The studied lower Paleogene sediments are dominated by calcite, phyllosilicates, quartz and few amounts of feldspars (Table 2). Calcite and phyllosilicates show opposite behaviour. This may explain the carbonate dilution by the land derived terrigenous materials. The dominance of calcite over other minerals in the bulk fraction is consistent with the high abundance of calcareous fossils (Faris et al., 1999).

The clay minerals distributions in the lower Paleogene sediments reflect the climatic conditions and the weathering processes at the source area as well as the differential hydraulic sorting during transportation and deposition. Smectite dominates the clay mineral assemblages. Kaolinite is the second abundant clay mineral in the studied sediments, whereas low illite contents were obtained. Palygorskite occurred with subordinate amounts at specific horizons. Neither chlorite nor mixed-layer clays were found in the studied shales.

It is worthy mentioning that, clay minerals of the studied sediments are of detrital origin and there is no evidence for the influence of diagenesis. Hoffman and Hower (1979) referred to the mineralogical criteria for shale diagenesis, which include: i) conversion of smectite to illite through mixed layer, ii) the appearance of chlorite, and iii) disappearance of K-feldspars as a result of decomposition. Furthermore, the presence of smectite implies that the clay minerals are not transformed due to burial diagenesis (Chamley, 1989).

Smectite, the dominant clay mineral in the studied sediments, indicates that the source area had experienced a warm climate with alternating pronounced dry and less pronounced wet seasons. The smectite has been transported to the ocean either in river run-off during wet seasons and/or as aeolian particles during dry seasons. Hallam et al. (1991) has referred to the volcanogenic smectite, being derived directly from the weathering and alteration of volcanic materials. Although the Late Paleocene-Early Eocene time is characterized by massive eruption of flood basalts (Eldholm and Thomas, 1993), the volcanogenic origin of smectite would be excluded due to the absence of associated accessory minerals like biotite, sphene, and relict glass shards. High abundance of smectite was recorded from the lower Paleogene sediments at other localities in central Egypt (Marzouk, 1985; Soliman et al., 1989).

Kaolinite, the second abundant clay mineral encountered in the studied sediments, has resulted from the chemical weathering of acidic igneous and metamorphic rocks or their detrital weathering products under tropical to subtropical humid climatic conditions (Hendriks, 1985; Marzouk, 1985; Chamley, 1989).

Illite typically forms under conditions completely different from those under which kaolinite and smectite are formed. It typically forms in soils with little chemical weathering in cold and/or dry climates, and in areas of high relief where physical erosion is predominant. The relatively lower illite contents of the studied shales were produced by physical erosion of illite-bearing source rocks. The presence of illite with quartz suggests high detrital input in dry climates.

The lower proportions of the palygorskite determined from the lower Esna Shale sediments at G. Um El-Ghanayum and G. El-Shaghab developed on various crystalline substrates such as granites and greenschists provided that hydrolysis and evaporation conditions were strong enough (Chamley, 1989).

Apart from the climatic controls, which affect clay mineral formation, the relative abundance of kaolinite and illite comparing to smectite is clearly influenced by hydraulic sorting and relative sea-level changes. The lower proportions of kaolinite and illite relative to smectite in the studied sediments would be explained as kaolinite and illite tend to concentrate in relatively near-shore shallow water settings, reflecting their coarse-grained nature and their strong tendency to flocculate compared to smectite, whereas smectite tends to settle as finer particles in deeper offshore settings (Raucsik and Merenyi, 2000). As the studied sediments represent deposition in the distal deeper part of the basin, it is expected to find higher concentrations of kaolinite and illite with lower smectite abundances at the proximal shallower settings. Moreover, detrital smectite in marine sediments increases during sea-level highstand periods, whereas kaolinite and mica increase during lowstand periods. The presence of abundant smectite is generally linked to transgressive seas (Tantawy et al., 2001).

Summary and Conclusions

Four lithostratigraphic sections covering the Early Paleogene time were measured and sampled at the Nile Valley and the Kharga Oasis, Central Egypt. The studied interval includes two shale-dominated formations; the upper Dakhla Shale and the Esna Shale separated by the carbonate dominated Tarawan Chalk. The grain-size distribution, mineralogical composition, total carbonate-contents and the carbonate microfacies have been determined. The grain-size distributions of the Dakhla and Esna shales are quite similar to each other and are dominated by silt (medium and coarse silt) with generally small amounts of sand and clay. Mineralogical analysis carried out by XRD revealed the presence of smectite, kaolinite, illite and palygorskite as the principal clay minerals, and calcite, quartz and K-feldspars as non-clay minerals. Calcite is the most abundant non-clay mineral and this is consistent with the high calcareous fossil content of the studied sediments. Smectite, the most abundant clay mineral, has been formed under warm climatic conditions with alternation of pronounced dry and less pronounced wet seasons. The smectite abundance relative to kaolinite was governed by dominant hydraulic segregation during transportation. Smectite was drifted to deeper settings, whereas kaolinite was concentrated in the proximal nearshore and/or non-marine parts of the basins. Petrographic examination of the Tarawan Chalk and the limestone interbeds in the upper Dakhla Shale enables to identify four microfacies. These microfacies are mudstone/wackestone, wackestone, wackestone/packstone and packstone microfacies. Dissolution of original test wall and replacement and infilling by iron oxides and recrystallized calcite were the main diagenetic features. The Dakhla Shale sediments especially those at Qena region have high carbonate contents relative to sediments of the Esna Shale. The water depth, sediment supply, sea-level changes and the carbonate productivity were the major controls on the carbonate accumulations of the studied sediments.

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References

Awad, G. H. and Ghobrial, M. G. (1965) Zonal stratigraphy of the Kharga Oasis. *Geol. Surv. Egypt*, **34**, 77 pp.

Chamley, H. (1989) *Clay sedimentology*. Berlin, Springer-Verlag, 623 pp.

Dunham, R. J. (1962) Classification of carbonate rocks according to depositional textures. *In: Classification of Carbonate Rocks* (Ham, W. E. ed.), AAPG Mem., **1**, 108-121.

El-Hawat, A. S. (1997) Sedimentary basins of Egypt: An overview of dynamic stratigraphy. *In: African basins, Sedimentary basins of the world, 3* (Selley, R. C. ed.) Amsterdam, Elsevier, 39-85.

Eldholm, O. and Thomas, E. (1993) Environmental impact of volcanic margin formation. *Earth Planet. Sci. Lett.*, **117**, 319?329.

Faris, M., Abd El-Hameed, A. T., Marzouk, A. M. and Ghandour, I. M. (1999) Early Paleogene calcareous nannofossil and planktonic foraminiferal biostratigraphy in Central Egypt. J. *N. Jb. Geol. Paläont.*

Abh., 213- 2, 261-288.

Folk, R. L. (1959). Practical petrographic classification of limestones. *Bull. AAPG*, **43**, 1-38.

Folk, R. L. (1968) *Petrology of Sedimentary Rocks*. Austin, University of Texas Publication, 170 pp.

Galehouse, J. S. (1971) Sedimentation analysis. *In: Procedures in sedimentary petrology*. (Carver, J. R. E. ed.), New York, Wiley and Sons, 69-94.

Hallam, A., Grose, J. A. and Ruffell, A. H. (1991) Paleoclimatic significance of changes in clay mineralogy across the Jurassic-Cretaceous boundary in England and France. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **81**, 173-187.

Hardy, R. and Tucker, M. (1988) X-ray powder diffraction of sediments. *In: Techniques in Sedimentology* (Tucker, M., ed.), Cambridge, Blackwell Science, 191-228.

Hendriks, F. (1985) Upper Cretaceous to lower Tertiary sedimentary environments and clay mineral associations in the Kharga Oasis area, Egypt. *N. Jb. Geol. Paläont. Mh.*, **10**, 579-591

Hermina, M. (1990) The surroundings of Kharga, Dakhla and Farafra Oases. *In: The Geology of Egypt* (Said, R. ed.), Rotterdam, Netherlands, A. A. Balkema Publishers, 259-292.

Hoffman, J. and Hower, J. (1979) Clay mineral assemblages as low grade metamorphic geothermometers: application to the thrust faulted disturbed belt of Montana, USA. *In: Aspects of Diagenesis* (Scholle, P.A. and Schluger, P.S., Eds.), Special Publs., Soc. Econom. Paleont.Miner., **26**, 55-79.

Issawi, B. (1972) Review of Upper Cretaceous-Lower Tertiary stratigraphy in Central and Southern Egypt. *Bull. AAPG*, **56**, 1448-1463.

Lewis, D. W., and McConchie, D. (1994) *Analytical Sedimentology*. New York, Chapman and Hall, 197 pp.

Luning, S., Marzouk, A. M. and Kuss, J. (1998) The Paleocene of central east Sinai, Egypt: 'esequence stratigraphy' in monotonous hemipelagites. *J. Foram. Res.*, **28**, 19-39.

Marzouk, A. M. (1985) Sedimentological and stratigraphical studies on the Upper Cretaceous-Lower Tertiary succession near Qena, Egypt. *Unpublished M. Sc. Thesis, Tanta University*, Egypt, 170 pp.

McCave, I. N. (1984) Size spectra and aggregation of suspended particles in the deep ocean. *Deep-Sea Res.*, **31**, 329-352.

Moore, D. M. and Reynolds, R. C. (1989) *X-ray diffraction and the identification and analysis of clay minerals*. Oxford Univ. Press, 332 pp.

Raucsik, B. and Merenyi, L. (2000) Origin and environmental significance of clay minerals in the Lower Jurassic formations of the Mecsek Mts., Hungary. *Acta Geol. Hungarica*, **43**, 405-429.

Said, R. (1962) *The Geology of Egypt*. New York, Elsevier, 377 pp.

Said, R. (1990) Cenozoic. *In: The Geology of Egypt*. (R. Said, ed.), Rotterdam, Netherlands, A. A. Balkema Publishers, 451-486.

Soliman, H. A., Ahmed, E. A., Aref, M. A. 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.*, Egypt **18**, **1-F**, 42-67.

Soutar, A., Johnson, S. R. and Baungartner, T. Y. R. (1981) The Monterey Formation and Related Siliceous Rocks of California. *In: Search of modern depositional analogs to the Monterey Formation* (Garrison, R. E. and. Douglas, R. G., eds.), Pacif. Sec. Soc. Econ. Paleont. Mineral., 123-147.

Speijer, R.P. and Schmitz, B. (1998) A benthic foraminiferal record of Paleocene sea level and trophic/redox conditions at Gebel Aweina, *Egypt. Palaeogeogr. Palaeoclimat. Palaeoecol.*, **137**, 79-101.

Strougo, A. (1986) "The Velascoensis Event" a significant episode of tectonic activity in the Egyptian Paleogene. *N. Jb. Geol. Paläont. Abh.*, **173**, **2**, 253-269.

Tantawy, A. A., Keller, G., Adatte, T., Stinnesbeck, W., Kassab, A. and Schulte, P. (2001) Maastrichtian to Paleocene depositional environment of the Dakhla Formation, Western Desert, Egypt: sedimentology, mineralogy and integrated micro- and macrofossil biostratigraphies. *Cret. Res.*, **22**, 795?827.

Zittel, A. K. (1883) Beiträge zur Geologie und Paläontologie der Libyschen Wuste und der angrenzenden Gebiete von Aegypten. *Palaeontographica*, **30**, **3.F.**, 1, 147, 2, 237. pp.

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