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LITHOFACIES, ENVIRONMENTS OF DEPOSITION AND PROVENANCE OF THE UPPER CARBONIFEROUS ABU DURBA FORMATION, SOUTHWEST SINAI, EGYPT

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ABSTRACT

The studied Abu Durba Formation unconformably overlies the Upper Cambrian Naqus Formation (at Gabal Ekma) and the Lower Carboniferous Abu Thora Formation (at Wadi Feiran area) and unconformably underlies the Lower Cretaceous Malha Formation. This formation is composed of interbedded sandstones, siltstones, and shales, in addition to channel lag deposits at the base of the sedimentary sequences.

The Abu Durba Formation is divided into five lithofacies. These lithofacies are: lithofacies A (conglomerate) that is interpreted as a channel lag as a result of scouring of the floor and sides of the fluvial channels, lithofacies B (sandstone) which represents fluvial channel deposits, lithofacies C (interbedded sandstone and siltstone) represents coarse-grained overbank deposits (levee and crevasse splay deposits), lithofacies D (siltstone-dominated facies) of overbank flood deposits, and lithofacies E (gray to black siltstone and shale) that was deposited in quiet marine water.

Petrographic investigation revealed that the studied Abu Durba sandstones are mainly quartz arenite with few samples of subarkose and sublitharenite reflecting their high maturity. Modal analysis showed that the Abu Durba sandstones were mainly derived from plutonic source with some contributions from metamorphic and reworked pre-existing sandstone sources.

Keywords: lithofacies, environments of deposition, provenance, Upper Carboniferous, Abu Durba Formation, southwest Sinai, Egypt.

INTRODUCTION

Geology of the Paleozoic on both sides of the Gulf of Suez has been studied by several authors. Some of these studies dealt with the stratigraphy of the Paleozoic succession (e.g., Abdallah and El-Adindani, 1963; Kora, 1989a; 1992; and El-Kelani and Darwish, 2001). Many other studies concerned with Paleozoic fauna and flora (e.g., Kora, 1989a; b; 1992; 1995; and Lejal-Nicol, 1990). Moreover, sedimentological and petrographical studies on the Paleozoic rocks have been done by many workers (e.g., Abu-Zeid et al., 1991; and Abu El-Enain, 1997).

The Paleozoic succession in Wadi Feiran area, southwest Sinai is subdivided (from base to top) into the following five lithostratigraphic units: Araba Formation, Naqus Formation, Abu Durba Formation, Aheimer Formation, and Qiseib Formation (Issawi et al., 1981 and Allam, 1989). The term Abu Durba Formation was first introduced by Said (1971) for the sand and shale sequence described by Hassan (1967) overlying older Paleozoic sandstones in the Abu Durba area. However, Issawi et al. (1981) gave this term only to the lower part of Hassan's (1967) succession. Several studies dealt with the lithostratigraphy of the Abu Durba Formation on both sides of the Gulf of Suez (e.g., Kora, 1989b; 1992; 1995).

According to several authors (e.g., Issawi et al., 1981; Klitzsch and Wycisk, 1987), the Abu Durba Formation is Early Carboniferous in age. However, Kora (1989b; 1992; 1995) identified different fossils from this formation and assigned a Late Carboniferous (Early Moscovian) age to it. The Abu Durba Formation is correlated with the upper part of the Abu Darag Formation exposed on the western side of the Gulf of Suez (Kora, 1992). Its lower part is coeval with the Rod El Hamal Formation of Abdallah and El-Adindani (1963).

The main target of the present work is to throw more light on the lithofacies and depositional environments, in addition to the provenance of the Upper Carboniferous Abu Durba Formation in southwest Sinai.

METHODS OF STUDY

To accomblish the target of the present work, two surface lithostratigraphic sections (section A at Gabal Ekma and section B at Wadi Feiran area) (Figs. 1 and 2) of the Abu Durba Formation have been measured, described, and sampled in the field. Sandstone samples were thin-sectioned and examined under the polarizing microscope for petrographical studies. The modal analysis (framework mineral composition) of 16 sandstone samples was quantified using the Gazzi and Dickinson point-counting method (Ingersoll et al., 1984). A minimum of five hundred points were counted per each thin section at a spacing of 0.5 mm. Each thin section was point-counted for different types of quartz (Q), feldspars (F), and rock fragments (L). Chert was counted as rock fragments. The authigenic kaolinite and the secondary pores, which were thought to be resulted from the dissolution of feldspars, were counted as feldspars.

Representative sandstone and siltstone samples have been analyzed for major (14 samples) and trace (9 samples) elements using the XRF (X-ray fluorescence spectrometry) techniques. Ten major elements were analyzed: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, and P in addition to fifteen trace elements including V, Cr, Co, Ni, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, and Nd. Chemical analyses were performed at the laboratories of the Geology Department, Faculty of Science, Shinshu University, Matsumoto, Japan and the Department of Earth and Planetary Sciences, Tokyo University, Japan.

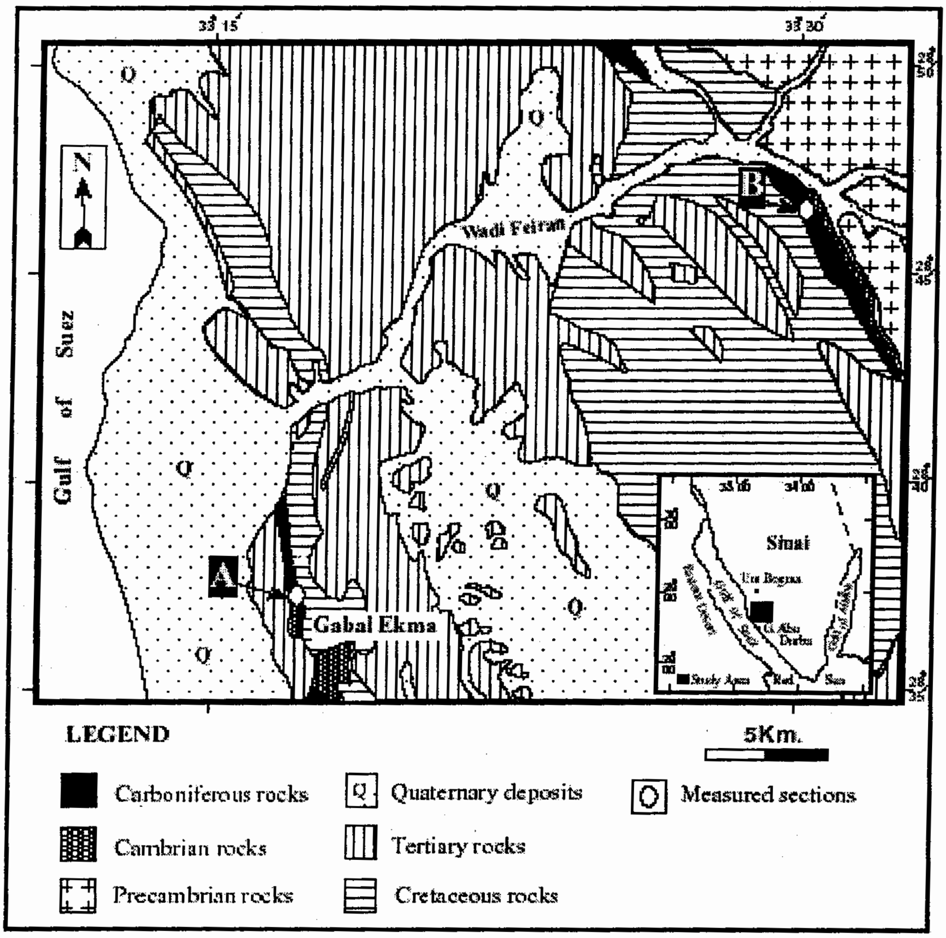

Fig. (1): Geologic map of the area of study (simplified after the Geological Survey of Egypt, 1994) showing the location of measured sections

LITHOSTRATIGRAPHY

In the present study, the Abu Durba Formation is 62.75 m and 31 m thick at sections A and B, respectively. It unconformably overlies the Upper Cambrian Naqus Formation (at Gabal Ekma) and the Lower Carboniferous Abu Thora Formation (at Wadi Feiran area) (Fig. 2) and unconformably underlies the Lower Cretaceous Malha Formation. The basal unconformable contact is characterized by sharp and uneven nature. It is represented by about 40 cm-thick conglomerate bed consisting of quartz pebbles and granules embedded in coarse- and fine-grained sand at both sections (A and B) and of lithoclasts from the underlying rocks at the basal part of the Abu Durba Formation (Pl. 1-A).

This formation is composed of interbedded sandstones, siltstones, and shales. The sandstones range from fine- to coarse-grained with scattered quartz pebbles and granules. They exhibit reddish white and brown colors. They are poorly consolidated with the occurrence of carbonate and iron oxides as cementing materials. The sandstone bodies decrease in thickness and in grain size upwards. They exhibit lenticular geometry and occur in the form of repeated fining-upward sequences. Each sequence begins at the base by coarse-grained sandstone (associated with lag gravels) and grades upward into finer sandstone, siltstone, or shale. The most common primary structures in the sandstones of the Abu Durba Formation include channeling and scouring in the underlying fine clastics with the occurrence of coarse clastics (conglomeratic beds), which represent lag deposits at the base of the channels. Other primary structures in the sandstones include tabular- and tangential planar cross bedding (Pl. 1-B), trough cross bedding with basal zones of coarse detritus occurring in the fills of few troughs, thin flat bedding (Pl. 1-C), and straight-crested-flat-topped ripple marks (Pl. 1-D). Desiccation cracks are common on the surface of some sandstone and siltstone beds (Pl. 1-E). The siltstones are also variable in color (white, yellow, violet, and red). They are either massive or laminated. Sometimes, the siltstones include thin, fine-grained sandstone bands. Some sandstone and siltstone beds are capped with thin iron oxides band. The shale varies in color from black to greenish gray, and sometimes it is mottled. It is laminated and fissile. The Abu Durba Formation contains plant fossils in the form of leaves, roots and drifted logs (Pl. 1-F). Issawi and Jux (1982) recorded drifted logs of *Lepidodendron* and *Calamites* from this formation.

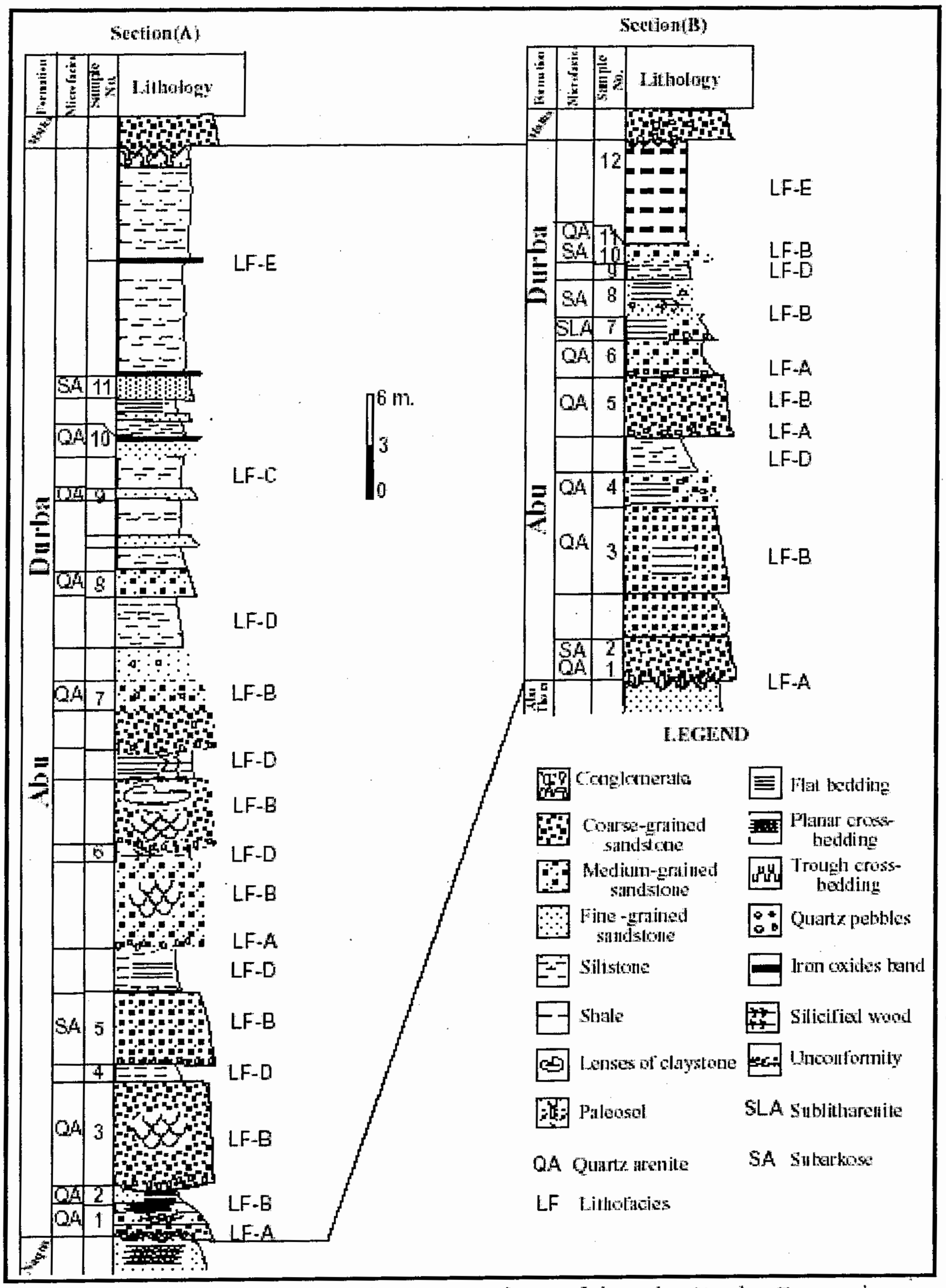

Fig.(2): Lithostratigraphic columnar sections of the Abu Durba Formation. Section (A) at Gabal Ekma, Section (B) at Wadi Feiran.

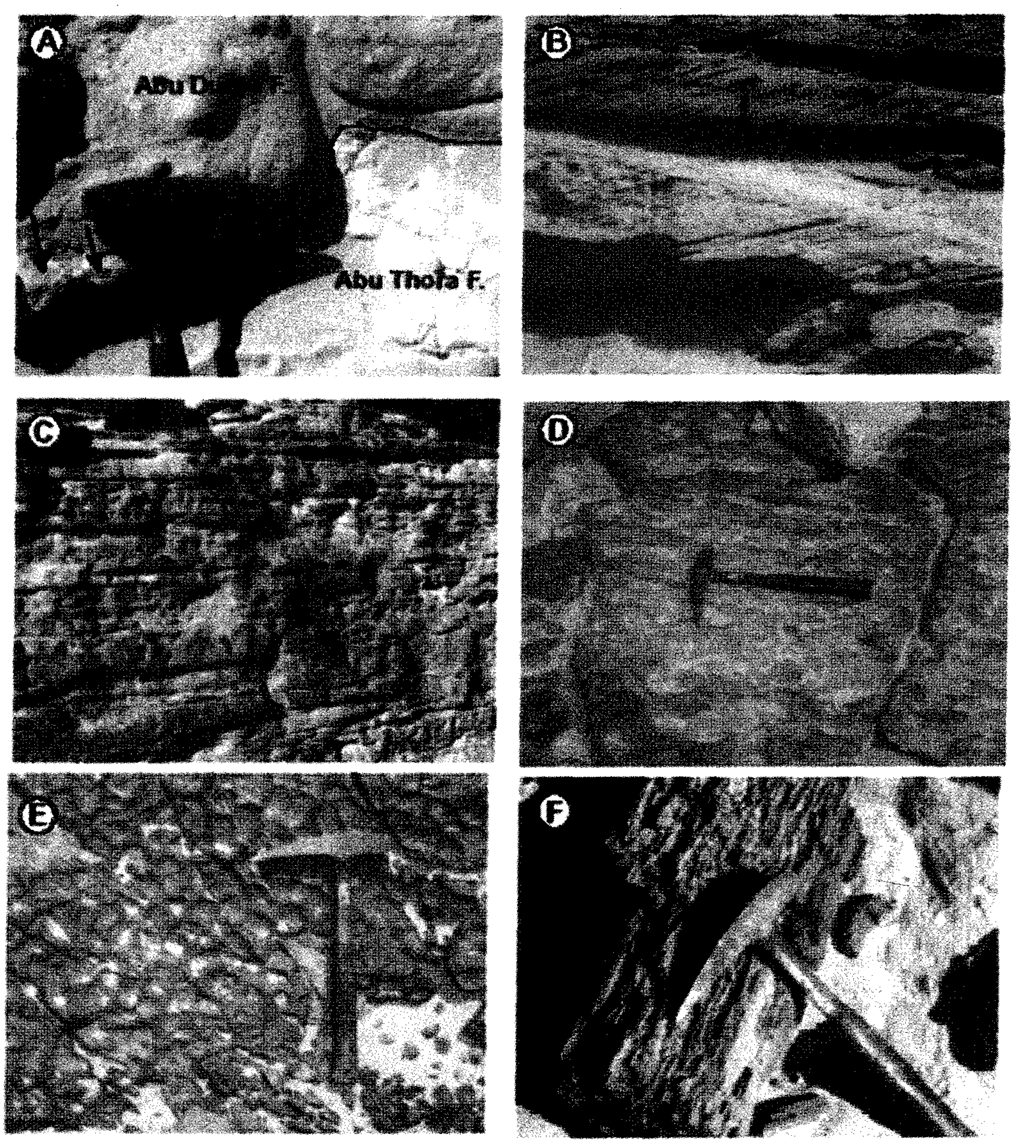

Plate 1: Field photographs of the Abu Durba Formation showing: A) The contact between the Abu Durba Formation and the underlying Abu Thora Formation (notice the sharp and uneven contact, white lithoclasts from the Abu Thora Formation, see arrows, and the basal conglomerate). B) Tangential cross-bedded sandstones (above) separated from tabular cross-bedded sandstone (below) by massive fine-grained sandstone beds in lithofacies B. C) Thin flat bedded sandstone in lithofacies C. D) Straight-crested and flat-topped ripple marks in lithofacies B. E) Desiccation cracks in lithofacies D. F) Plant fossils (drifted logs) in lithofacies C.

LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS

The studied Abu Durba Formation is dominantly siliciclastic (Fig. 2). Its lithology ranges from coarse-grained sandstone with quartz pebbles and granules to shales, in addition to the conglomeratic lag deposits at the base of some sedimentary sequences. The Abu Durba Formation can be divided into five lithofacies. Each lithofacies exhibits specific lithology and primary sedimentary structures reflecting its depositional environments. These lithofacies are: lithofacies A (conglomerate), lithofacies B (sandstone), lithofacies C (interbedded sandstone and siltstone), lithofacies D (siltstone-dominated facies), and lithofacies E (gray to black siltstone and shale).

Lithofacies A (conglomerate)

Description:

Lithofacies A occurs at the base of the sedimentary sequences (Fig. 2) as thin beds (40 cm- thick) and extends laterally for tens of meters. It grades upward into lithofacies B. It is erosive-based, structureless (massive or crudely bedded), lenticular in geometry, multicolored, and mainly clast-supported and matrix-filled, and monomictic. It is composed mainly of rounded to subrounded quartz pebbles and granules. The pebbles and granules are of variable diameter and occur in random distribution.

Interpretation:

Lithofacies A resembles Miall's (1978) Gm facies. The conglomerate at the base of the sequence is interpreted as a channel lag as a result of scouring of the floor and sides of the channels (Miall, 1978; Turner, 1983). The poor sorting and the size of the clasts indicate upper flow regime conditions related to a major flood event and rapid dumping of sediment (Mader, 1985). The small thickness of this lithofacies indicates that it may be a distal downslope position. Gibling and Rust (1984) indicated that abundant intraclasts of variable size is expected in braided-river deposits. The conglomerate facies may represent proximal braided river deposits, which evolved into medial to distal braidplain sandstone facies (Amireh and Abed, 1999). This is indicated by the occurrence of the coarse-grained sandstone of lithofacies B above the conglomerate of lithofacies A.

Lithofacies B (sandstone)

Description:

This lithofacies occurs mostly at the base of the sequences above the channel lags of lithofacies A and grades upward to the overbank flood deposits of lithofacies D. It occurs in the form of vertically repeated fining-upward sequences 1.5 to 12 m. thick. The sandstone bodies are lenticular in shape, erosive-based and scoured. They are composed of multicolored (reddish brown and white), poorly- to moderately sorted coarse- to fine-grained sandstone and locally contain scattered granules. Occasionally, they contain claystone lenses. In this lithofacies, trough cross-bedding, tangential- and tabular cross-bedding (Pl. 1-B), flat bedding, current ripple marks (Pl. 1-D), desiccation cracks and convolute bedding are the most common primary structures. Plant roots and logs were recorded in this lithofacies. Pedogenic features including reddening and mottling are common in lithofacies B.

Interpretation:

Lithofacies B includes Miall's (1978) St (trough cross-bedded sandstone), Sp (planar cross-bedded sandstone), Sh (horizontal-laminated sandstone), and Sr (ripple cross-laminated sandstone) facies. The occurrence of trough cross-bedding, planar cross-bedding and flat bedding above an erosion surface and lag deposits suggests that the fining-upward sequences are of fluvial origin (Cant and Walker, 1976). The lenticular geometry, erosive bases and fining upward trends of this lithofacies indicate deposition within channels (Buatois and Mangano, 2003). Trough cross-bedding results from the migration of dunes whereas the planar (tabular) cross-bedding is attributed to the migration of sandwaves and transverse bars. The formation of the parallel laminated sandstones is attributed to upper flow regime plane bed. Other evidences that support the fluvial interpretation of this lithofacies include: poor sorting, red coloration, abundance of plant fragments, absence of marine fossils, absence of flaser bedding and herringbone cross-stratification.

Lithofacies C (interbedded sandstone and siltstone)

Description:

This lithofacies is composed of successions up to 12.75 m thick of sharp-based fine- to medium-grained sandstone interbedded with laminated siltstone. The sandstones vary in thickness from 0.6 to 1.5 m while the siltstones are 1.2 to 2.4 m thick. It occurs only near the top of the formation in section A overlying the overbank flood deposits of lithofacies D and underlying the marine shelf gray siltstones of lithofacies E. The primary structures in the sandstones of this lithofacies include thin flat bedding (Pl. 1-C) and lamination, small-scale cross-bedding, and current ripples. The siltstones are generally massive or flat laminated. Plant fossils including logs (Pl. 1-F) and leaves occur in this lithofacies. Iron oxides bands occur at different levels of this lithofacies.

Interpretation:

Lithofacies C resembles Facies 1 (coarse-grained overbank deposits) of Fielding (1984). Fielding (op. cit.) interpreted it as levee deposits formed at the margins of major distributary channels and added that the thick sandstone beds represent minor crevasse splay deposits. In addition, Aitken and Flint (1994) interpreted his Facies Association 3A (sharp-based interbedded sandstone and siltstone) as being crevasse splay deposits. This lithofacies was deposited by settling from suspension (laminated siltstone) and high energy, tractional flows (cross-bedded and flat-laminated sandstone) (Aitken and Flint, op. cit.).

Lithofacies D (siltstone-dominated facies)

Decription:

Lithofacies D consists of mottled multicolored (gray, green, yellow, and red) and massive to thinly flat laminated siltstone with occasional thin claystone bands. Its thickness ranges from 0.9 to 3 m. Mostly, it is overlain by the conglomerate- or the sandstone facies with sharp and/ or erosional contact and underlain by the sandstone of lithofacies B with sharp contact. Desiccation cracks (Pl. 1-E) infilled with medium- to fine-grained sandstone commonly occur at the top of this lithofacies. Common occurrence of paleosols is observed in this lithofacies. It contains plant rootlets and leaves. The roots lie in a horizontal or subhorizontal plane.

Interpretation:

This lithofacies resembles the siltstone-dominated overbank flood deposits (Facies 2 of Fielding, 1984) of minor distributary channels, deposited from turbulent suspensions. It occurs in elongate belts bordering minor distributary channels (Fielding, 1986). Mudcracks and red coloration are evidences of subaerial exposure (Thompson, 1970; Collinson, (1978).

Lithofacies E (gray to black siltstone and shale)

Description:

Lithofacies E represents the top part of the studied Abu Durba Formation. Its thickness ranges from 6 m in section A to 12 m in section B. It is sharp-based and laterally persistent. It is made up of dark gray thinly parallel laminated siltstone in section A and black fissile shale in section B.

Interpretation:

This lithofacies indicates deposition from low energy, suspension fallout in the absence of waves and currents (Buatois and Mangano, op. cit.). It is interpreted as being deposited in marine shelf environments (Buatois and Mangano, op. cit.). Based on macro- and microfauna, Kora (1995) indicated that the topmost part of the Abu Durba Formation (black shales) was deposited in quiet marine water of normal salinity protected from wave action conditions.

PETROGRAPHY AND MODAL ANALYSIS

The modal analysis data of the investigated sandstone samples of the Abu Durba Formation are presented in Table (1). The main framework grains are coarse- to fine quartz grains (average 95.23 %), feldspars (orthoclase and microcline) (average 3.07 %), and rock fragments (average 1.70 %) (Table 1). However, quartz pebbles and granules are frequently scattered in the sandstones. According to the classification of Folk (1980), these sandstones are mainly classified as quartz arenite with few. samples of subarkose (five samples) and sublitharenite (sample B-7 only) (Figs. 2, 3 and Pl. 2-A and B) reflecting their high maturity.

The quartz grains are subangular to subrounded and moderately- to poorly sorted. The contacts between the quartz grains have different types including point, straight, and concavo-convex (Pl. 2-A). The recognized detrital quartz grains are subdivided into two main classes: monocrystalline (Qm) (average 81.07 %) and polycrystalline (Qp) (average 14.16 %). The monocrystalline quartz grains are either nonundulose (Qnu) (Pl. 2-A) with an average 68.64 % or undulose (Qu) (Pl. 2-C) with an average 12.43 % (Table 1). Some monocrystalline quartz grains have elongate shape and straight borders (Pl. 2-D) and others contain irregularly scattered inclusions of apatite and rutile needles. The polycrystalline quartz grains display different types: grains composed of only two or three individuals (Pl. 2-E), grains consist of polyindividuals and schistose structure with straight (Pl. 2-F), slightly curved (Pl. 2-G), or irregular or crenulated (Pl. 2-H) intercrystal boundaries, and grains with bimodal size distribution of individual crystals within a single grain (Pl. 3-A). Many samples contain rounded quartz grains with syntaxial quartz overgrowths (Pl. 3-B).

Feldspars, which are rare, include orthoclase and microcline only. When present, feldspars are altered and affected by dissolution during diagenesis leaving secondary pores (Pl. 3-C). Rock fragments are also of small proportions and are represented by chert (Pl. 3-D), carbonates (Pl. 2-B), and claystones.

TABLE 1. MODAL ANALYSIS DATA OF THE SELECTED SANDSTONE SAMPLES OF THE ABU DURBA FORMATION.

Sample	Qnu	Qu	Qm	Qp	Qt	F	L	Lt	Total
A-3	61.8	17.4	79.2	16.2	95.4	0	4.6	20.8	100
A-5	74.9	9.2	84.1	7.1	91.2	7.2	1.6	8.7	100
A-7	80.1	15.7	95.8	3.2	99	0	1	4.2	100
A-8	76.6	6.1	82.7	13.3	96	2.5	1.5	14.8	100
A-9	64	14.2	78.2	18.2	96.4	3	0.6	18.8	100
A-10	72.1	13	85.1	12.4	97.5	1.5	1	13.4	100
A-11	70.1	17.5	87.6	6.1	93.7	3.3	3	9.1	100
B-1	68.9	10.6	79.5	19.2	98.7	1.3	0	19.2	100
B-2	65.1	15.4	80.5	11.1	91.6	6.8	1.6	12.7	100
B-3	73.6	10.5	84.1	15.9	100	0	0	15.9	100
B-4	71.9	8	79.9	19.1	99	1	0	19.1	100
B-5	74.1	15.6	89.7	6.3	96	4	0	6.3	100
B-6	63.9	8	71.9	27.1	99	0	1	28.1	100
B-7	56.1	10.5	66.6	25.4	92	0	8	33.4	100
B-8	51.8	14.1	65.9	21.9	87.8	12.2	0	21.9	100
B-10	73.3	13.1	86.4	4	90.4	6.3	3.3	7.3	100
Average	68.64	12.43	81.07	14.16	95.23	3.07	1.7	15.86	100

Qm = monocrystalline quartz grains, Qnu = nonundulose quartz grains, Qu = undulose quartz grains, Om = Qnu + Qu, Qp = polycrystalline quartz grains, Qt = Qm + Qp, F = feldspars, L = lithic fragments, Lt = L + Qp

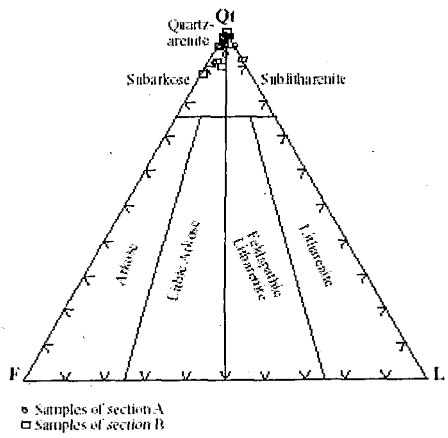

Fig. (3) QtFL ternary diagram showing the compositional classification of the Abu Durba sandstones (After Folk, 1980).

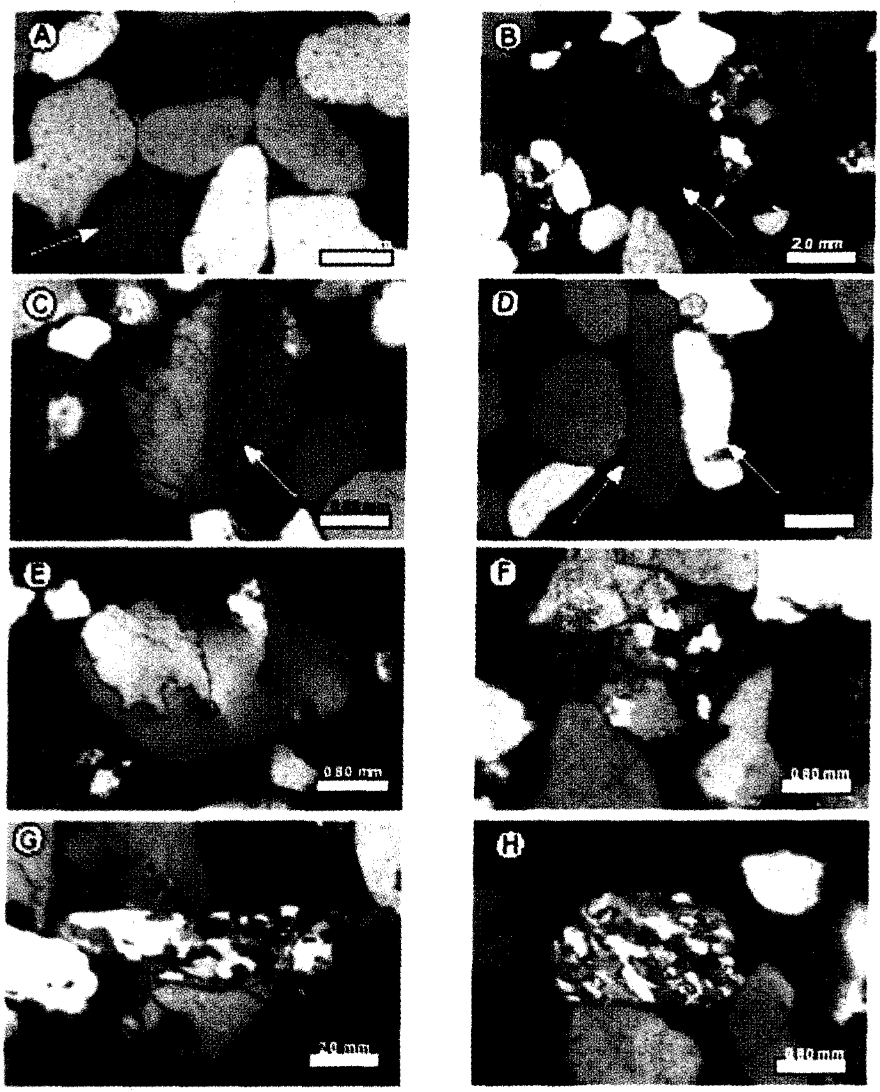

Plate (2): Photomicrographs of diagnostic features of the Abu Durba sandstones, A) Quartz arenite consisting mainly of subangular to subrounded nonundulose monocrystalline quartz grains (notice the different types of grain-to-grain contacts), S. No. A-7, B) Sublitharenite consisting mainly of mono- and polycrystalline quartz grains and carbonate rock fragments (arrow), S. No. B-7. C) Undulose monocrystalline quartz grains (arrow), S. No.A-8. D) Monocrystalline quartz grains with elongate shape and straight borders (arrow), S. No. A-5, E) Polycrystalline quartz grain composed of three crystals, S. No. A-8, F) Polycrystalline quartz grain with straight intercrystal boundaries, S. No, B-3, G) Polycrystalline quartz grain with slightly curved intercrystal boundaries, S. No. B- 7, H) Polycrystalline quartz grain with crenulated intercrystalline boundaries, S. No. A-I. All photos were taken under crossed nicols.

The cementing materials include one or more of the following: iron oxides(3 %), silica overgrowth (1 %), carbonates (2 %), and authigenic kaolinite (4%). The authigenic kaolinite was formed after the alteration of mica (Pl. 3-E, F) and feldspars. The matrix materials occur in few samples and are represented by detrital clay and silt-sized quartz grains. In thin sections, few heavy minerals (less than 1 %), including zircon, epidote, tourmaline, and apatite are recorded.

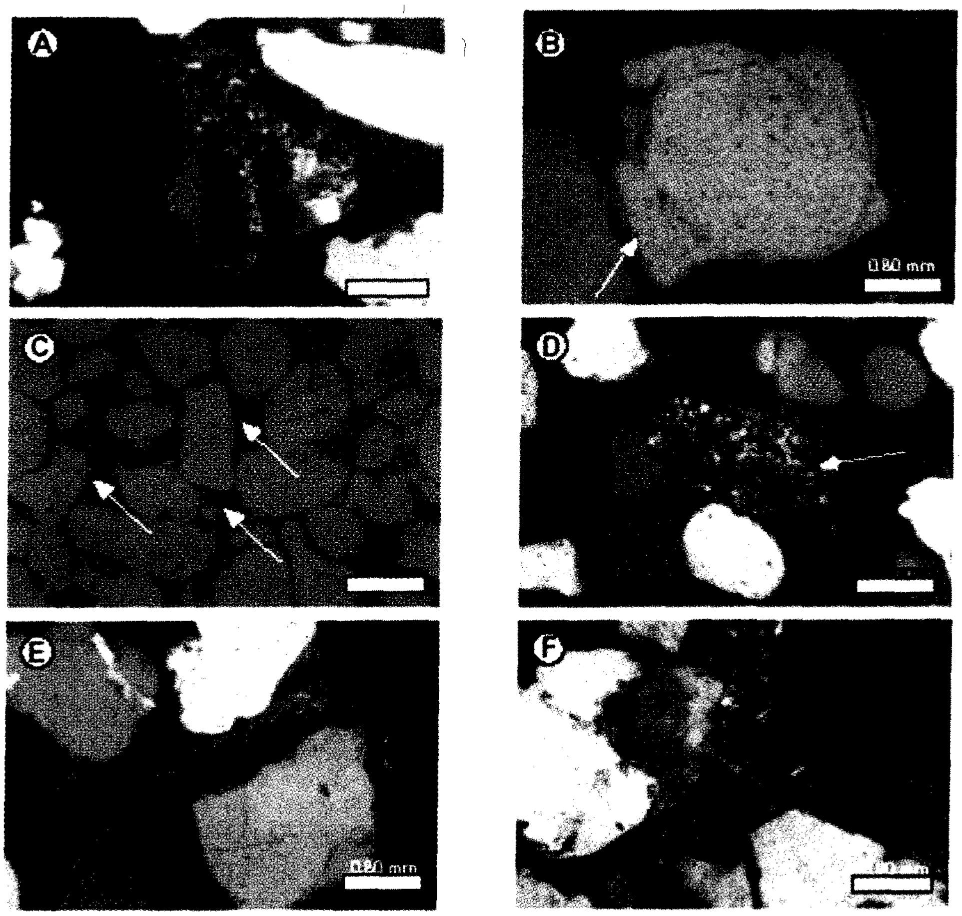

Plate (3): Photomicrographs of the Abu Durba sandstones. A) Polycrystalline quartz grain displaying a bimodal size distribution of the individual crystals, S. No. A-8, B)Monoerystalline quartz grain with syntaxial quartz overgrowth (arrow), S. No. A-5, C) Secondary pores produced as a result or dissolution of feldspars (arrows), S. No. A-8, DJ Sublitharenite consisting of monocrystalline quartz grains and chert fragments (arrow!, S. No.. B-7, E) Authigenic kaolinite cement formed after the alteration of mica, S. No. 8-3, F) Authigenic kaolillite enclosing relics of mica, S. No. B-8. All photos ,were taken under crossed nicols except the photo C was taken under plane-polarized light.

Detrital Modes and Provenance:

The detrital quartz types (Qp, Qnu, and Qu) of the studied Abu Durba sandstones were plotted on the provenance discrimination diagram of Basu et al. (1975) (Fig. 4). This plot shows that all the quartz of the studied sandstone samples is of plutonic origin. The plutonic origin of the Abu Durba sandstones is confirmed by the following features that occur in these sandstones: a) the quartz is mainly monocrystalline and nonundulose (Basu et al., 1975; Hindrix, 2000), b) the polycrystalline quartz grains exhibit straight to slightly curved intercrystal boundaries (Basu et al., 1975; Folk, 1980), c) the polycrystalline quartz grains are composed of 2-3 crystals (Basu et al., 1975), and d) the occurrence of apatite and tourmaline.

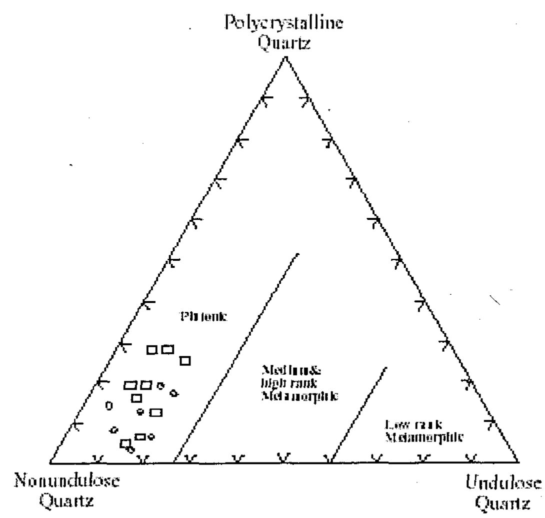

Fig. (4): Ternary plot of detrital quartz types of the sandstones of the Abu Durba Formation on the provenance discrimination diagram of Basu et al. (1975). Symbols as in Fig. 3.

In addition to the plutonic source rocks of the Abu Durba sandstones, there are other features indicating their metamorphic and preexisting sandstone sources. Features indicating metamorphic origin include: a) monocrystalline quartz grains that exhibit elongate shape (Folk, 1980), b) polycrystalline quartz grains with irregular or crenulated intercrystal boundaries (Basu et al., 1975; Asiedu et al., 2000), c) polycrystalline quartz grains that display a bimodal size distribution (Blatt et al., 1980), and d) occurrence of epidote (Morton, 1985). Reworked sandstone source of the Abu Durba sandstones is indicated by the presence of quartz grains with rounded overgrowths. According to El-Sherbini (1996), the acidic igneous rocks supplied sometimes some clastics to the Abu Durba Formation. According to Abu El-Enain (1997), the clastics of the Abu Durba Formation were derived from multisources and were transported for variable distance from the source area. The above discussion indicates that the Abu Durba sandstones were mainly derived from plutonic source with some contributions from metamorphic and reworked pre-existing sandstone sources.

GEOCHEMISTRY

Major and trace element compositions of representative sandstone and siltstone samples of the Abu Durba Formation are listed in Tables 2 and 3. Table (2) shows that most of the samples are rich in SiO_2 (66.08 - 99.44 %), very wide range of Al_2O_3 (0.13 - 28.29 % %), and low percent of TiO_2, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, and P_2O_5.

Major elements correlates well with the grain size (e.g., SiO_2 % increases from siltstone to sandstone; TiO_2 %, Al_2O_3 %, Fe_2O_3 %, and K_2O % decrease from siltstone to sandstone) (Table 2). The depletion of Na_2O and CaO is probably due to the small amount or absence of plagioclase feldspars (as confirmed by the petrographical investigation). Generally, the quartz arenite is poor in these two cations.

Table 2. Major oxide values (wt. %) of selected sandstone and siltstone samples of the Abu Durba Formation.

Sample	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
A-1	96.86	0.07	1.33	0.37	0	0.05	0.23	0	0.03	0.01	98.95
A-2	94.726	0.347	4.807	0.264	0.003	0.051	0.371	0.091	0.053	0.006	100.72
A-5	96.4	0.24	1.79	0.24	0	0.08	0.22	0.01	0.02	0.02	99.02
A-6	66.08	1.53	28.29	2.64	0	0.28	0.24	0.14	0.1	0.06	99.36
A-8	97.19	0.1	1.64	0.23	0	0.02	0.05	0	0.01	0.01	99.25
A-9	98.899	0.092	1.576	0.284	0.004	0.073	0.014	0	0.006	0.004	100.95
A-11	99	0.11	0.13	0.05	0	0.02	0.08	0	0.01	0	99.4
B-1	97.595	0.16	1.578	0.383	0.006	0.115	0.215	0	0.03	0.015	100.1
B-2	95.32	0.09	2.66	0.15	0	0.07	0.22	0.03	0.02	0.01	98.57
B-4	97.783	0.182	1.367	0.206	0.006	0.144	0.364	0	0.026	0.015	100.09
B-7	96.53	0.22	1.4	0.68	0	0.07	0.29	0.01	0.05	0.01	99.26
B-9	90.97	0.39	6.09	0.28	0	0.02	0.45	0.55	0.04	0.01	98.8
B-10	93.16	0.51	2.87	0.47	0.01	0.39	1.27	0.01	0.04	0.03	98.76
B-12	99.442	0.106	0.057	0.058	0.003	0.076	0.065	0	0.003	0.006	99.82

Note: All samples are sandstones except samples A-6 and B-9 are siltstones.

Table 3. Trace element composition (ppm) of selected sandstone and siltstone samples of the Abu Durba Formation.

Sample	V	Cr	Co	Ni	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	La	Ce	Nd
A-1	20.6	7.9	1.9	4.6	3.2	2	0.5	17.4	6.3	864	1	29	8	24	14
A-5	12.8	3.8	2.5	15.2	8.4	1.5	0.2	48.5	14.8	842	5	38	28	54	23
A-6	93.7	143	6.1	6.9	15.4	37	ND	102	51.8	392	31	38	114	190	102
A-8	20.7	4.9	0.7	3.9	3.2	2.3	ND	13.9	4.7	713	5	91	5	7	4
A-11	4.1	0.2	1.6	11	3.5	ND	ND	8.3	4.8	1176	2	48	ND	10	6
B-2	24.4	4.9	2.5	14.1	3	2.1	0	48.9	7.4	1083	3	20	12	22	13
B-7	20.2	9.5	7.1	15.5	7.9	1.8	0.4	50.5	6.4	799	5	26	6	21	12
B-9	71.4	14.7	4.3	2.5	6.3	6.5	0.5	52.3	10.6	800	9	34	7	19	7
B-10	35.9	9.1	2	29.5	5.7	3.9	0.1	71.7	15.7	477	16	73	34	51	24

ND = not detected
Note: All samples are sandstones except samples A-6 and B-9 are siltstones.

Variations in the major element geochemistry of the selected sandstone and siltstone samples are shown on Harker's diagrams (Fig. 5). Generally, SiO_2 % increases with decreasing the content of TiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, and K_2O due to the increase in textural and mineralogical maturity. Textural maturity is indicated by the little amount or absence of matrix. Mineralogical maturity is characterized by the increase in the quartzose content and the decrease in unstable detrital grains such as feldspars and rock fragments (Gu et al., 2002). Prominent negative correlation between SiO_2 % and Al_2O_3 % (r = -0.99) assures that most of SiO_2 occurs as quartz grains (Akarish and El-Gohary, 2008). However, there is a slightly positive correlation of SiO_2 % with MnO % (r = 0.19) indicating that the studied sediments are enriched in MnO.

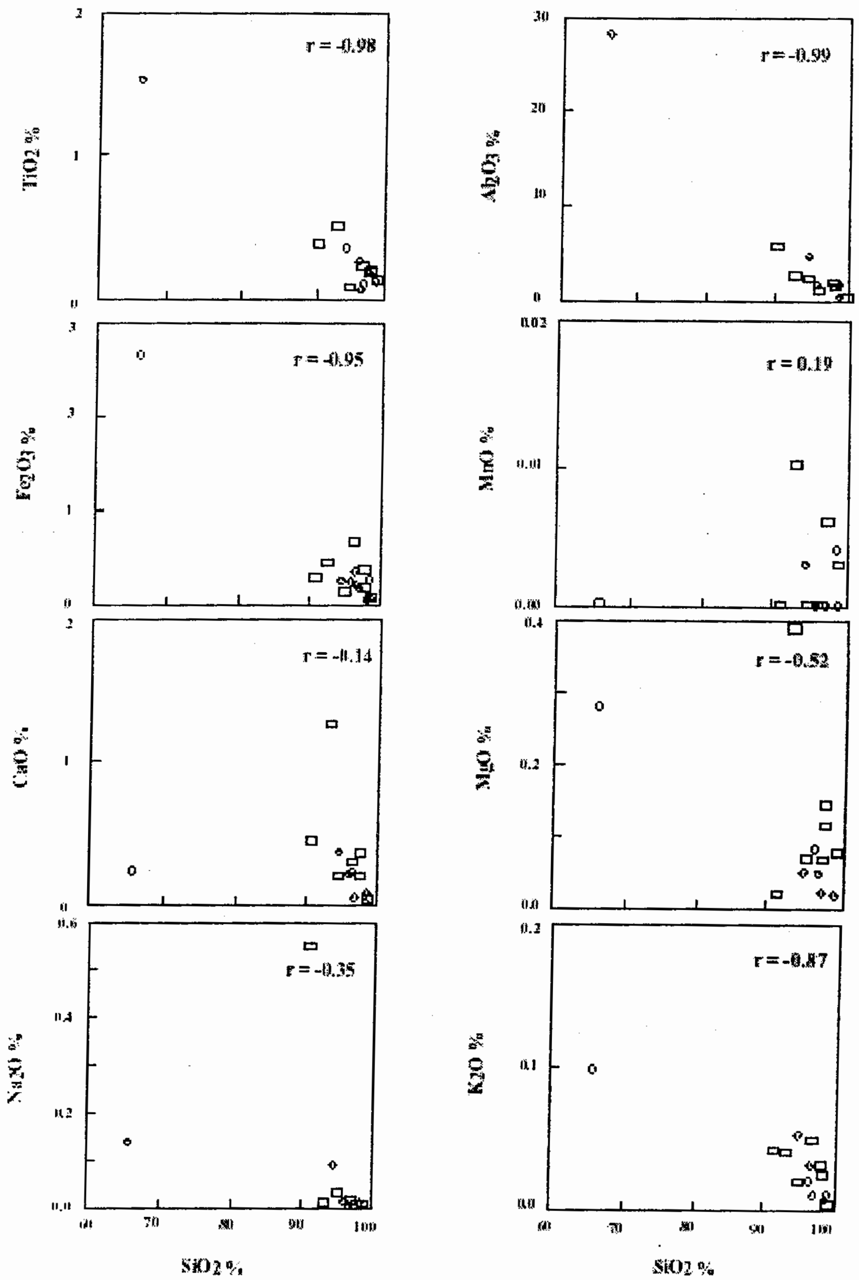

Fig. (5): Harker's Variation diagrams of major elements for selected sandstone and siltstone samples of the Abu Durba Formation. Symbols as in Fig. 3.

Plots of SiO_2 % versus the trace elements (Y, Sr, Cr, and Nb) show negative correlations (Fig. 6) indicating that most of the trace elements are concentrated in the clay fraction. However, slightly positive correlation of SiO_2 % with Ba and Ni (r = 0.11 and 0.17, respectively) occur (Fig. 6). Based on the SiO_2/Al_2O_3 and Fe_2O_3/K_2O ratios, Herron (1988) presented his scheme for chemical classification of terrigenous sands and shales. On this scheme (Fig. 7), the Abu Durba sediments are mainly classified as quartz arenite and Fe-sand.

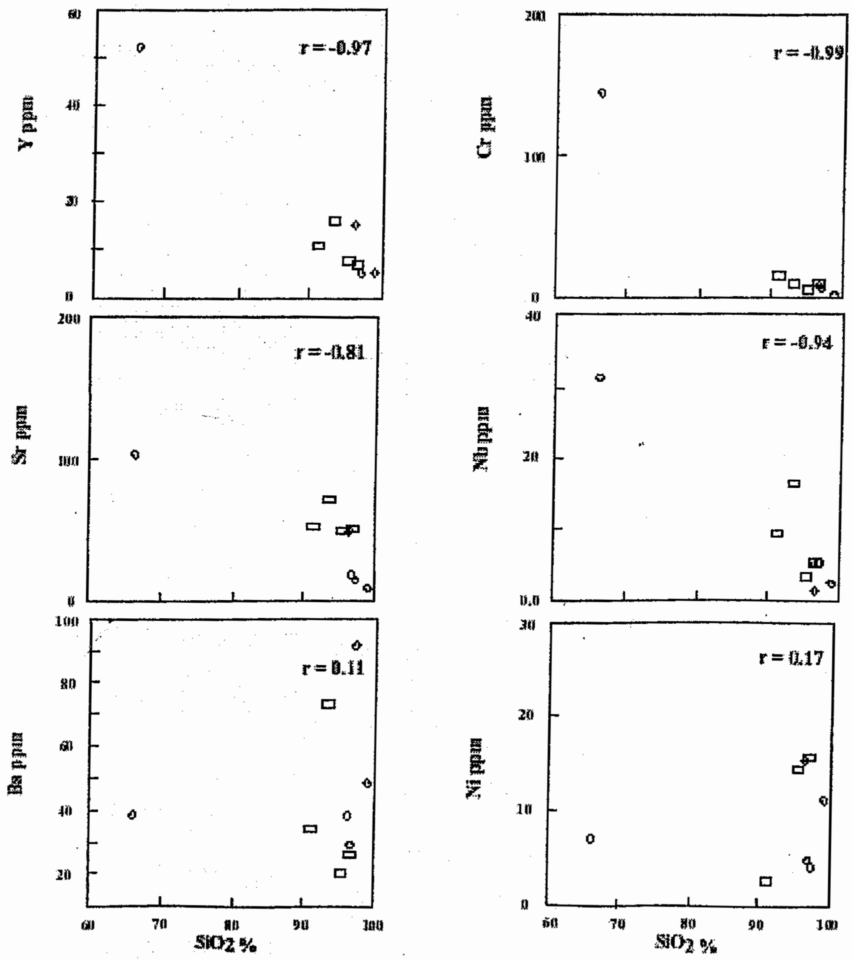

Fig. (6): Plots of SiO2 % versus some trace elements (Y, Sr, Cr, Nb, Ba, and Ni) for the Abu Durba Formation sediments. Symbols as in Fig. 3.

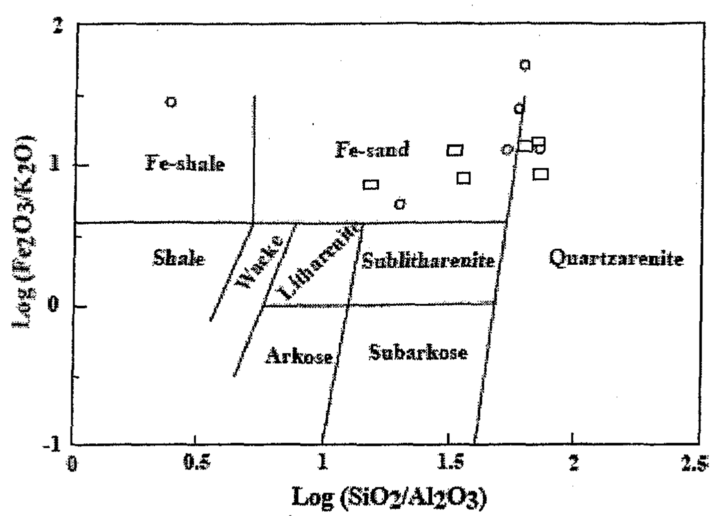

Fig. (7): Major-element classification of the terrigenous sediments of the Abu Durba Formation (After Herron, 1988). Symbols as in Fig. 3.

CONCLUSIONS

The studied Abu Durba Formation unconformably overlies the Upper Cambrian Naqus Formation (at Gabal Ekma) and the Lower Carboniferous Abu Thora Formation (at Wadi Feiran area) and unconformably underlies the Lower Cretaceous Malha Formation. This formation is composed of interbedded sandstones, siltstones, and shales. Conglomeratic lag deposits occur at the base of sedimentary sequences. The Abu Durba Formation is divided into five lithofacies. Each lithofacies has its own environment of deposition. These lithofacies are: lithofacies A (conglomerate) (channel lag deposits), lithofacies B (sandstone) (fluvial channel deposits), lithofacies C (interbedded sandstone and siltstone) (levee and crevasse splay deposits), lithofacies D (siltstone-dominated facies) (overbank flood deposits), and lithofacies E (gray to black siltstone and shale) (low energy marine shelf deposits).

Petrographic investigation revealed that the studied Abu Durba sandstones are mainly quartz arenite with few samples of subarkose and sublitharenite reflecting their high maturity. Modal analysis showed that the Abu Durba sandstones were essentially derived from plutonic source with some contributions from metamorphic and reworked pre-existing sandstone sources.

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السحنات الصخرية ، البيئات الترسيبية وصخور المصدر لمتكون أبو دربة (الكربوني المتأخر) ، جنوب غرب سيناء ، مصر

حسني الدسوقي سليمان

قسم الجيولوجيا ، كلية العلوم ، جامعة المنوفية ، شبين الكوم ، مصر

تهدف الدراسة الي القاء الضوء علي السحنات الصخرية والبيئات الترسيبية بالاضافة الي صخور المصدر لمتكون أبو دربة (الكربوني المتأخر) في جنوب غرب سيناء بمصر. يتكون متكون أبو دربة من طبقات متبادلة من الحجر الرملي والحجر الغريني والطفل بالاضافة الي طبقات رقيقة من الكونجلوميرات الكتلية أو ضعيفة التطبق عند قاعدة التتابعات الرسوبية.

وقد أمكن تقسيم متكون أبو دربة الي خمس سحنات صخرية هي الكونجلوميرات Conglomerate والحجر الرملي Sandstone والحجر الرملي المتبادل مع الحجر الغريني Interbedded sandstone and siltstone والحجر الغريني Siltstone (ترسبت جميعها في بيئة نهرية) والحجر الغريني والطفل الرمادي الي الأسود Gray to black siltstone and shale التي ترسبت في بيئة بحرية هادئة.

ودلت الدراسة البتروجرافية علي أن الحجر الرملي لمتكون أبو دربة أساسا عبارة عن كوارتز أرينيت Quartz arenite مع عينات قليلة من Subarkose و Sublitharenite مما يدل علي نضوج هذه الأحجار الرملية. وقد دلت الدراسة أيضا علي أن المصدر الرئيسي للأحجار الرملية لهذا المتكون عبارة عن صخور نارية جوفية مع بعض الاضافات من صخور متحولة وصخور رملية سابقة التكوين.