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LITHOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE LOWER CRETACEOUS SEDIMENTS OF ABU DARAG AREA, GULF OF SUEZ, EGYPT.

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ABSTRACT

The lower Cretaceous sediments in Abu Darag area are mainly formed of sandstones, argillaceous sediments and clay beds.

According to Trask (1930), Folk and Ward (1950) the sandstones are very fine to very coarse grained, ranging from very well sorted to very badly sorted, having symmetrical characters and vary from platykurtic to leptokurtic. It has been concluded that the sandstones were deposited in a beach environment with turbidity currents (Sahu, 1964).

INTRODUCTION

The lower Cretaceous succession of Abu Darag area lies in the stretch of El Galala El Bahariya. The sediments are well exposed at Bir Heimer, Bir Abu Darag, Wadi Qiseib and Bir Abu Sandug, roughly limited by latitudes $29^{\circ} 19' 30''$ to $29^{\circ} 31' 40''$ N and longitudes $32^{\circ} 26' 54''$ E to the Gulf of Suez-Ras Gharib asphaltic motor route and at a distance of about 80 kms south of Suez.

These sediments which are represented by non-fossiliferous varicoloured sandstones, termed Lower

Cretaceous Nubia sandstones by Said (1962) whereas Abdallah and El-Adindani (1963) gave them the formal name Malha Formation at the type locality of Wadi Malha. However, recently, Zaghloul et al. (1984) stated that the assignment of these clastics to Malha Formation seemed to need modification. Kolkila et al. (this volume) studied the petrography and diagenesis of these sediments and suggesed that the sandstones were deposited -most probably-not far from the source supply, whereas the silt size grade were detected on the flood plain of alluvial cycles (Mackin, 1973; Allen, 1964, and Visher, 1965). Alluvial cycles beside deep weathering of iron silicate minerals could provided the red colour to the thick laminated clayey layers in all the studied scections. Also, tectonism had played its role on both sides of the Gulf as well which caused the noticeable differences in lithological characters (Abdallah and El Adindani, 1963).

The main goal of the present work is the lithostratigraphic and the sedimentologic studies of the Lower Cretaceous sandstones in Abu Darag area and the associated clay. Four geologic sections were measured and studied at; Bir Heimer,Bir Abu Darag, Wadi Qiseib and Bir Abu Sandug. The studied sandstone formation is represented mainly by a series of sandstone, argillaceous sandstone and clay beds. Mechanical analyses for selected 30 samples, representing the sandstones and clays using both dry and wet methods of grain size analyses were carried out and interpreted using two approaches. The first approach uses the grain size paramaters of Trask (1930), Folk and Ward (1950), while the second one used the discriminant functions of sahu (1964).

Sixty sandstone samples and ninety clay samples were selected from the study area. The geology of the area was investigated to locate the sandstones and the clays. Location of sampling and cross section sites in the area are shown in (Fig. 2).

GEOLOGY OF THE LOWER CRETACEOUS SEDIMENTS OF ABU DARAG AREA :

In many parts of the coastal stretch between Gabal Ataqa and Northern Galala plateau, there is a series of non-fossiliferous, varicoloured sandstones that closely resemble the Nubia sandstones of Southern Egypt. These sandstones underlie the Cenomanian and overlie the Jurassic sediments where the latter occur. All previous studies referred to a comformable relation between these sandstones of Nubia facies and the overlying Cenomanian marls.

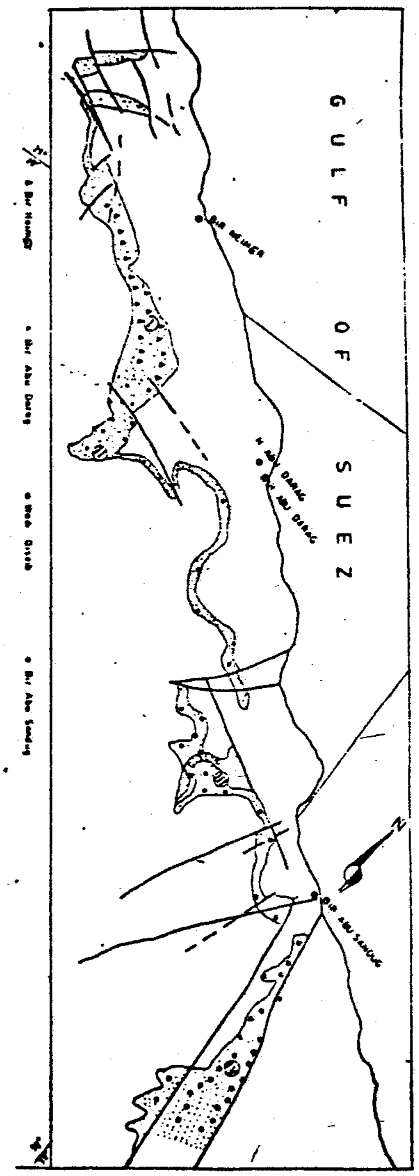

Fig. (2) - Location of sampling and the cross-sections sites in Abu Darag Region.

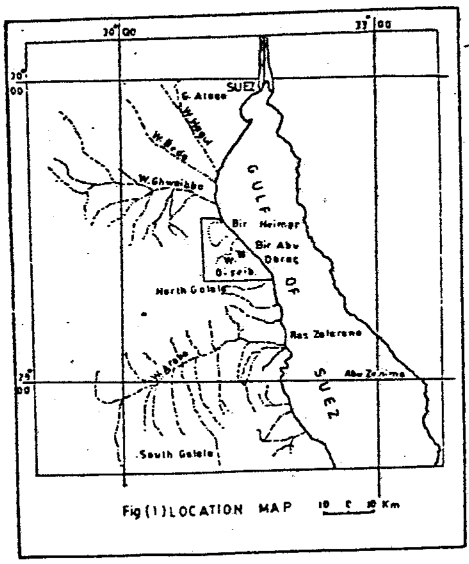

Fig. (1) - Location map showing the studied area.

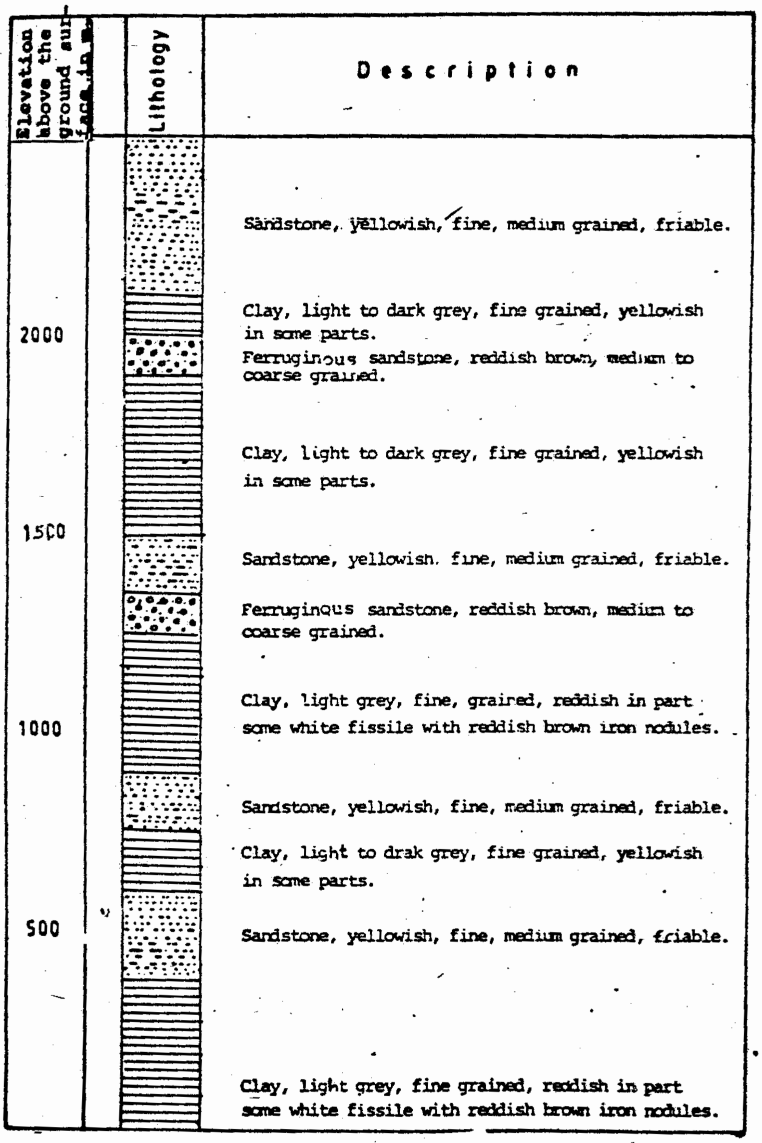

Fig. (3)- Compiled columnar section showing the thickness and lithology of Lower Cretaceous sediments at Abu Darag area.

The sandstone beds are yellowish, white, reddish brown, fine, medium to coarse grained and they are interbeded by layers of clay with typical grey, yellow, white, and reddish colour. The lower surface of the sandstone bed is unexposed. The exposed part ranges between 5 and 30 ms. in thickness where four geolgic sections were measured and sampled form Abu Darag area.

The detailed description of the ideal section representing the succeession of the Lower Cretaceous sediments for the Abu Darag area is shown (Fig. 3).

Ripple marks, stratification, graded-bedding and cross bedding are the main primary structures used in determining the environmental conditions prevailing during the deposition in the area.

Secondary Structures :

El-Kholy (1987), stated tht the main secondary structure in Abu Darag area is represented by an asymmetric anticlinal fold mainly affecting the Late Carboniferoas and Permo-Triassic rocks with an axis striking N 64^{o} E-56^{o} W. The recorded mesofolds are following two diretions, ENE-WSW and NNW-SSE. These meso-folds are mainly asymmetric. Also, sets of joints are mainly trending towards ENE-WSW, NW-SE, E-W,

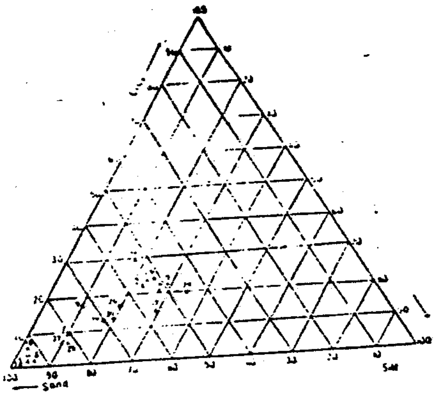

Fig. (4)- Ternary diagram showing classification and nomenclature of Abu Darag sandstones, after Pettijohn (1975).

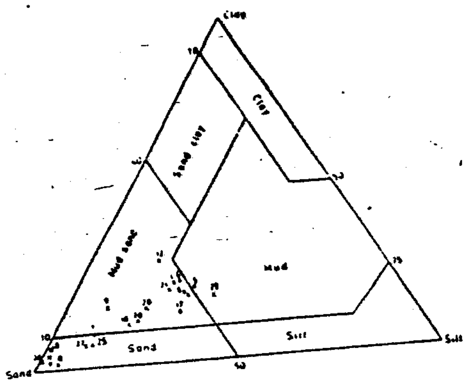

Fig. (5)- Ternary diagram showing classification and nomenclature of Abu Darag sandstones, after Pettijohn et al (1973)

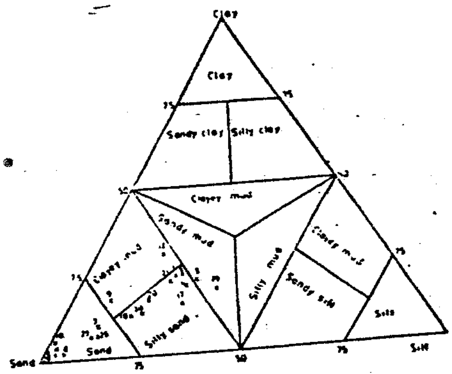

Fig. (6)- Ternary Diagram showing classification and nomenclature of Abu Darag sandstones, after Picard (1971).

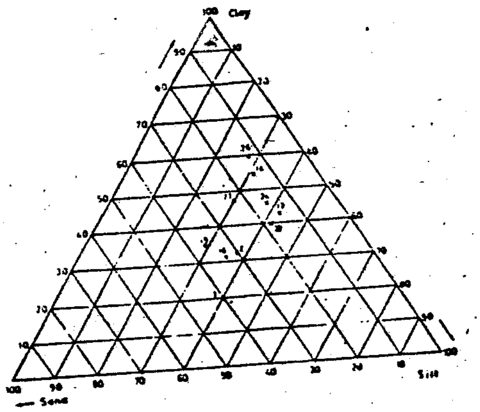

Fig. (7)- Ternary diagram showing classification and nomenclature of Abu Darag clays, after Pettijohn (1975).

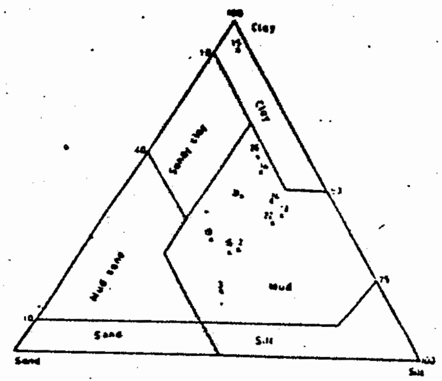

Fig. (8)- Ternary diagram showing classification and nomenclature of Abu Darag clays, after Pettijohn et al (1973).

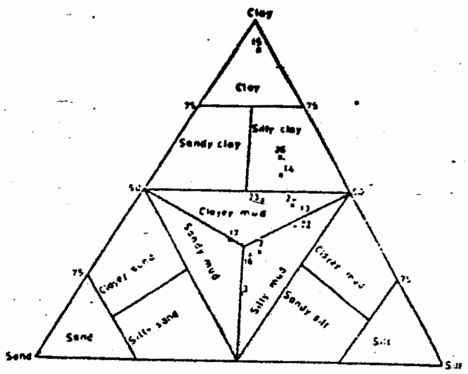

Fig. (9)- Ternary diagram showing classification and nomenclature of Abu Darag clays, after Picard (1971).

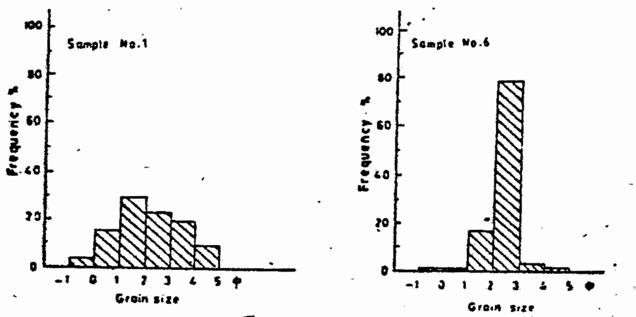

Fig. (10)- Histograms representing grain size analyses of Bir Heimir sandstones.

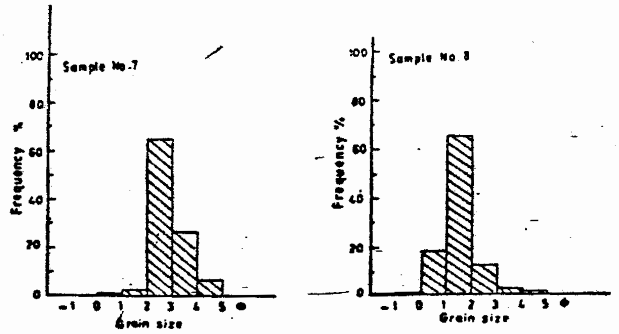

Fig. (11)- Histograms representing grain size analyses of Abu Darag sandstones.

NE-SW and WNW-ESE directions. Faults are mainly of normal strike-slip types. Their prevailing trends are NNW-SSE, NE-SW, NW-SE and ENE-WSW trends, the NE-SW fault set is relatively younger than NNW-SSE one.

The recorded unconformities in the area under consideration are of the angular type. The first unconformity is recorded between Permo-Triassic and Early Cretceous sandstones, where the Permo-triassic rocks dip 15^{o} to SE whereas the overlying Early Cretaceous sandstone is nearly horizontal as stated by El-Kholy (1987).

The second angular unconformity is recorded between Gebel Duwi Formation and Wadi Irkas Formation. Where the beds of Gebel Duwi Formation dip 15^{o} to NW and overlained by the horizontal beds of Wadi Irkas Formation. The unconformity surface includes rounded to subrounded phosphatic limestone pepples and coarse sandstones embedded in fine sand matrices.

MECHANICAL ANALYSES

A- Rock Nomenclature :

Mechanical analyses of selected 30 samples representing the sandstones and clays collected from Abu Darag area have been carried out. Both dry and wet methods of grain size

Table (1) - Data of the Mechanical analyses for the study of the argillaceous sandstone samples by wet method

No.	Sand %	Silt %	Clay %	Rock Name	
				According to pettijohn et al (1957)	According to picard (1971)
1	52	26	22	Mud sand	Silty sand
4	53	[illegible]	21	Mud sand	Silty sand
6	51	24	24	Mud sand	Silty sand
7	80	10	10	Sand	Sand
8	92	3	5	Sand	Sand
9	72	10	18	Mud sand	Clayey sand
10	70	16	14	Mud sand	Silty sand
11	94	3	3	Sand	Sand
12	53	17	30	Mud sand	Clayey sand
17	55	28	17	Mud sand	Silty sand
18	93	2	5	Sand	Sand
20	64	19	17	Mud sand	Silty sand
21	52	24	24	Mud sand	Silty sand
25	82	12	6	Sand	Sand
27	82	10	8	Sand	Sand
28	94	2	4	Sand	Sand
30	67	18	15	Mud sand	Silty sand

Table (2) - Data of the Mechanical analyses for the study clay samples by wet method

No.	Sand %	Silt %	Clay %	Rock Name	
				According to pettijohn et al (1957)	According to picard (1971)
2	30	37	33	Mud	Silty Mud
3	40	40	20	Mud	Silty Mud
5	49	27	24	Mud	Sandy Mud
13	15	[illegible]	42	Mud	Clayey Mud
14	14	31	55	Mud	Silty Clay
15	1	8	91	Clay	Clay
16	32	35	33	Mud	Silty Mud
19	37	29	34	Mud	Sandy Mud
22	18	42	40	Mud	Clayey Mud
23	22	30	48	Mud	Clayey Mud
24	18	38	44	Mud	Clayey Mud
26	12	28	60	Mud	Silty Mud
29	46	34	20	Mud	Sandy Mud

Table (3): Grain size measurements parameters of the examined Abu Darag Sandstones

Sample No.	Ø5	Ø16	Ø25	Ø50	Ø75	Ø84	Ø95	Mz	σ_I	SK_I	KG	Md	So	Sk
1	0.25	0.32	0.60	1.20	2.40	2.55	3.10	1.36	0.989	0.272	0.649	1.20	0.5	1.0
6	0.223	0.70	1.10	1.62	2.03	2.42	4.30	1.58	1.048	0.122	2.652	1.62	0.830	1.083
7	1.52	2.40	2.60	3.20	3.90	4.1	5.0	1.58	0.952	0.046	1.097	3.200	0.816	0.990
8	-0.30	0.40	0.70	1.30	1.66	1.92	2.45	1.21	0.797	-0.174	1.174	1.30	0.649	0.687
18	0.85	1.40	1.90	2.50	2.90	2.50	3.9	2.133	0.737	-0.091	1.25	2.500	0.809	0.882
21	0.60	1.30	1.60	2.10	2.50	2.73	3.10	2.043	0.736	-0.159	1.138	2.10	0.8	0.907
25	0.95	1.62	1.85	2.50	3.70	3.52	4.35	2.546	0.990	-0.169	1.032	2.50	0.760	0.947
27	1.20	1.60	2.20	2.70	3.30	3.62	4.20	1.717	0.959	0.477	1.118	2.700	0.816	0.336
28	0.30	0.60	1.20	1.92	2.35	2.63	3.20	1.716	0.946	-0.209	1.033	1.92	0.714	0.765
30	1.42	2.10	2.35	3.16	4.22	4.95	5.30	3.403	1.30	0.179	0.850	3.16	0.746	0.993

Table (4): Nomenclature of Grain Size parameters of Abu Darag sandstones (Folk and Ward 1957).

Sample No.	M_z Mean size	σ_I Inclusive graphic Standard Deviations	SK Skewness	KG Kurtosis
1	Medium sand	Moderately sorted	Fine skewed	Very platy kurtic
6	Medium sand	Poorly sorted	Fine skewed	Very lepto kurtic
7	Medium sand	Moderately sorted	Near-symmetrical	Meso kurtic
8	Medium sand	Moderately sorted	Near-symmetrical	Lepto kurtic
18	Fine sand	Moderately sorted	Near-symmetrical	Lepto kurtic
21	Fine sand	Moderately sorted	Coarse Skewed	Letpto kurtic
25	Fine sand	Moderately sorted	Coarse skewed	Meso kurtic
27	Medium sand	Moderately sorted	Near-symmetrical	Lepto kurtic
28	Medium sand	Moderately sorted	Coarse skewed	Meso kurtic
30	Very fine sand	Poorly sorted	Fine skewed	Platy kurtic

analyses of the samples chosen from four sections are as follows :

- Six samples have been taken from Bir Heimer section.
- Five samples have been taken from Wadi Abu Darag section.
- Ten samples have been taken from Wadi Qiseib section; and
- Nine samples have been taken from Bir Abu Sandug section.

All samples represent the Lower Cretaceous age.

The results are given in Tables (1) and (2) and are plotted on ternary diagrams (Figs. 4 to 9).

According to the nomenclature given by Pettijohn et al. (1973), it was found that 33.4 of the study samples are mud sand, 40% mud, 23.3% sand, and 3.3% are clay.

According to Picard (1971) it is revealed that 26.6% are silty sand, 23.3% sand, 13.3% silty mud, 10% sandy mud, 6.6% clayey mud, 3.3% clay and 6.6% silty clay.

B- Grain Size Analysis of Sandstone :

I- Histograms and Cummulative Curves :

The data obtained from the dry sieve mechanical analyses were plotted in the form of histograms for each individual sample (Figs. 10 to 14).

These figures show that the sandstones of Abu Darag of different localities consist mainly of very coarse sand to very fine sand. However,some of the samples contain a marked amount of very coarse sand.

According to the recommendations cited by Folk (1966). Friedman (1967), Moiola and Weiser (1988), Pettijohn et al. (1973) and Amaral and Pryor (1977), a quarter phi unit should be used in sieve analysis for the best estimates of grain size parameters and shape of the cummulative curve. Maximum accuracy in determining grain size parameters is assured when the data were plotted as cummulative curves on probability paper (Figs. 15, 16 and 17).

II- Grain Size Parameter :

Two methods are generally used for the determination of the grain size parameters :

(1) A cummulative curve is drawn from the data of sieve analyses from which quantitative readings may be made, or;

(2) Statistical parameters are obtained directly from size data without the intermediary graph-plotting stage.

Folk (1966), gave an excellent review of the grain size parameters and pointed out the advantages of the graphical methods.

In the present work, the classical grain size parameters of Trask (1930) and the more recent statistical grain size parameters of Folk and Ward (1957) are used.

1- Measurements of Average Grain Size :

The medium diameter (Md) of Trask (1930) was directly read from the cummulative curves (Md = quartile 50) and found to vary between 1.20 mm and 3.20 mm (Table 3). This indicates that the studied samples of Abu Darag sandstones range between very fine to very coarse in size. The medium daimeter of Trask does not represent-in fact-the average gain size, since it is based only on one point of the cummulative curve. The best measurement on overall average size is the mean as computed by the method of moments, where the entire size curve enters into the computation graphic measurements have aimed at approximately this median as closely as possible but by much simpler and quicker methods.

Folk and Ward (1957) pointed out that the mean is a very misleading value and should be abandoned. They calculated values for average size, sorting, skewness and kurtosis at specific percentiles in phi units on the log-probability curves of grain size distribution of the studied samples. The proposed scales of standard deviation and the verbal limits of skewness and kurtosis of Folk and Ward (op.cit.) are adopted in the present study. The formulae used are the following:

The mean size (MZ) of Folk land Ward (1957) is more efficient than the median diameter of Trask (1930), as indicated by McCamman (1962). Kolklia (1972) calculated the 0 values and the mean size range between very coarse to very fine-in size.

In Abu Darag area ther (0) values and the mean size (MZ) are given in Tables (3), (4). The mean size (MZ) varies from 1.21 0 to 3.4 0; i.e. Abu Darag sandstones range in size between medium sand to very fine sand.

2- **Sorting : (So)**

The sorting coefficient (So) of Trask (1930) was calculated for each sample, according to :

$$So = Q_1 / Q_3$$

Table (5): Environmental interpretation of Abu Darag sandstone based on Sahu's (1964) Linear Discriminant

Sample No.	Y_1	Y_2	Y_3	Y_4
1	0.223	102.4944	-9.4805	5.8531
6	6.4305	148.1834	-9.6401	15.5530
7	1.0361	105.4168	-7.6612	6.8897
8	2.0496	79.2530	-4.3116	5.6585
18	-1.5208	88.4899	-3.6445	7.3224
21	-1.4126	85.7529	-3.329	6.2076
25	-1.8943	120.2913	-6.9833	5.7664
27	-0.2329	116.6331	-9.8472	9.9966
28	0.8388	100.9958	-6.2779	4.9378
30	-3.614	185.2876	-14.6694	7.4781

To sum up the disriminant functions of Sahu indicate that the sandstones of Abu Darag were deposited in beach environment with shallow agitation.

Turbidity currents had a role during deposition of the Abu Darag sandstones.

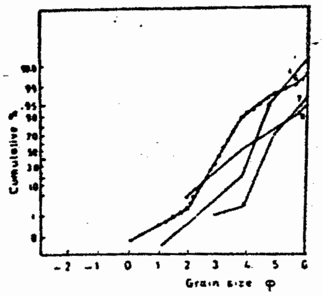

Fig. (15)- Cumulative curves of Abu Darag sandstones.

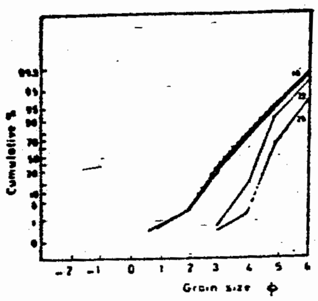

Fig. (16)- Cumulative curves of Abu Darag sandstones.

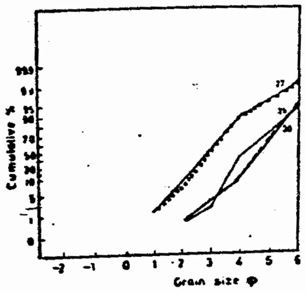

Fig. (17)- Cumulative curves of Abu Darag sandstones.

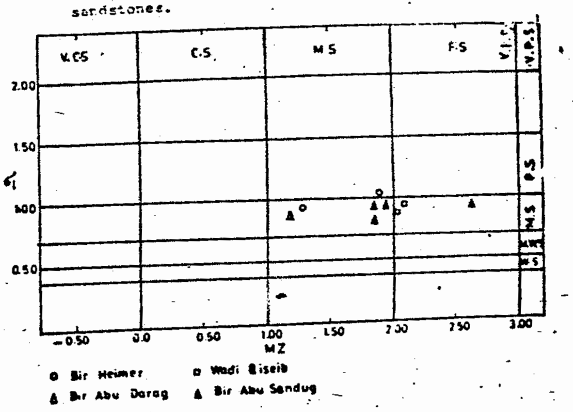

Fig. (18)- The relationship between Mean size (M) and sorting (σ_1).

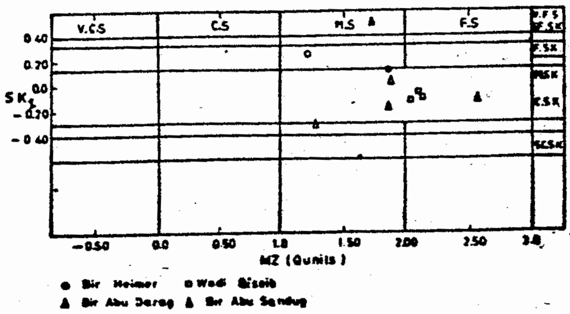

Fig. (19)- The relationship between Mean size (M_z) and Kurtosis (K_G).

According to the verbal scale of Fuchtbauer (1959), it is found that Abu Darag sandstones range between very well-sorted to very badly sorted.

The inclusive graphic standard deviation (6_1) of Folk and Ward (1957) is given by :

$$6_1 = \frac{084-016}{4} + \frac{095-05}{6.6}$$

According to these parameters; sandstone of Abu darag have values of 6_1 varying from 0.736 0 to 1.30 0 in Table (3) which indicates that the sandstones vary from moderately sorted to poorly sorted, according to the verbal scale given by Folk and Ward (1957).

3- **Skewness (SK) :**

Skewness can be obtained by using the inclusive graphic skewness (SK_1) of Folk and Ward (1952) where it is calculated according to :

$$SK_1 = \frac{016 + 084 - 2050}{2(084 - 016)} + \frac{05 + 095 - 2050}{2(095 - 05)}$$

In Abu Darag sandstones the ranges of SK_1 are shown in Table (7) which, according to the verbal scale of Folk and Ward (1957) indicate coarse skewed to find skewed.

4- **Kurtosis (KG) :**

the Graphic Kurtosis (KG) of Folk and Ward (1957) is given by :

$$KG = \frac{095 - 05}{2.44\ (075-025)}$$

The calculated values of (KG) for Abu Darag sandstones given in Tables (3,4) vary between 0.649 and 2.652. According to the verbal scale of Folk and Ward (1957), Abu Darag sandstones range between very platy-Kurtic to very lepto-kurtic in character.

C- **The Relationship between grain size parameters :**

1- Mean sie (MZ) versus inclusive graphic Standard Deviation (6_1):

Fig. (18) shows the relationship between (MZ) and (6) which indicates that most of the samples are moderately stored to poorly sorted. On the other hand, most of the medium sand and vey fine-sand are moderately and poorly sorted. The general moderately sorted to poorly soreted of the sand indicates a beach environment.

Mason and Folk (1958) pointed out that values of 6_1 higher than 0.03 indicate beach environemnt of deposition, which is the case for the studied samples.

2- **Mean Size (MZ) Versus skewness (SK_1) :**

Friedman (1981); and Moiola and Weiser (1968) used the relationship between the mean size and skewness to differentiate between different environments. Fig. (19) shows the relations between (MZ) and (SK_1) for the Abu Darag sandstones. The nearly symmetrical character of most samples whether medium sand or fine sand points to beach environment.

3- **Mean Size (MZ) Versus Kurtosis (K_G) :**

Fig. (10) shows the relationship between (MZ) and (K_G) which indicate that most of Abu Darage sandstone samples are mesokurtic to leptokurtic, indicating typical beach environments.

4- **Sorting (So) Verses Skewness (SK_1) :**

Fig, (21) shows the relationship between sorting and skewness from which appears that most of Abu Darag sandstones whether moderately sorted or badly sorted and are near-symmetrical.

5- Sorting (So) Versus Kurtosis (K_G) :

Fig. (22) shows the relationship between sorting and Kurtosis. Most of Abu Darag sandstones whether moderately well sorted or moderately sorted are leptokurtic to mesokurtic.

6- Skewness (SK_1) Versus Kurtosis (K_G) :

Fig. (23) shows the relationship between skewness and Kurtosis. The distinct near-symmetrical character accompanied by the distrinct mesokurtic character is an indication of beach environment of deposition of Abu Darag sandstones.

D- The Discriminant Functions of Sahu :

Sahu (1964) introduced four discriminant functions based on the graphical parameters of Folk and Ward (1957) to differentiate between aeolian, beach, shallow agitated, marine, deltaic and turbidity environments.

The four discriminant functions have been calculated. The results are given in Table (5) in which the discriminant function (Y) of most Abu Darag sandstones indicates beach

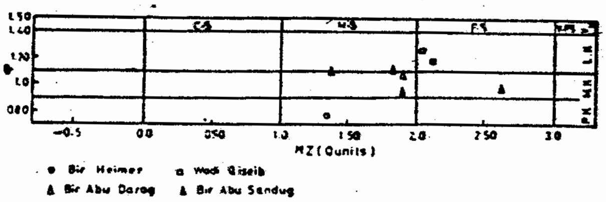

Fig. (20)- The relationship between Sorting (σ) and Skewness.

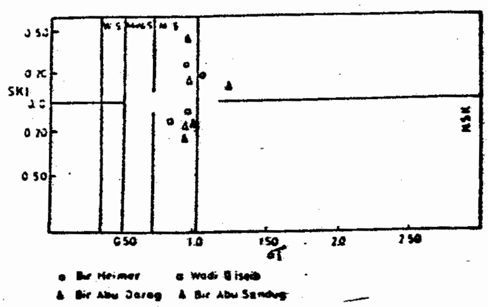

Fig. (21)- The relationship between Sorting (σ) and Kurtosis (K_G).

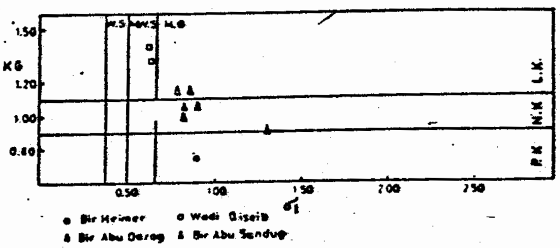

Fig. (22) - The relationship between skewness (SK_1) and Kurtosis (K_G).

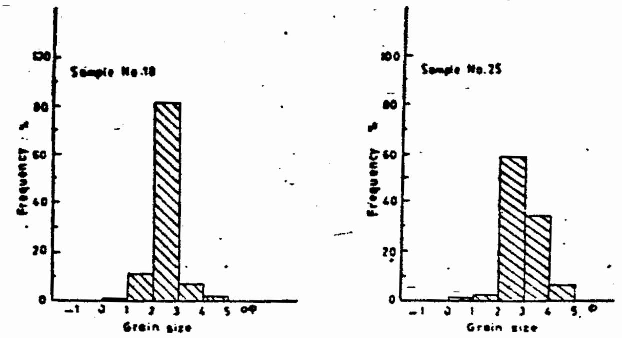

Fig. (12)- Histograms representing grain size analyses of Wadi Qiseib sandstones.

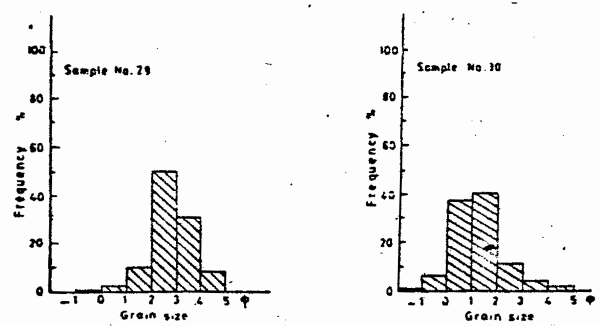

Fig. (13)- Histograms representing grain size analyses of Abu Sandug sandstones.

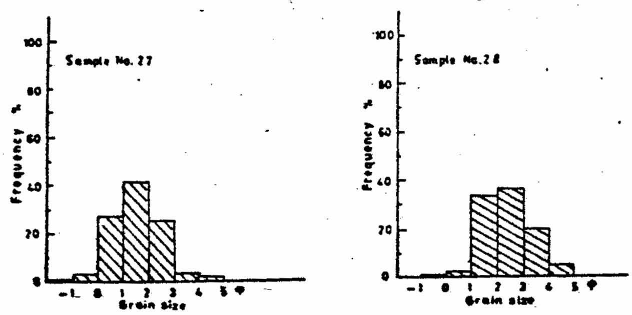

Fig. (14)- Histograms representing grain size analyses of Abu Sandug sandstones.

environment. Most of (Y_2) values are greater than 65.650 which indicates a shallow agitated marine environment. A similar conclusion can be attained from (Y_3).

(Y_3) function where most of (Y_3) are greater than 7.419. Some values indicate an aeolian environment. This means that Abu Darag sandstones were deposited mostly in shallow marine environment but some samples indicate aeolian origin. This could be attributed to small experimental errors in sieve analyses.

All the values of (Y_4) given in Table (5) (except samples No. 6 and 27) are less than 9.8433 indicating the role of turbidity currents during the deposition of Abu Darag sandstones.

To sum up the discriminant functions of Sahu (1964) indicate that the sandstones of Abu Darag were deposited in beach environment with gentle agitation. Besides turbidity currents had played a role during deposition of the Abu Darage sandstones.

CONCLUSIONS

The present study deals with the lithostratigraphy and sedimentology of a Lower Cretaceous sandstones in Abu Darag area and its associated clays. The examined sandstone formations consist mainly of a series of sandstones, agrillaceous sandstones and clay beds.

Four stratigraphic columnar sections were measured and studied from the following localities: Bir Heimer, Wadi Abu Darag, Wadi Qiseib and Bir Abu Sandug. From these four localities a compiled columnar section for the Lower Cretaceous sediments of Abu Darag area have been made.

Ten samples of friable sandstones representing the investigated area have been mechanically analyzed and interpreted using two approaches. The first approach is the use the grain size parameters of Folk and Ward (1957), while the second one applies the discriminant functions of Sahu (1964). The following conclusions are reached:

The Abu Darage sandstones vary between very coarse to very fine (Trask, 1930), well sorted and very badly sorted (Trask, 1930) and (Folk and Ward, 1957). They have symmetrical and asymmetrical, platykurtic to very leptokurtic character and are believed to be deposited in a beach environment with turbidity enverents (Sahu, 1964).

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