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Geochemical Study of the Shales of Gebel Ghorabi Member, Bahariya Oasis, Western Deser, Egypt

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Abstract: Shale samples from two surface sections representing the lowermost part of the Cenomanian Bahariya Formation (Gebel Ghorabi Member) were chemically analyzed. The data indicate deviation of their composition from the average published data. They are characterized by the presence of free silica, authigenic iron oxides, halite and gypsum. The material was derived from different types of weak to moderately weathered provenances under an arid condition and the shales passed through fluvial and shallow marine environments during their deposition.

Keywords: Geochemistry, Baharia Oasis, Baharia Formation, Cenomanian and Gebel Ghorabi Member.

INTRODUCTION

The surface and subsurface sediments of the Bahariya Formation, Bahariya Oasis, Western Desert were studied by different authors on paleontological, petrographic and mineralogical basis. The present work is concerned with the lowermost part of this formation defined as Gebel Ghorabi Member (Dominik, 1985), in a trial to identify their conditions of formation based solely on geochemical data. For this purpose, two surface sections were sampled from the Bahariya Oasis and their lithologic sequence are given in Figs. (1-A and 1-B).

MATERIALS AND METHODS

Thirteen selected shale samples from Gebel Ghorabi Member (Bahariya Formation) were chemically analyzed at the labs of EPRI following the standard methods of silicate analysis (Vogel, 1961 and Popova and Stolyarova, 1974). Colorimetric spectrophotometry was used to measure Ti, Mn, P, V and Zn. The elements Zr, Y, Sr, Rb, Cu, Ni, Ba and Cr were detected using XRF.

Stratigraphy:

The stratigraphy of the Bahariya Oasis has been dealt with by different authors such as Said (1962) and El-Akkad and Issawi (1963). The Bahariya Formation (Lower Cenomanian) covers the floor of the Bahariya Oasis as well as parts of the cliffs surrounding the depression. The base of this formation is not exposed whereas its top is covered by a limestone bed of the Heiz Formation (Upper Cenomanian). Lithologically, the Bahariya Formation consists of friable, cross-bedded varigated sands and sandstones (sometimes micaceous and gypseous) with hard dark brown ferrugenous bands.

Dominik (1985) assigned an Upper Cenomanian age for the Bahariya Formation and considered El-Heiz Formation as its topmost member. He subdivided the Bahariya Formation into three members; Gebel Ghorabi Member at the base, Gebel Dist Member in the middle and El-Heiz Member at the top.

Gebel Ghorabi Member (Dominik, 1985) is the lowermost rock unit exposed at Bahariya Oasis. It is composed of sandstones, red beds, abundant ironstone bands with little argillaceous deposits.

Geochemical Composition:

The thirteen samples representing the Gebel Ghorabi Member were chemically analyzed for their major and trace elements. Geochemical analysis data of the studied samples are given in Table (1) and Fig. (2). The frequencies of most elements show discordance when compared with the published data by Turekian and Wedephol (1961), Pettijohn (1975) and NASC (1984) as seen in (Table 2). These discrepancies may be attributed to different factors such as source rock composition, sedimentological and diagenetic conditions. The shale samples can be classified as silty shales when presented on the ternary diagram SiO_2, Al_2O_3 and CaO + MgO (Fig. 3-A).

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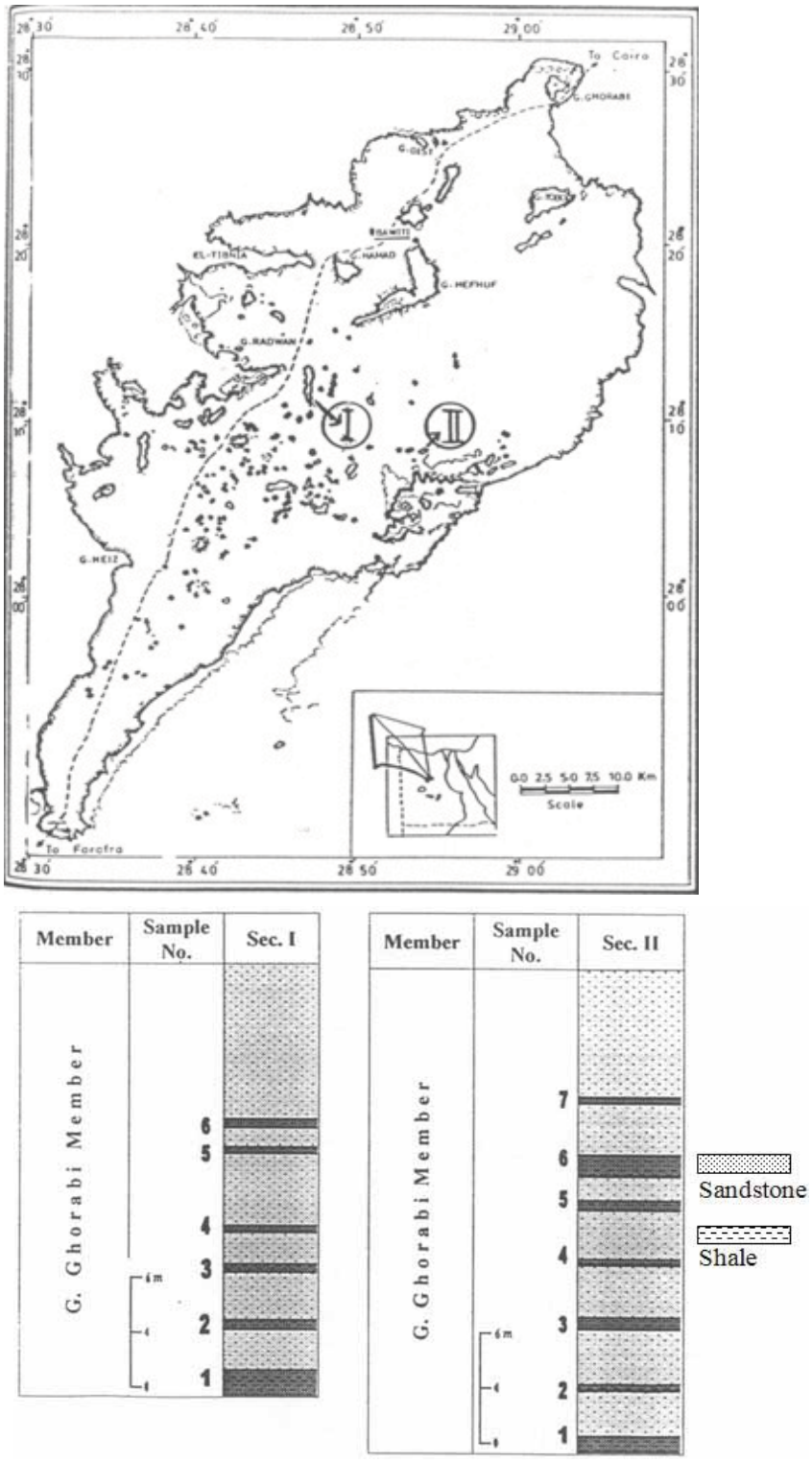


Fig. 1: A-Location map of the Bahariya Oasis showing the position of the studied sections. B - Lithology of the studied sections (I & II) and analyzed samples.

Table 1: Geochemical data of the studied shale samples of G. Ghorabi Member.

Sec. No.	Sp. No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	P_2O_5	LOI	SO_3	Cl	Zr	Y	Sr	Rb	Cu	Ni	Ba	Cr	V	Zn
I	6	49.00	0.40	14.50	8.60	0.01	0.01	0.02	2.96	3.20	0.47	0.01	0.05	9.20	2.24	0.01	1103	26	182	34	20	11	615	45	254	844
	5	48.80	2.50	15.20	7.80	0.02	0.07	2.20	1.12	1.60	0.47	2.01	0.03	19.07	0.23	0.02	654	38	142	---	22	10	204	53	682	711
	4	60.00	2.00	14.60	0.30	0.01	0.05	1.70	1.96	3.20	0.43	0.04	0.02	15.10	1.32	0.10	337	27	167	---	23	9	168	57	421	334
	3	50.80	5.40	14.00	6.00	0.01	0.08	0.40	2.80	3.90	0.30	0.05	0.04	14.10	1.74	0.07	382	17	154	---	53	20	192	62	562	236
	2	53.00	0.30	18.80	4.60	0.01	0.09	0.10	2.12	1.40	2.16	2.03	0.04	16.13	0.05	0.03	512	116	178	17	39	20	195	60	416	317
	1	60.00	1.70	13.30	4.20	0.01	0.01	1.40	1.68	2.10	2.51	2.01	0.05	8.02	1.41	0.01	1003	66	338	46	68	12	552	40	320	664
II	7	51.30	0.16	13.90	8.40	0.01	0.07	2.10	2.24	2.10	0.50	0.02	0.02	18.60	0.15	0.01	589	70	189	10	44	17	423	46	426	624
	6	43.00	3.84	11.40	3.80	0.01	0.03	1.40	1.68	3.30	1.86	0.03	0.02	31.30	0.04	0.02	547	78	166	24	67	17	251	46	216	129
	5	49.00	1.70	12.20	6.20	0.01	0.09	2.07	4.24	4.00	0.50	1.03	0.04	18.40	0.12	0.03	592	134	157	29	85	45	231	62	565	367
	4	50.30	1.80	18.50	3.20	0.01	0.06	0.70	1.68	3.70	0.86	0.05	0.01	18.08	2.10	0.09	828	76	176		75	28	313	60	152	423
	3	43.50	0.40	18.00	4.00	0.01	0.02	1.40	1.68	3.20	0.77	0.03	0.06	25.10	1.93	0.09	831	75	161	10	63	34	348	84	544	334
	2	67.50	0.20	8.40	2.80	0.05	0.01	0.70	1.12	2.10	2.74	0.04	0.06	13.30	0.07	0.06	843	65	142	10	79	15	165	44	416	611
	1	65.30	0.30	13.10	2.40	0.01	0.06	1.70	0.84	4.90	0.30	1.02	0.19	10.30	0.05	0.06	1015	63	167	---	44	10	137	58	324	540

Table 2: Comparison of the chemical composition of the studied shales from Gebel Ghorabi Member with published average shales composition.

Composition	Present study n = 13	1	2	3
SiO_2 %	54.00	64.82	58.10	58.50
Al_2O_3 %	13.40	17.05	15.40	15.00
TiO_2 %	1.60	0.80	n.a.	0.77
Fe_2O_3 %	4.80	5.70	4.02	4.72
MgO %	1.20	2.83	2.44	2.50
CaO %	2.00	3.51	3.11	3.10
Na_2O %	3.00	1.13	1.30	1.30
K_2O %	1.10	3.97	3.24	3.10
P_2O_5 %	0.00	0.15	n.a.	0.16
Sr ppm	178	142	n.a.	300
Ba ppm	245	636	n.a.	580
V ppm	407	130	n.a.	130
Ni ppm	19	58	n.a.	68
Cr ppm	55	125	n.a.	90
Zn ppm	471	n.a.	n.a.	95
Cu ppm	52	n.a.	n.a.	45
Zr ppm	710	200	n.a.	160

1 = NASC (Gromet *et al.,* 1984).
2 = Average shale (Pettijohn, 1975).
3 = Average shale (Turekian and Wedephol, 1961).

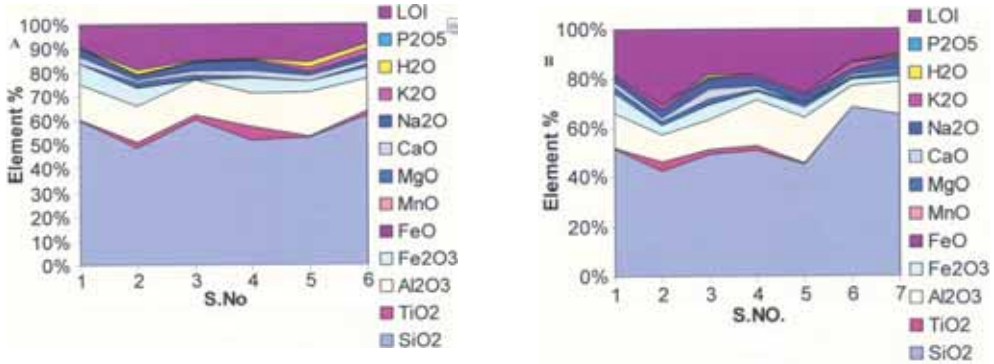


Fig. 2: Geochemical composition of Gebel Ghorabi shales:
A - Section I.
B - Sectiion II.

Interelement Relations:

Pearsons correlation coefficient values (r) were calculated for each pair of elements composing the studied shale samples (Table 3). The most significant observations are:

- SiO_2 shows a moderate negative correlation with Al_2O_3 (r = - 0.43) indicating the presence of free silica (Fig. 3-B).
- The absence of strong correlation between Al_2O_3 and Fe_2O_3 (r = 0.06) may reflect an authigenic origin of the iron oxides (Fig. 3-C).
- The positive correlation (r = 0.44) between Na_2O and Cl^- (Fig. 3-D) indicates the presence of halite. Meanwhile; most of the analyzed samples contain more Na than the requirements of halite. The excess sodium can be related to different clay minerals and feldspars.

Table 3: Correlation coefficients of the analyzed oxides and trace elements.

Correlations	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	P_2O_5	LOI	SO_3	Cl	Zr	Y	Sr	Rb	Cu	Ni	Ba	Cr	V	Zn
SiO_2	1.00																								
TiO_2	-0.41	1.00																							
Al_2O_3	-0.42	-0.11	1.00																						
Fe_2O_3	-0.33	0.01	0.06	1.00																					
FeO	0.52	-0.26	-0.61	-0.24	1.00																				
MnO	0.30	0.23	0.32	0.19	-0.39	1.00																			
MgO	-0.19	-0.01	-0.22	0.01	-0.21	0.19	1.00																		
CaO	-0.36	0.16	0.05	0.43	-0.31	0.33	-0.09	1.00																	
Na_2O	0.02	0.24	-0.10	-0.28	-0.25	0.09	0.06	0.23	1.00																
K_2O	0.24	-0.16	-0.28	-0.29	0.56	-0.43	-0.31	-0.32	-0.54	1.00															
H_2O	0.09	0.01	0.19	0.09	-0.24	0.35	0.15	-0.12	-0.40	0.22	1.00														
P_2O_5	0.52	-0.34	-0.19	-0.24	0.08	-0.07	0.07	-0.34	0.47	-0.12	0.15	1.00													
LOI	-0.82	0.28	0.11	-0.02	-0.16	0.10	0.29	0.02	-0.01	-0.02	-0.31	-0.40	1.00												
SO_3	-0.08	0.15	0.45	0.00	-0.27	-0.36	-0.43	0.22	0.24	-0.27	-0.32	-0.22	-0.22	1.00											
Cl	0.06	0.09	0.27	-0.70	0.12	0.02	-0.10	-0.19	0.43	-0.24	-0.37	0.09	0.08	0.39	1.00										
Zr	0.41	-0.53	-0.05	0.09	0.17	-0.63	-0.18	-0.31	0.09	0.17	-0.03	0.50	-0.43	0.26	-0.20	1.00									
Y	-0.27	-0.34	0.08	-0.05	-0.00	0.32	0.15	0.29	-0.07	0.33	0.23	-0.01	0.31	-0.48	-0.20	-0.07	1.00								
Sr	0.21	-0.08	0.02	-0.02	-0.22	-0.36	0.01	-0.06	-0.23	0.42	0.39	-0.02	-0.41	0.23	-0.37	0.38	0.04	1.00							
Rb	0.02	-0.14	-0.22	0.27	-0.08	-0.42	-0.13	0.39	-0.20	0.46	0.21	-0.12	-0.16	0.06	-0.66	0.36	0.32	0.67	1.00						
Cu	-0.15	0.08	-0.30	-0.25	0.36	-0.10	0.04	0.15	0.22	0.43	-0.19	-0.05	0.25	-0.10	0.13	0.07	0.58	0.13	0.24	1.00					
Ni	-0.55	0.01	0.21	0.09	-0.11	0.32	0.09	0.70	0.28	-0.13	-0.15	-0.20	0.40	0.07	0.19	-0.19	0.68	-0.20	0.11	0.65	1.00				
Ba	-0.03	-0.24	0.13	0.49	-0.25	-0.52	-0.18	0.25	-0.18	0.06	-0.11	0.22	-0.25	0.52	-0.48	0.56	-0.14	0.64	0.69	-0.09	-0.07	1.00			
Cr	-0.46	0.00	0.58	-0.19	-0.29	0.31	0.03	0.30	0.35	-0.41	-0.09	0.12	0.35	0.27	0.64	-0.21	0.20	-0.41	-0.42	0.10	0.61	-0.33	1.00		
V	-0.22	0.15	-	0.30	0.02	0.40	0.38	0.22	-0.23	-0.29	0.35	-0.05	0.08	-0.23	0.02	-0.43	-0.03	-0.33	-0.27	-0.15	0.22	-0.35	0.40	1.00	
Zn	0.51	-0.52	-0.14	0.46	0.20	-0.35	0.04	-0.18	-0.32	-0.02	0.16	0.19	-0.62	0.09	-0.44	0.67	-0.29	0.28	0.24	-0.35	-0.43	0.54	-0.49	-0.02	1.00

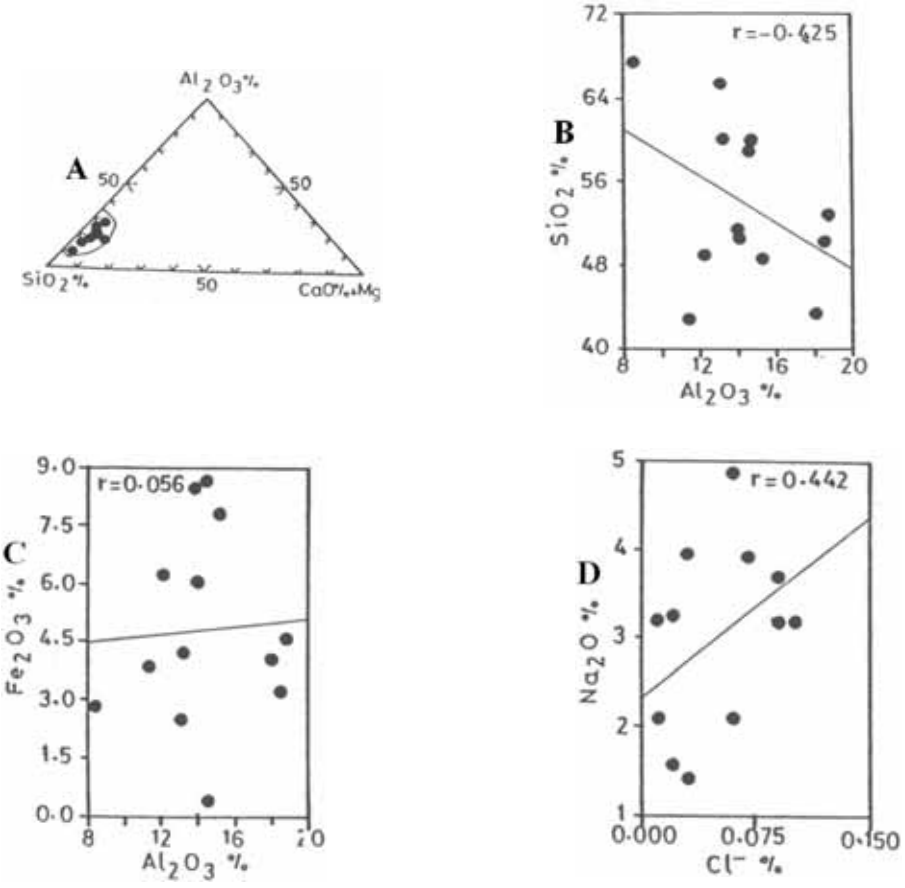


Fig. 3: Elements Interrelation:

A - Triangular diagram showing the relation SiO_2, Al_2O_3 and (CaO+MgO).

B - Bivariant diagram of SiO_2 and Al_2O_3.

C - Bivariant diagram of Fe_2O_3 and Al_2O_3.

D - Bivariant diagram of Na_2O and Cl .

Provenance Study:

Geochemical parameters and functions used by different authors were applied to identify the provenance of the studied shales of Gebel Ghorabi Member as follows:

High levels of Cr and Ni with a strong positive correlation between them have been used by various authors (e.g., Hiscott, 1984; Wrafter and Graham, 1989 and Garver *et al.,* 1994, 1996) to infer a mafic to ultramafic provenance. The present studied samples are moderately enriched in Cr (average 47.7 ppm) which have a strong positive correlation with Ni (r = 0.61) and high Cr/Ni ratio (3.5). This means an intermediate basement or a mixed mafic and reworked sedimentary provenance.

The high K_2O/Na_2O ratio favors the occurrence of illite, while the low ratio means that these sediments have originated from basic or intermediate igneous rocks (Garrels and Christ, 1965 and Weaver, 1967). This ratio was found to be 0.36 for the studied samples suggesting a basic or intermediate provenance.

Brooks (1973) and Spears and Kanaris (1976) found that the Carboniferous sediments in England have high TiO_2/Al_2O_3 ratios reflecting a strong correlation to the ratios in the parent basalt. Amajor (1987) utilized the TiO_2 versus Al_2O_3 binary plot to distinguish between granitic and basaltic source rocks. Application of this plot on the studied shale samples (Fig. 4-A) led to basaltic and granitic provenances in nearly equal proportions.

Plotting of the studied shale samples on the provenance discrimination function diagram of Roser and Korsch (1988) illustrated in (Fig. 4-B) showed that the samples fell within different fields of the diagram indicating igneous and reworked sedimentary provenances (F_1 and F_2 in Table 4).

Weathering Effect:

The chemical index of alteration (CIA) defined as

$CIA = 100 \times Al_2O_3 / (Al_2O_3 + C_2O + Na_2O + K_2O)$ has been established as a general indicator of the degree of weathering in any provenance region (Nesbitt and Young, 1982). High values (76-100) indicate intensive chemical weathering in the source area whereas low values of 50 or less indicate unweathered areas. The CIA values for the studied shales (Table 4) range between 58 and 82 indicating moderate chemical weathering.

McLennan (1993) considered the Rb/Sr ratios of sediments as a monitor of the degree of source rock weathering. He considered the values of 0.32 and 0.8 as limits indicating upper continental crust and post Achean Australian shales respectively. The Rb/Sr values for the present studied samples are in the range 0.0-0.2 indicating weak weathering of the source area.

Table 4: Discrimination functions (F_1 and F_2) and chemical indices of alterations calculated for the studied shale samples.

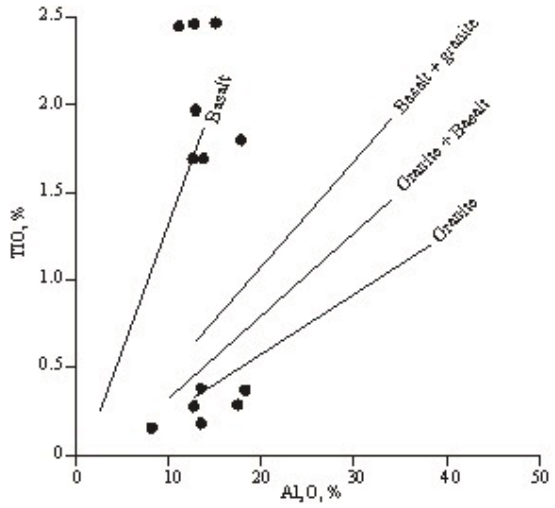
Section No.	Sample No.	F_1	F_2	CIA
I	6	3.9	0.4	68.62
	5	4.5	0.6	82.65
	4	2.9	2.0	72.31
	3	3.8	0.8	66.66
	2	0.5	5.7	76.79
	1	8.2	1.2	67.89
II	7	0.3	0.3	74.18
	6	4.8	0.2	62.50
	5	3.8	1.5	58.26
	4	2.2	1.1	74.78
	3	1.0	0.7	81.93
	2	7.7	1.4	58.50
	1	4.1	5.5	68.44

Environment of Deposition:

The average V content of the studied shale (407 ppm) is higher than the published average for shales (Table 2). This enrichment is supposed to occur in marine shales (Ernst, 1970) and may reflect their high organic matter content. The V/Cr ratio has been used as a paleo-oxygenation indicator by different authors. Values of V/Cr > 2 are thought to represent anoxic depositional conditions, whereas values below 2 are indicative of more oxidizing conditions (Ernst, 1970 and Dill *et al.,* 1988). The V/Cr values for the studied shale samples (7.5) are higher than 2 indicating anoxic conditions.

Campbell and Williams (1965) used the K/Rb ratio as an indicator of environment (250-300 for non marine and brackish water shales and 150-200 for marine shales). The ratio is found to be 343 for the studied shale samples indicating non marine conditions.

A



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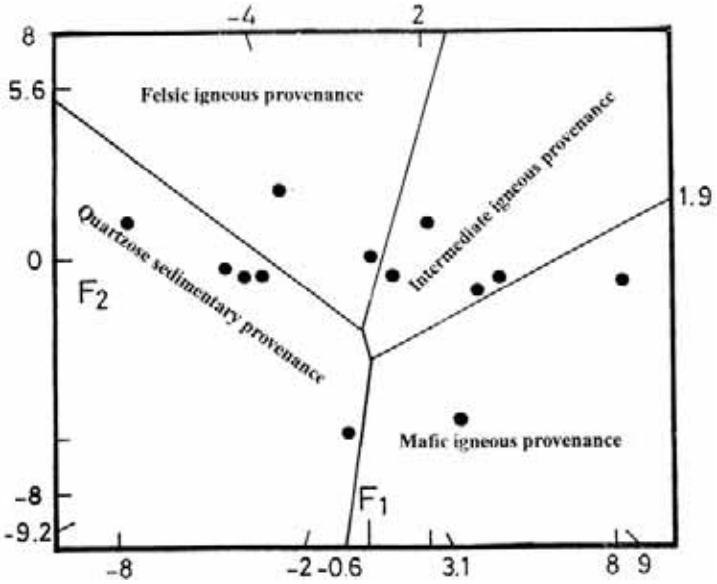

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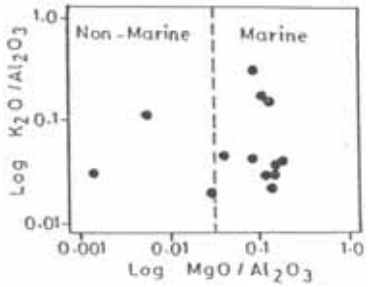

Fig. 4: Provenance and environment:

A - TiO2/Al2O3 binary plot (Amajor, 1987).

B - Provenance-discrimination functions diagram (Roser and Korsch, 1988).

C - Depositional environment of the studied samples based on the relation between log MgO/Al2O3 and log K2O/Al2O3 (Roaldest, 1978).

The relation between K_2O/Al_2O_3 and MgO/Al_2O_3 was used by Roaldest (1978) to differentiate between marine and non-marine clay. Application of this relation on the studied shales (Fig. 4-C) revealed that most samples fall within the marine environment while only a few samples fell within the non-marine environment.

In conclusion, it is suggested that the sediments of G. Ghorabi Member probably passed through different environments varying from fluvial, eolian and shallow marine.

Migdisove (1960) stated that higher TiO_2/Al_2O_3 ratio for clays indicates a humid climate. This ratio was found to be 0.1 for the studied shale samples which may indicate an arid climate.

Conclusion:

The studied shales of Gebel Ghorabi Member (Cenomanian, Bahariya Formation, Bahariya Oasis) can be classified as silty shales. Their mineral and chemical composition was affected by different factors such as the composition of source rocks, environment of deposition and diagenetic processes.

The study revealed the occurrence of free silica, authigenic iron oxides, halite and gypsum.

The detrital material of these shales were derived from different varities of igneous rocks in addition to reworked older sediments. These source rocks were affected by weak to moderate chemical weathering under nearly arid climatic condition with low humidity.

The study proved that the sediments of Gebel Ghorabi Member passed through different environments varying from fluvial to shallow marine during their formation.

This conclusion is in concordance with the published works of different authors (e.g., Issawi *et al.,* 1999) while climatic condition may be confirmed by the possible occurrence of evaporite minerals such as halite and gypsum.

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