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Contributions to the Petrology of Upper Cretaceous of El Duwi Formation at Gabal El Galala El Qibliya area, North Eastern Desert, Egypt

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Abstract

The Upper Cretaceous succession exposed at Saint Anthony , Saint Paul, and Wadi El Dakhl areas was measured and studied in detail. The studied sequence is subdivided lithostratigraphically, into the Galala Formation (Cenomanian-Early Turonian), Wata Fotrmation (Late Turonian), El Duwi Formation (Coniacian-Santonian), and Sudr Chalk (Campanian-Maastrichtian), Esna Shale (Paleocene-Early Eocene) and Thebes Formation (Early Eocene). The examined rock units in Gabal El Galala area include El Duwi Formation and Sudr Chalk were studied lithostratigraphically, petrography, mineralogy, geochemistry, radioactivity and tectonic setting. On the other hand, the major and trace elements were focused on the studied rock units. The Upper Cretaceous exposures in southeastern Galala represented by Carbonate – dominated successions inter-bedded with shale, a few sandstone beds, and marl horizons and capped by Sudr chalk. The average chemical compositions of the shale from the study area are (33.37-59.55%) for SiO2, (6.51-16.49%) for Al2O3, (1.07-2.33 %) for CaO, (1.16-2.09%) for MgO, (0.99-3.10%) for Na2O, (0.45-1.6%) for K2O, (1-2.86%) for P2O5, (5.37-8.865%) for Fe2O3, (31-791 ppm) for Rb, (291-1500 ppm) for Zr, (331-2834 ppm) Sr, (15-61 ppm) for Ga, (89-711 ppm) for V and (9-45 ppm) for U. Detailed environmental scanning-electron microscope (ESEM) study was carried out on the shale and Chalk. This study appears the characterization of the assembly as pyrite, gypsum and jarosite. The tectonic setting reveals that the shale and chalk of the upper Cretaceous in El Duwi Formation were originated from greywacke in active continental margin area.

Keywords

Upper Cretaceous; Gabal El Galala; El Duwi Formation, petrology; lithostratigraphy; geochemistry.

Introduction

The Pre-rifting rocks along the western side of the Gulf of Suez constitute one of the famous Upper Cetaceous sedimentary cover in Gabal El Galala area. The Upper Cretaceous rocks are represented by carbonates with a few clastics (Abdallah and Adindani, 1963). Ghorab (1961) classified the Cretaceous rocks in the Gulf of Suez region into five Formations, namely from base to top; Galala Formation (Cenomanian - Early Turonian), Wata Fotrmation (Late Turonian), Matulla Formation (Coniacian - Santonian), and Sudr Chalk (Campanian - Maastrichtian), Esna Shale (Paleocene-Early Eocene) and Thebes Formation (Early Eocene). In the Gabal El Galala area, the contact between Matulla Formation and the Campanian-Maastrichtian Sudr Chalk are associated with phosphatic horizons.

Sediments of Late Campanian and Early Maastrichtian age are widely distributed in the upper parts of the Southern Galala Plateau and the foot slopes of the Northern Galala Plateau facing Wadi Araba. In the lower part they are composed of well-bedded flaky limestone intercalated with chalk and sandstones. In the upper part they consist of fossiliferous, chalky, sandy and argillaceous limestone intercalated with green shale (Samaan et al., 2015).

The chalky deposits are widely distributed within this interval, named the Sudr Chalk by Ghorab (1961) in Wadi Sudr, west central Sinai. Several authors have studied the stratigraphy and sedimentology of the outcropping Upper Cretaceous–Lower Tertiary succession in the Eastern Desert of Egypt e.g. Awad and Abdallah, 1966; Bandel and Kuss, 1987; Kuss and Leppig, (1989), Said (1990) and Schütz (1994). Meshref (1990), Scheibner et al. (2001a, b) and Speijer and Wagner (2002). 1989; Sheata, 1988, El-Kammar, and El-Kammar, 1996 Shehata et al., 2010, Nagm et al, 2010, Wilmsen and Nagm, (2012), Wilmsen and Nagm (2013), El-Kammar, (2014) and Samaan et al., 2015. The synsedimentary tectonics of the Upper Cretaceous-Paleocene carbonate-dominated strata in the northern part (Galala area) are found in Kuss (1986) and Moustafa and Khalil (1995). They form the basis for further detailed investigations by Gietl (1998) and Scheibner et al. (2000). Figure (1), shows the cross-section of the Galala Mountains including the studied areas and main Formations in the area under consideration (Schütz 1994). The Upper Cretaceous is dominated by siliciclastic marls, shales and (dolomitic) limestone (Wata, Raha and El Duwi). The El Duwi Formation represents the uppermost Cretaceous in the study area.

Geological setting:

The Galala Mountains are located in the Eastern Desert of Egypt and range from Ain Sukhna near Suez 100 km to south (Figure 1). Black squares show the locations of the key sections: St. Anthony, St. Paul, Bi'r Dakhl. The exposed rock units in the area under investigation are represented by various lithological associations. It ranges in age from Late Paleozoic to Quaternary. The exposed rock units in the area under investigation (Figure1) are represented by various lithological associations ranging in age from Late Paleozoic to Quaternary and from base to top:

Rod El-Hamal Formation:

This Formation is of Upper Carboniferous age. It is essentially constituted of argillaceous and arenaceous beds with some limestone-rich horizons.

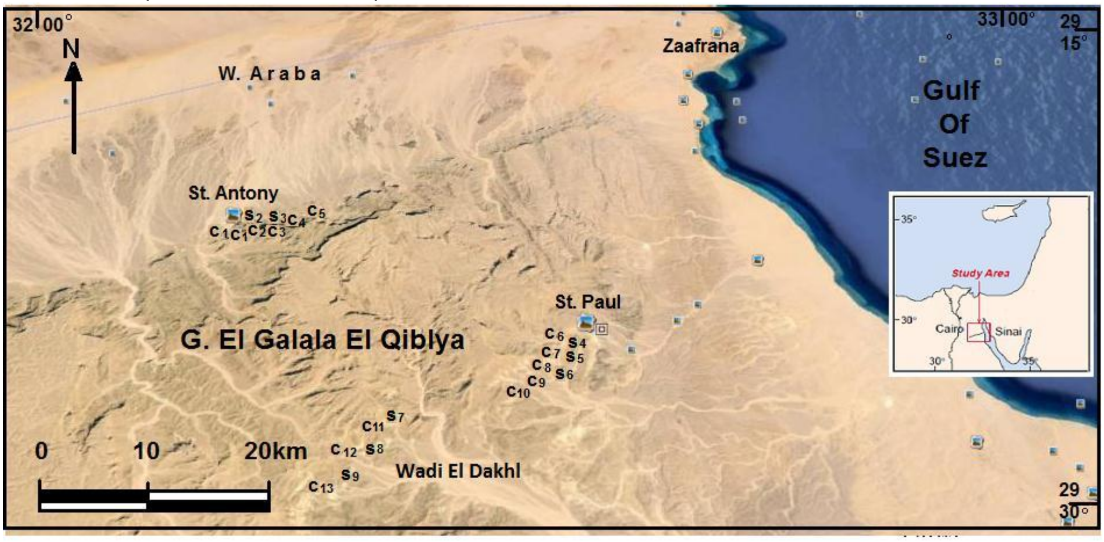


Figure 1 Location map and sample locations in Gabal El Galala El Qibilya area; 9 samples (S1 to S9) are collected along the black shale beds and 13 chalk samples (C1 to C13) were collected from St. Anthony, St. Paul and Wadi El Dakhl along phosphatic rocks in the base of Sudr chalk.

Qiseib Formation:

This is of Permo–Triassic age. The average thickness of this unit is about 20 m. It is mainly composed of varicolored bleached and thickly bedded sandstone.

Malha Formation:

This Formation is possibly equivalent to a part of what is called the Nubian sandstone and shale. It represents the Early Cretaceous sediments outcropping in the western part of the Gulf of Suez area. This Formation has been subdivided into two members: a lower shale, clay, and sandstone with conglomerate member and an upper tabular and cross-bedded sandstone member.

D- El-Galala Formation:

This Formation is equivalent to Quseir variegated shale and El Galala Formations belongs to (Cenomanian - Coniacian) (Fig. 2). It conformably overlies Malha Formation and represents the first Cretaceous Sea transgression in the area under consideration. It is of Late Cretaceous age. It is mainly composed of varicolored shale and silt with sandy limestone interbeds and Oyster limestone. It consists of multicolored shale, grey, brownish yellow, green, reddish, violet and black alternating with yellow to grey limestone. The age of this Formation is regarded to be Pre-Campanian.

El Duwi Formation:

In St. Paul section, El Duwi Formation represents the Coniacian to Early Campanian succession (Fig. 3). It consists mainly of clastic rocks; sandstone, shale, chalk intercalated with sandy limestone and dolomitic limestone interbeds. It is shale at the base, chalk at the middle part, whereas phosphatic limestone characterizes the upper part of the Formation.

In Wadi El Dakhl, the Duwi Formation measures 39 m thick. The lower part of the Formation is composed of sandstone and shale intercalations, while the upper part of the Formation is composed of sandy dolostone and sandy limestone, intercalated with fossiliferous calcareous sandstone.

In St. Anthony section El Duwi Formation (Campanian – Maastrichtian), Said (1990) extended the use of the term El Duwi Formation to laminated grey clays and chert phosphatic bands at Safaga area. In the studied area, El Duwi Formation is conformably overlies El Galala Formation and is wavy at the upper contact (unconformity surface) with thickly bedded chalk and chalky (Fig. 4), limestone (Sudr Formation). The Duwi Formation consists of shale, conglomeratic phosphorite which contains black pebbles and shark teeth. At Wadi El Dakhl area, marl is cut by limestone boulder (Fig. 5).

Sudr Formation:

This rock unit was first proposed by Ghorab (1961). It belongs to the Late Cretaceous (Campanian – Maastrichtian) (Fig. 2). This Formation unconformably overlies Duwi Formation and is composed of thickly bedded chalk and chalky limestone

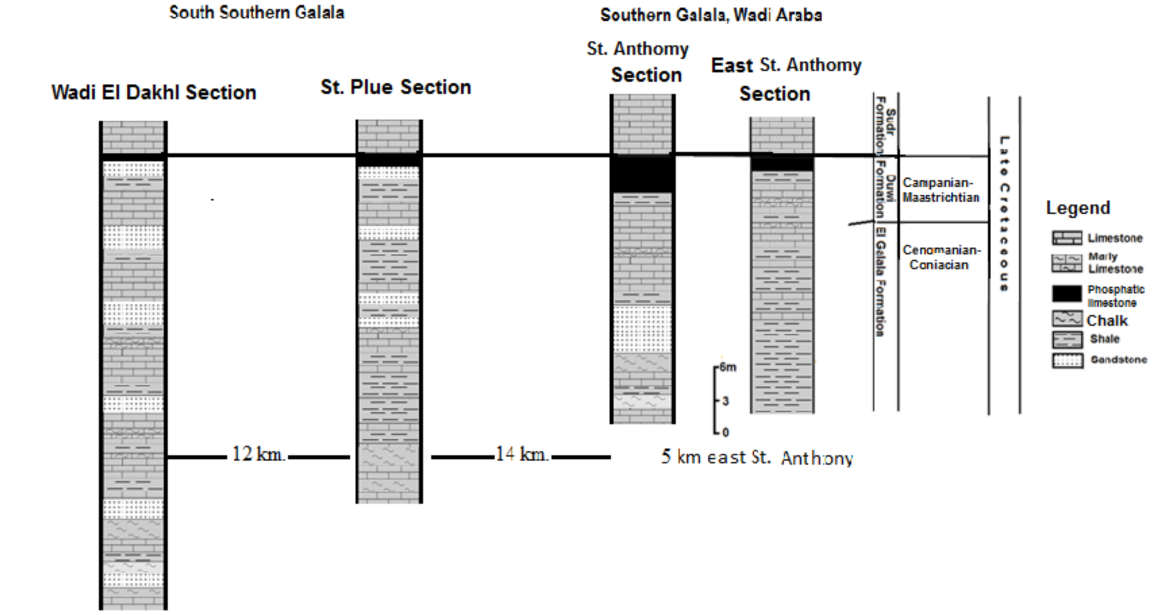


Figure 2 Lithostratigraphic sections for Late Cretaceous phosphate in St. Anthony, St. Paul, Wadi El Dakhl area, southern Galala, Eastern Desert.

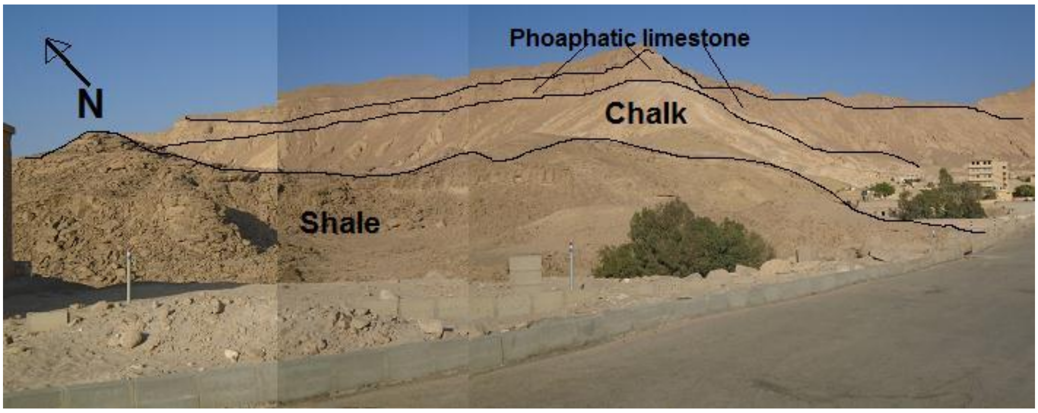


Figure 3 Panoramic view showing the shale, chalk and phosphatic limestone in St. St. Paul.

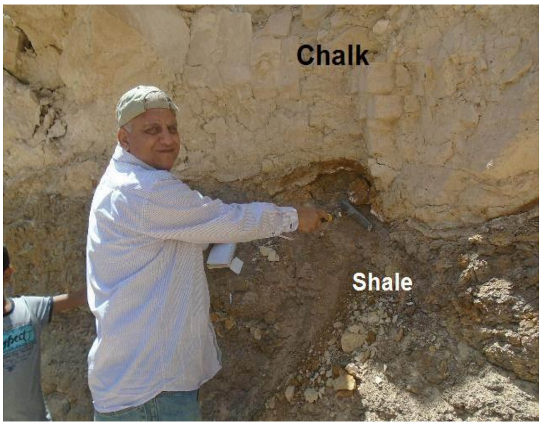


Figure 4 Contact between gray shale and chalk in St. Anthony.

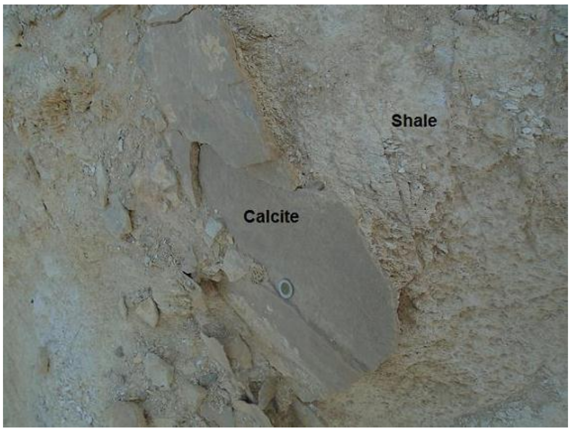


Figure 5 limestone boulder in marl at Wadi El Dakhl area.

Sampling and Methodology:

Twenty two samples are collected along the black shale (S1 to S9) and chalk (C1 to C13) of El Duwi Formation at St. Anthony, St. Paul and Wadi El Dakhl of southern Galala (Fig. 1) shows the distribution of the samples in the area under study. The collected samples were chemically analyzed for major oxides and trace elements. The chemical analyses were carried out in the laboratories of Egyptian Petroleum Research Institute [EPRI], Egypt. Then the samples were investigated using Environmental Scanning Electron Microscopy (ESEM) model Philips XL, 30, attached by Energy Dispersive X-ray unit (EDX). Thin section of the raw rock mineral was prepared cutting a section of the rock followed by grinding and polishing of the rock sample before fixing on a petrographic slide. Thin section for the different pellets were later viewed and photographed under the microscope with magnification factor of 20 and 50.

Results and discussion

Mineralogy of El Duwi Formation:

The results of the petrographic analysis revealed that El Duwi Formation were formed in shallow marine environment Jones and Hockey (1964) and Odigi and Brown-Awala (1992). El Duwi Formation contains the phosphorus rich horizons with presence of organic rich intraclastic and intrapelic phosphorites. The diffuse red brown iron staining present in all the samples and particularly strongly developed in phosphatic rocks of El Duwi Formation in St. Anthony (Fig.8) shows that primary sedimentary ferrous minerals (such as siderite, pyrite and glaconite), had undergone oxidation and alteration. Although glaconite is considered to have been the primary iron bearing mineral, oxidation and alteration has progressed to the stage where no glaconite could be identified as observed by Akande et al. (1999). Sant Anthony phosphatic rocks of El Duwi Formation characterized by shark Teeth (Fig.9), and cellophane peliode type (Fig.10). In St. Pule phosphatic rocks of El Duwi Formation characterized by fossil

(Fig.8), bones (Fig.9) and cellophane pesslite type (Fig. 10). Wadi El Dakhl characterized by carbonate groundmass (Fig.11), contain apatite (Fig.12), and angular quartz grains (Fig. 13).

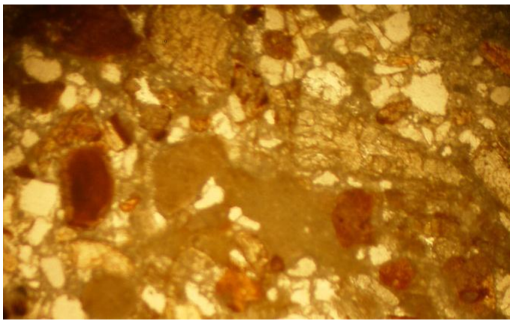


Figure 6 Thin section of brown iron staining in phosphatic rocks of El Duwi Formation in St. Anthony

Figure 8 Shark Teeth in phosphatic limestone in St. Anthony

Figure 7 Collophane Peloide type in in phosphatic limestone in St. Anthony

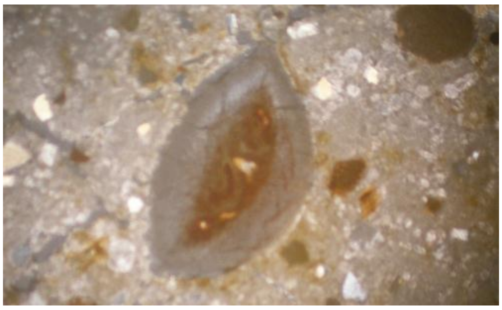


Figure 9 Micro fossil in phosphatic limestone in St. Pule.

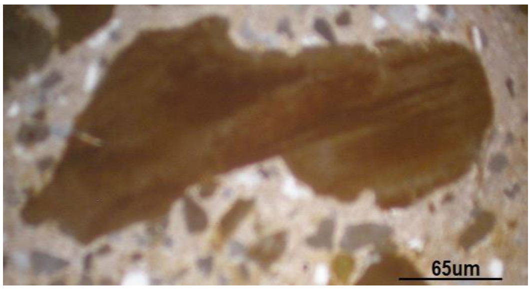


Figure 10 Bones in in phosphatic limestone in St. Pule

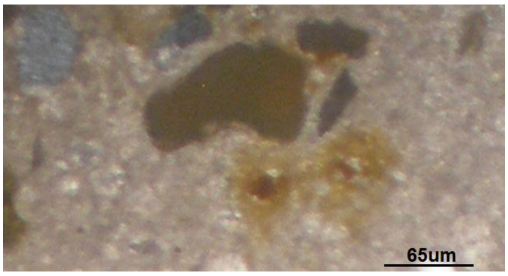


Figure 11 Collophane Pesslite type in phosphatic limestone in St. Pule

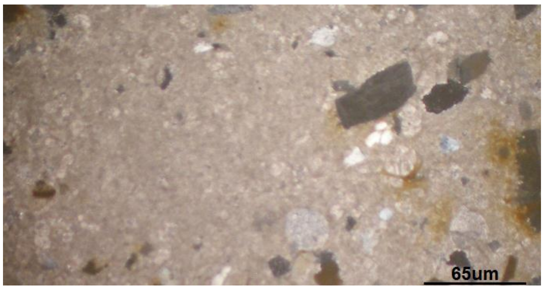


Figure 12 Carbonate groundmass in phosphatic limestone of Wadi El Dakhl area

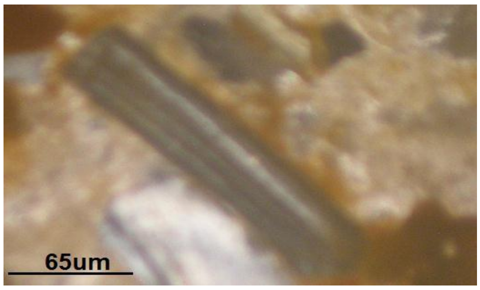


Figure 13 Apatite crystal in phosphatic limestone of Wadi El Dakhl area.

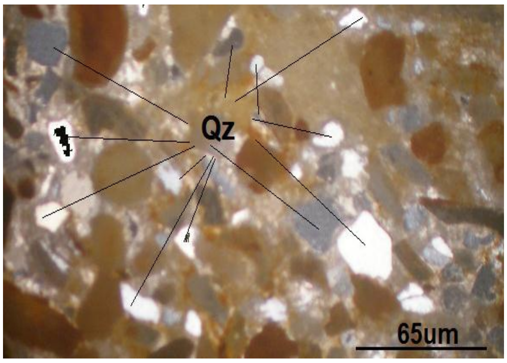


Figure 14 Angular quartz grains in phosphatic limestone of Wadi El Dakhl area.

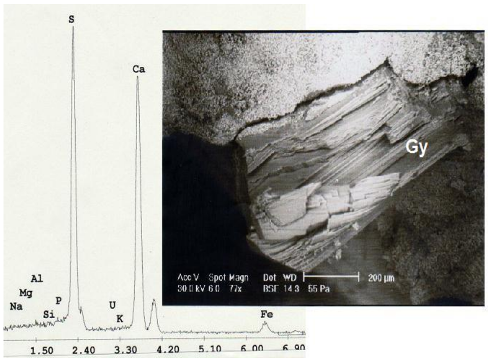


Figure 15 ESEM image for gypsum in El Duwi Formation in St. Anthony and there EDX chart.

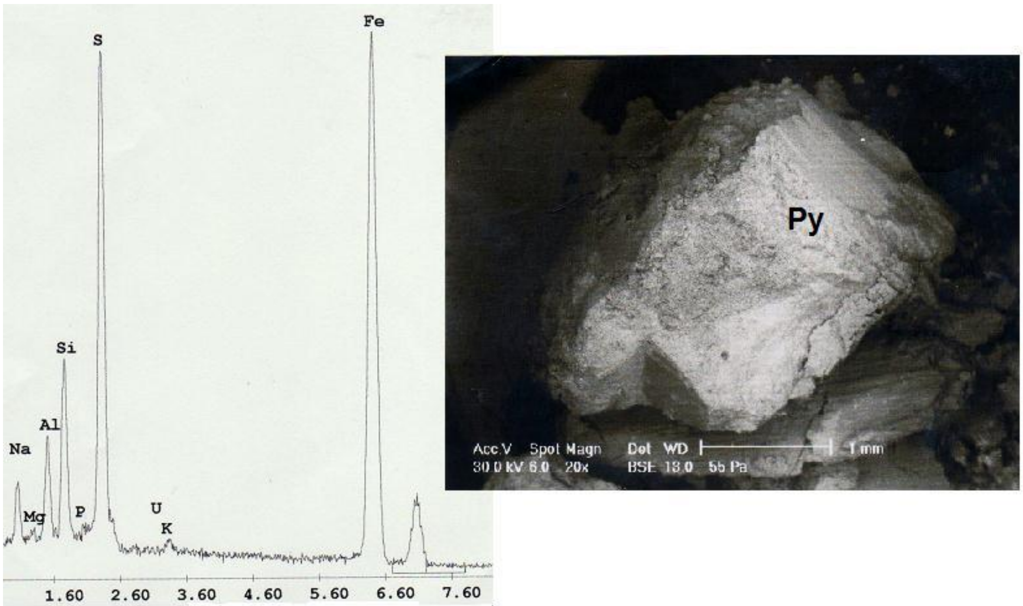


Figure 16 ESEM image for pyrite in El Duwi Formation in St. Anthony and there EDX chart.

Mineralogy of El Duwi Formation:

The ESEM indicates that El Duwi Formation of St. Anthony contain

- Gypsum CaSO4 which EDX chart gives that the chemical contents are 55.45% for SO3, 37.80% for CaO 3.04% for Fe2O3 and 0.62% for UO2 (Fig. 15).

- Pyrite (FeS) which EDX chart gives that the chemical contents are 22.34% for SO3, 47.73% for Fe2O3 and 19.57% for SiO2 (Fig.16).

- Gypsum carrying jarosite which EDX chart gives that that the chemical contents are 19.31% for SO3, 12.27% for CaO, 49.15% for Fe2O3 and 0.14% for UO2 (Fig.17).

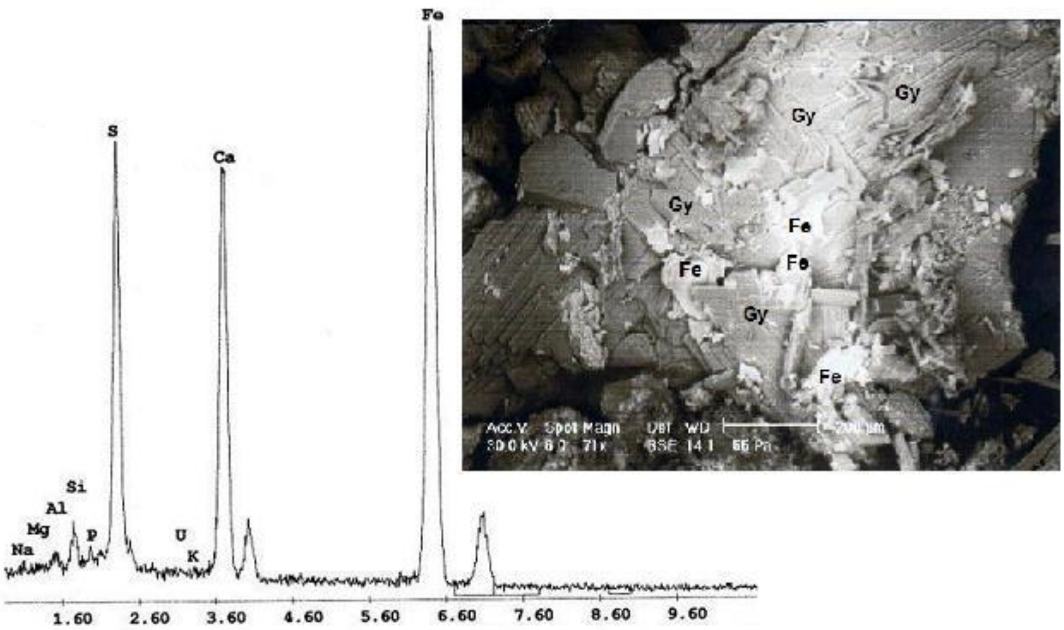


Figure 17 ESEM image for gypsum caring jarosite in El Duwi Formation in St. Anthony and their EDX chart

Geochemistry:

Major oxides:

The results of chemical analysis for the studied shale and chalk in El Duwi Formation are given in Tables 1. These results gave that the shale of have high concentrations of SiO_2 (range from 33.73% to 59.55% with average 47.029%) that reflect mainly the presence of quartz and other silicate minerals (e.g. illite, kaolinite, montmorillonite, chlorite and smectite). in chalk low in SiO_2 (range from 7.31% to 11.91%) with an average 9.14% and Al_2O_3 in shale ranging from 6.51% to 16.41% with average 9.96%. In chalk, the Al_2O_3 range from 1.1% to 3.11% with an average 2.46% and deficiency in carbonates (calcite and dolomite), While chalk is low in SiO_2 and Al_2O_3. The chalk highly concentration in CaO% ranges from 37.2% to 49.19% with average 44.2%. A plot of Al_2O_3 versus SiO_2% shows a strong negative relation (Fig. 20-a), varying while plotting against the Fe_2O_3, Na_2O) and K_2O shows a strong positive relation (Figs. 20- b, c and d). These reflect the presence of clay minerals in these sediments. The presence of Fe_2O_3 (Fig. 20-b) in higher concentrations are indicative of oxidation, hydration and leaching processes during weathering (Mikkel and Henderson, 1983). Its average content reaches to 5.3% and are higher than those of Pettijohn (1975) and Jordanian and Israeli oil shale (1.12 and 1.20%). The enrichment of Fe_2O_3 in the studied shale may be attributed to their Formation under more reducing conditions with a high input of nonreactive iron to the basin (Ahmed 1997). The K_2O contents are sufficiently high, suggesting that montmorillionite is probably the main clay mineral available in this shale. This strong positive relation (Fig. 20-d) indicates that these sediments are of detrital origin, which occurs as detrital clay minerals (kaolinite and montmorillionite). The strong positive relation of TiO_2 with Al_2O_3 (Fig. 20-e) may suggest that Ti is essentially associated with clays and reflecting its terrigenous origin. The decrease of CaO and MgO with increasing Na_2O and K_2O shows the variation in chemical composition which also reflects changes in mineralogical composition of the sediments due to the effect of weathering and early diagenetic processes (Nesbitt and Young, 1982). Jordanian and Israeli oil shale are more calcareous (40.7% and 32.3% CaO respectively) (Ahmed 1997).

Table 1 The chemical analyses of the major elements oxides (wet %) of the studied rocks.

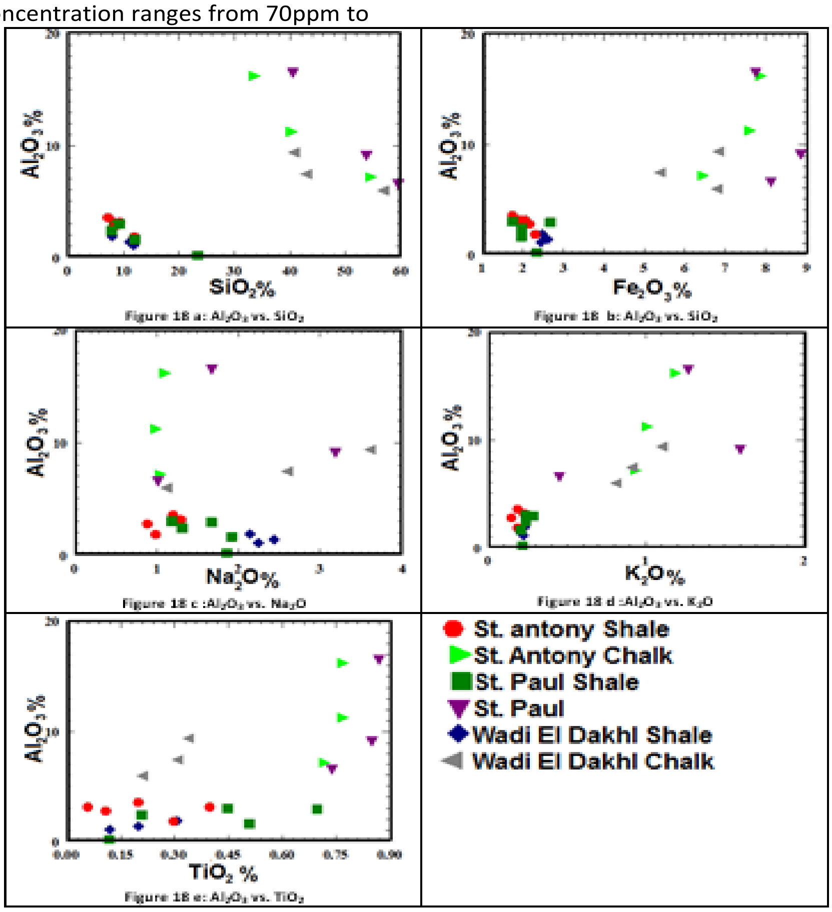
S.N.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
1	8.3	0.06	3.11	2.07	0.67	38.34	1.31	0.23	4.5	39.5	98.09
2	7.31	0.2	3.5	1.76	0.8	41.21	1.2	0.19	4.1	38.3	98.57
3	8.48	0.11	2.75	2.18	0.58	43.22	0.89	0.15	4.2	35.6	98.16
4	9.47	0.4	3.11	1.96	1.01	37.2	1.31	0.24	4.3	39.9	98.9
5	12.1	0.3	1.84	2.31	0.7	43.83	0.99	0.19	4.5	33.1	99.86
6	8.01	0.21	2.38	1.98	0.69	59.22	1.32	0.24	3.8	21.5	99.35
7	12.15	0.51	1.56	1.97	2.27	40.95	1.92	0.21	3.79	33.9	99.23
8	23.38	0.12	0.192	2.35	1.12	50.14	1.86	0.22	3.68	16.6	99.66
9	9.44	0.45	2.97	1.75	0.89	37.3	1.19	0.24	3.99	40	98.3
10	8.46	0.7	2.85	2.7	0.87	49.1	1.67	0.29	4.01	28.4	99.05
11	11.21	0.2	1.35	2.61	1.13	48.24	2.43	0.21	4.07	27.5	98.95
12	8	0.31	1.9	2.47	1.11	49.2	2.14	0.23	3.83	29.7	98.9
13	11.91	0.12	1.1	2.45	1.12	47.11	2.24	0.22	4.21	28.5	98.98
14	40.32	0.77	11.24	7.61	1.69	1.07	0.99	1.01	1	33.1	98.8
15	33.73	0.77	16.22	7.89	1.32	1.93	1.11	1.19	2.21	32.9	99.27
16	54.64	0.72	7.2	6.46	1.45	2.33	1.05	0.94	1.46	22,8	99.05
17	59.55	0.74	6.51	8.13	2.06	1.39	1.01	0.45	1.46	18.2	99.5
18	53.86	0.85	9.1	8.86	1.99	1.59	3.19	1.6	1.24	17.2	99.48
19	40.61	0.87	16.49	7.75	1.95	1.53	1.68	1.27	1.95	24.2	98.3
20	56.88	0.21	5.99	6.79	2.09	1.61	1.12	0.81	0.68	22.7	98.88
21	42.98	0.31	7.47	5.37	1.16	3.76	2.59	0.91	2.86	28.1	95.51
22	40.69	0.34	9.38	6.84	1.23	3.97	3.61	1.1	2.14	29.2	98.5
Av	25.52	0.42	5.37	4.28	1.27	27.47	1.67	0.55	3.09	29.4 3	

Table 2 The chemical analyses of the trace elements contents (ppm) of the studied rocks.

S.N.	Ba	Sr	Zr	Pb	Ga	Zn	V	U
1	38	796	10	14	12	39	200	25
2	39	872	13	17	11	30	225	12
3	32	785	10	16	11	55	129	18
4	39	694	16	13	10	45	146	10
5	29	498	13	18	12	41	50	20
6	33	899	7	17	12	51	256	10
7	37	674	21	15	14	39	150	9
8	41	778	29	18	12	58	162	9
9	25	794	7	10	12	47	330	12
10	42	681	11	14	12	42	250	11
11	39	971	13	14	12	47	70	9
12	39	874	34	17	13	39	110	8
13	41	1091	30	15	14	47	32	15
14	247	732	1500	43	69	311	23	23
15	400	1166	590	54	116	711	45	45
16	348	1628	975	31	93	280	41	41
17	271	1971	814	39	85	258	39	39
18	315	331	291	43	75	400	11	11
19	388	3143	675	61	56	378	25	25
20	318	355	310	15	87	89	9	9
21	163	2848	432	20	34	124	30	30
22	153	2500	400	24	30	126	20	20
Av	139	1140	281	24	36	148	106	18

Trace elements:

The distribution of trace elements in the studied rocks is largely determined by the mineral composition of the detrital fraction of the parent rocks and the physicochemical conditions prevailing ppm indicates that Sr is located at phosphatic limestone bed. In the Chalk, Sr enters the basin of deposition largely combined mainly with calcite. This fact is further supported by the positive relation between Sr and CaO (Fig. 21 a), in the studied carbonate rocks (r=0.54). Comparing the Sr contents with their average value in carbonates given by Turkian and Wedepohl (1961), the studied carbonates of the Chalk is relatively similar. The average contents of Ba in the studied El Duwi Formation range from 25 to 400 ppm with an average 139.864 (Table. 2). The average of Ba contents is more or less similar to Bllanca et al., (1999) in carbonate (147 ppm). It is know that Ba during transportation and deposition. The variation of the trace elements with respect to lithology and the concentrations of Sr, Ba, V, Zn , Ga, Rb and Zr (ppm) in the samples are illustrated in Table (2). The enrichment of Sr element up to 3143 enrichment in sedimentary deposits can be considered as indicators of high flux of biogenic material to the sediments and therefore of high surface - water productivity (Van Os et al, 1994). Also it is strongly adsorbed with clay minerals, reflecting positive relation of Ba with Al_2O_3, MgO and K_2O (r=0.49, 0.55 and 0.51; respectively (Figs. 21 b, c and d), The enrichment of barium in El Duwi Formations may be related to high biological productivity in the surface water of the open marine environment (Kora and Genedi, 1995). Vanadium concentration ranges from 70ppm to 711 ppm with an average 42 ppm in El Duwi Formation (Table.2). The vanadium content of the examined chalk is much higher than the corresponding V value for the average chalk reported by Wedepohl (1978). This may related to the clay content, which reflecting positive relation with Al_2O_3 (r=0.78) and K_2O (r=0.67) (Figs. 21 b and d). The contents of Zn in the studied sediments are relatively high in comparison with carbonate values given by Wedepohl (1978). Gallium and Rubidium do not vary greatly in the studied rock units, where the average Ga contents are range from 10 ppm to 61 ppm with an average 22.136 in El Duwi Formation (Table. 2). The Rb contents in the examined carbonates range between 9 ppm and 71 ppm with an average 31.046. The obtained Ga contents are higher than that reported by Wedepohl (1978), while the average Rb value in El Duwi Formation are very lower than the average value 79 ppm reported by Wedepohl (1978).



The high positive relation between Rb with Al2O3 and Ga with Al2O3 (Figs. 21g and h respectively) in the examined sedimentary rocks (Table.2) reflects that the clay minerals represented by kaolinite and montmorillionite. Similarly the Correlation Coefficient between Ga and Rb with K2O in the examined sediments are highly significant (r=0.72 and 0.81; respectively). This suggests that the main bulk of Ga and Rb are associated with k- bearing minerals. The average value for the Zr for the studied carbonates in El

Duwi Formation is much lower than the content (80 ppm) proposed by Wedepohl (1978).

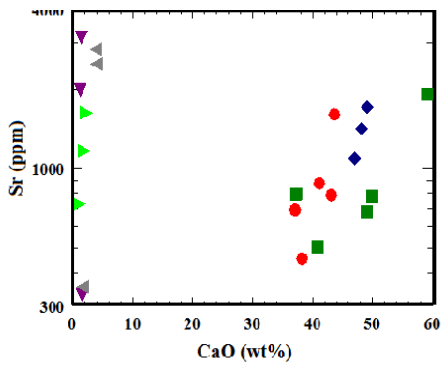


Figure 19 a: Sr vs. CaO

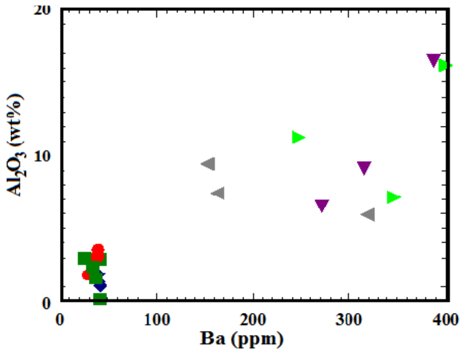


Figure 19b: Ba vs. Al_2O_3

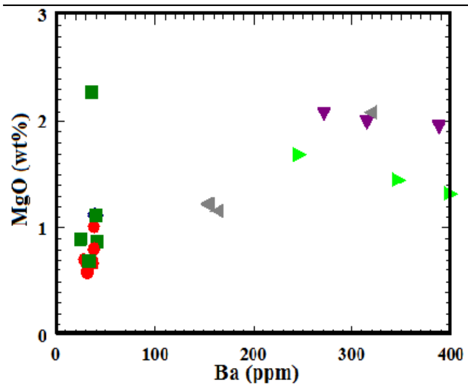


Fig.

figure 19c: Ba vs. MgO_3

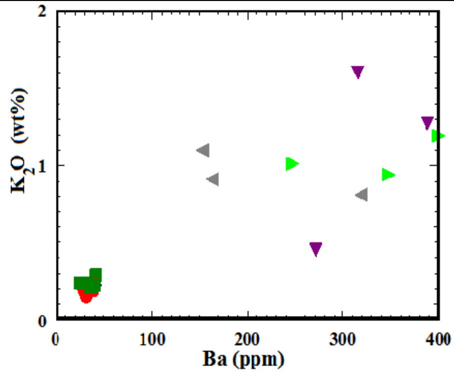


Figure 19d: Ba vs. K_2O

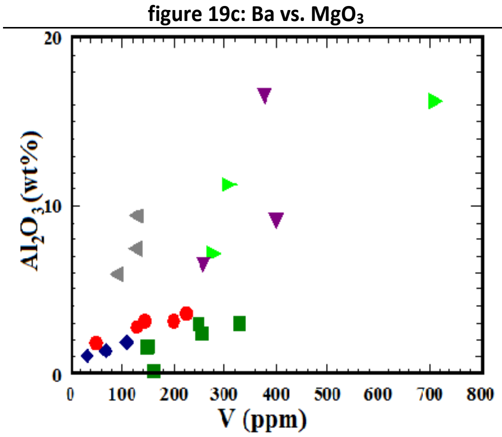


Figure 19e:V vs. Al_2O_3

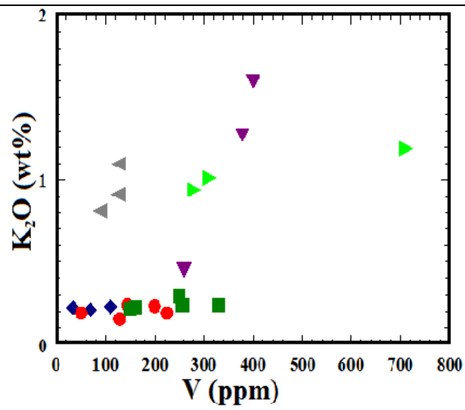


Figure 19f:V vs. K_2O

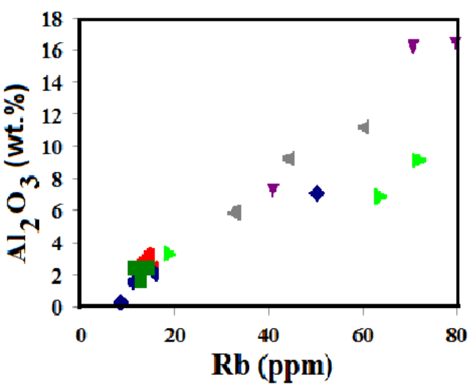


Figure 19g: Ga vs. Rb

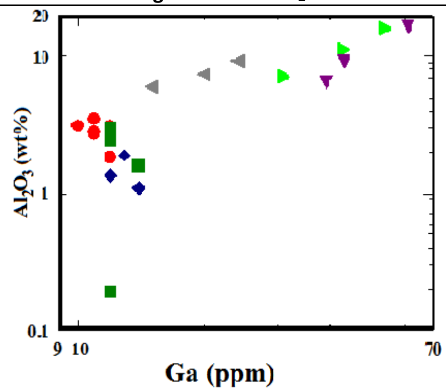


Figure 19h: Ga vs. Al_2O_3

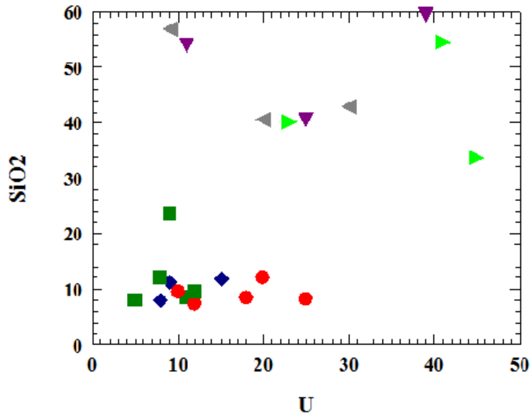


Figure 20a: U vs. SiO_2

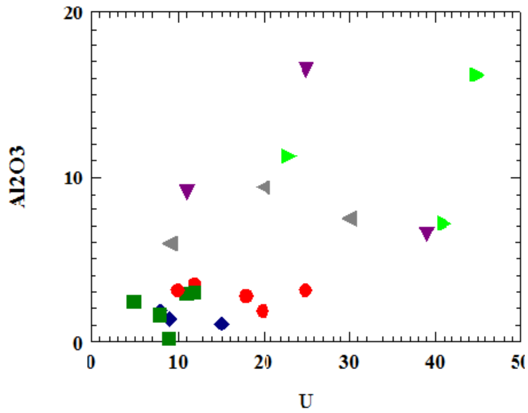


Figure 20b: U vs. Al_2O_3

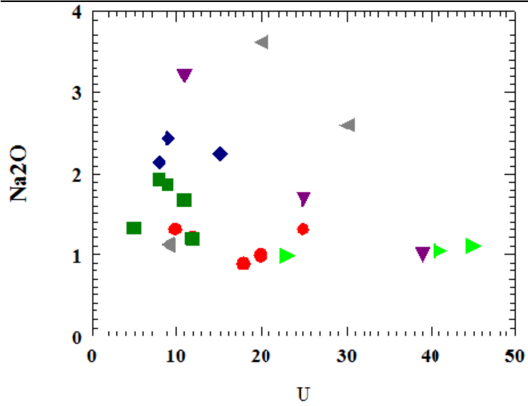


Figure 20c: U vs. Na_2O

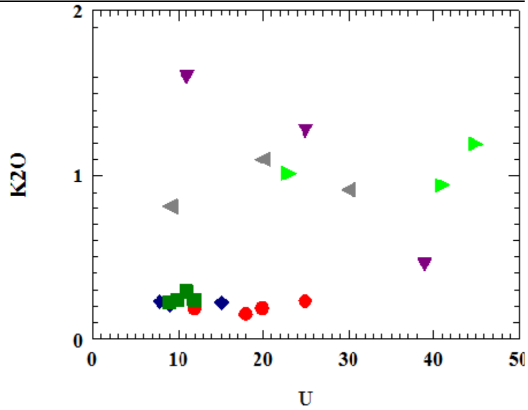


Figure 20d: U vs. K_2O

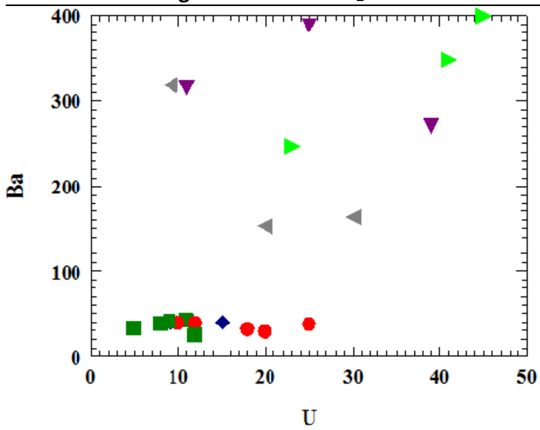


Figure 20e: U vs. Ba

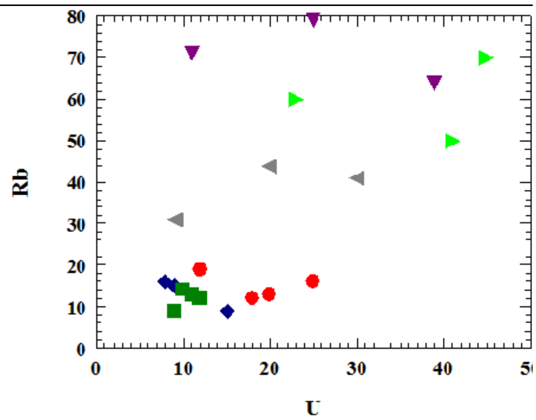


Figure 20f: U vs. Rb

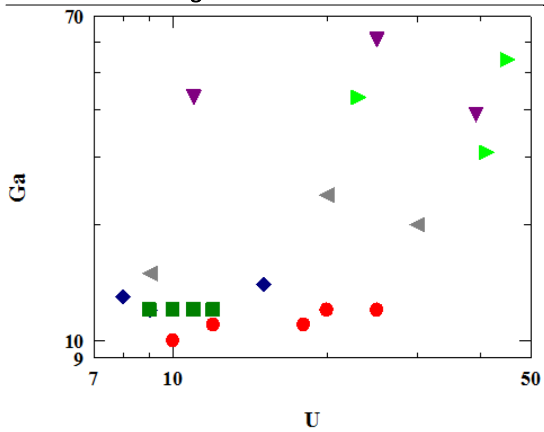


Figure 20g: U vs. Ga

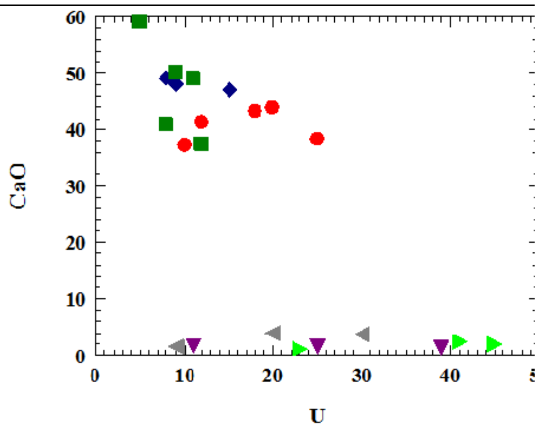


Figure 20h: U vs. CaO

Radioactivity:

Radiometric surveying, revealed that uranium content reaches to 50ppm, no specific uranium mineralization has been recorded. So uranium may be present as adsorbed on the iron and present between the fissile of the shale and increased near the top of the bed. Moh'd and Powell (2010) concluded that Organic matter could be related to elevated levels of uranium in highly bituminous marl (average of 25 ppm) in northwest Jordan and the average of U in black shale at the studied area is 24ppm, while the lowest values were encountered in oil shale (<6ppm).

Uranium naturally occurs in both U4+ and U6+ valence states. U6+ is extremely unstable in the supergene zone, as it can react with free oxygen to form UO2, which is favorable for its migration. In the transitional zone between oxidizing and reducing conditions, UO2 is generally reduced to U4+ and settles (Zhang and Zhao, 1984). In addition, reduction and adsorption of UO2 by microorganisms and organic matter can facilitate the deposition and concentration of uranium (Wang, 1986). Thus, apart from the source of uranium, abundant organic matter and microorganisms, as well as anoxic deposition and digenetic settings, are environmental factors that are favorable for uranium enrichment (Wang, 2003). As discussed above, the water seepages facilitated the dissolution and migration of uranium from many places to the black shale present below it, which relations with, SiO_2, Al_2O_3, Na_2O, K.O, Ba, Rb and Ga, while negative relation with, CaO, TiO_2, and V (Figs. 20 a, b, c, d, e, f, g, h, i and j).

Provenance, environment of deposition and tectonic setting:

Roser and Korsch (1986), proposed a classification of sedimentary basins based on simplified plate tectonic classification of continental margines and oceanic basins according to the nature of the underlying crust. Four types of sedimentary basins are recognized as follows:

- Oceanic Island Arc: sedimentary basins adjacent to oceanic island arcs or island are partly formed on thin continental crusts. Sediments are derived from calc-alkaline arc
- Continental Island Arc: sedimentary basins adjacent to island arc formed on a well-developed continental crust or in thin continental margins. sediments are derived from felsic volcanic source rocks.

Active continental margins: sedimentary basins developed on thick continental margins. These basins are developed on or adjacent to thick continental crust composed of older fold belts. Sediments are dominantly derived from granite-gneiss and siliceous volcanic of uplifting basement.

Passive Margins: sedimentary basins of the rifted continental margins of the Atlantic type developed along the edges of the continents. The sediments are generally highly mature and derived by recycling of older sedimentary and metamorphic rocks of continental platforms.

The diagram of (K_2O + Na_2O) against SiO2 according to Roser and Korsch (1986), it shows that the tectonic setting of all sample of El Duwi Formation fall in active continental margin area (Figure 20).

Conclusion

- Galala Mountains are located in the Eastern Desert of Egypt and range from Ain Sukhna near Suez 100 km to south. The exposed rocks units are ranges in age from Late Paleozoic to Quaternary and compose of Rod El-Hamal Formation, Qiseib Formation, Malha Formation, El-Galala Formation, El Duwi Formation and Sudr Formation.
- The El Duwi Formation contains the phosphorus rich horizons with presence of organic rich intraclastic and intrapelic phosphorites. In St. Anthony, samples show primary sedimentary ferrous minerals (such as siderite, pyrite and glaconite), shark Teeth and cellophane peliode type. In St. Pule, phosphatic rocks of El Duwi Formation are characterized by fossil, bones and cellophane pesslite. Wadi El Dakhl characterized by carbonate groundmass, apatite and angular quartz grains.
- The ESEM indicates that El Duwi Formation of St. Anthony contain gypsum $CaSO_4$ pyrite FeS and gypsum carrying jarosite.
- Major oxides: shale of have high concentrations of SiO_2 (range from 33.73% to 59.55% with average 47.029%) and Al_2O_3 in shale ranging from 6.51% to 16.41% with average 9.96%.while chalk low in SiO_2 (range from 7.31% to 11.91%) with an average 9.14% and Al_2O_3 range from 1.1% to 3.11% with an average 2.46% and deficiency in carbonates (calcite and dolomite). So chalk is low in SiO_2 and Al_2O_3. The chalk highly concentration in CaO% ranges from 37.2% to 49.19% with average 44.2. Al_2O_3 versus SiO_2 % and P_2O_5 show a strong negative relation and positive relation with Fe_2O_3, Na_2O, K_2O and TiO_2

- Trace elements of El Duwi Formation: Enrichment of Sr element up to 3143 ppm is located at phosphatic limestone bed. In the Chalk, Sr enters the basin of deposition largely combined mainly with calcite. Average contents of Ba in the studied El Duwi Formation range from 25 to 400 ppm with an average 139. It is know that Ba enrichment in sedimentary deposits can be considered as indicators of high flux of biogenic material to the sediments and therefore of high surface - water productivity. Also it is strongly adsorbed with clay minerals, reflecting positive relation with Al_2O_3 MgO and K_2O, The enrichment of barium in El Duwi Formation may be related to high biological productivity in the surface water of the open marine environment. Vanadium concentration ranges from 70ppm to 711 ppm with an average 42 ppm in El Duwi Formation. This may related to the clay content. The contents of Zn in the studied sediments are relatively high. Gallium contents are range from 10 ppm to 61 ppm with an average 22.136 in El Duwi Formation. The average Rb contents in the examined carbonates are 9 ppm and 71 ppm with an average 31.046. The high positive relation between Ga and Rb with Al_2O_3 reflects that the clay minerals may be representing the main host of Rb and Ga. Similarly the relations between Ga and Rb with K_2O in the examined sediments are highly significant. This suggests that the main bulk of Ga and Rb are associated with k- bearing minerals.
- Radioactivity: The relations between U (ppm) and different major and trace elements show that positive relation with, SiO_2, Al_2O_3, Na_2O, K.O, P_2O_5, Ba, Rb, Zr and Ga, while negative relation with, CaO, TiO2, and V. In El Duwi Formation the radioactivity occurs in shale
- Tectonically El Duwi Formation is originated from of greywacke in active continental margin area.

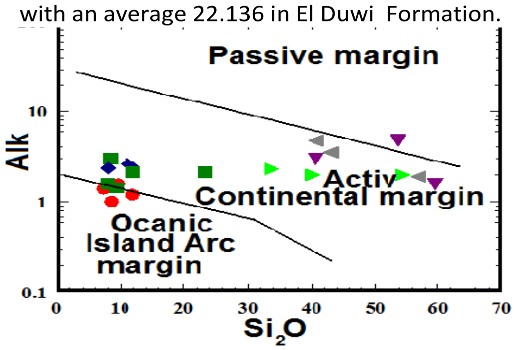


Figure 21 AlK vs SiO2

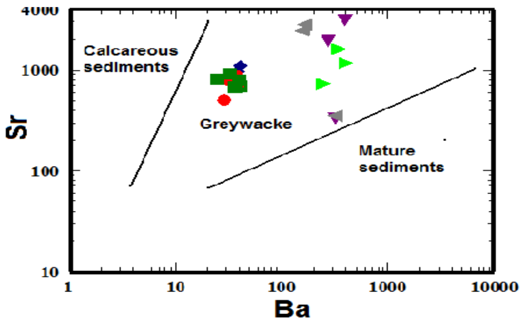


Figure 22 Sr vs Ba

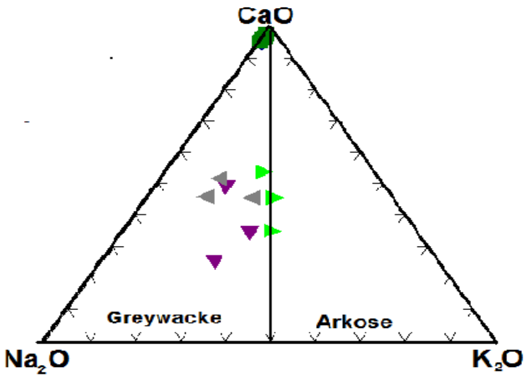


Figure 23 Na2O-CaO-K2O diagram

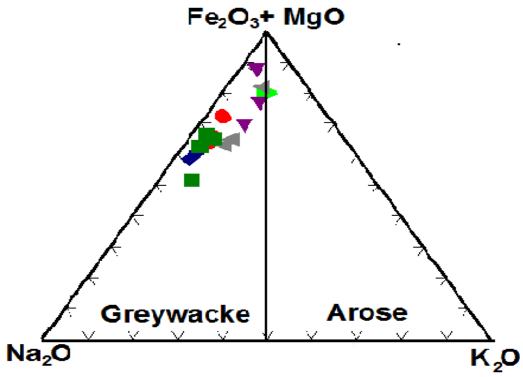


Figure 24 Na2O-(Fe2O3+MgO)-K2O diagram

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- The relation between Sr vs. Ba shows that all samples plot in greywacke field (Figure 18). Pettijohn et al. (1972) used the triangular CaO, Na2O and K2O to identify the origin of the sediments. (Figure 19) shows that all samples of shale and chalk fall in greywackes field.
- According to Ball et al., (1980), the triangular (Fe_2O_3 + MgO) - Na_2O - K_2O) diagrams show that all sample of shale and ckalk of the upper cretaceous in El Duwi Formation, Gabal El Galala El Qibliya fall in greywake field (Figure 24).

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