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U-MINERALS AND REE DISTRIBUTION, PARAGENESIS AND PROVENANCE, UM BOGMA FORMATION SOUTHWESTERN SINAI, EGYPT

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ABSTRACT

The lower Carboniferous sediments at SW Sinai comprises four stratigraghic formations from bottom: Um Bogma, El Hashash, Magharet El Maiah and Abu Zarab formations. The uranium bearing sediments are mainly confined and associated with Um Bogma Formation. The stratigraphic sections exposed at the six localities, (Talet Selim, Nasib, Abu Thor, Allouga, Abu Hamata and El Sahu), were studied in detail. These are exposed within a low basinal shaped area that was affected by several fault sets comprising strike-slip and step faults. These faults commonly trending (NW, NE, N-S and E-W) created a mosaic of faulted blocks within and outside the studied area, which to some degree helped the localization of the U-minerals.

The sedimentary rocks of the Um Bogma Formation comprise the sedimentary facies: gibbsite bearing sediments, shales, ferruginous siltstone, marl, dolostone, claystone and (Mn-Fe) ore. These sedimentary facies are well developed in the central parts of the studied area (Allouga and Abu Thor). The siltstone, shale and claystone are the main sedimentary facies hosting the U-minerals especially in the lower member of Um Bogma Formation.

The U-minerals found within these facies comprise U-oxides, U-silicates, and Uranyl-Oxyhydroxides, -silicates, -phosphates, arsenates, -vanadate-, -molybadate-, -carbonates and-sulphate complexes. The uranyl phosphate (phurcalite) $[Ca_2(UO_2)_3(PO_4)_2(OH)_4].4H_2O$, was first detected in the study area. The U-minerals association indicated formation under low temperature ($<100^oc$) oxidizing conditions with pH range 6-7.5 and high evaporation rate for the precipitation of the uranyl sulphate complexes.

The REE patterns of the above sedimentary facies suggest a provenance of recycled old sediments with contributions from plutonic component. These sediments were deposited in an active continental margin.

INTRODUCTION

The area east of Abu Zenima city on the west coast of the Gulf of Suez, is referred to as southwest Sinai region, particularly that located between lat. 28^0 55 – 29^0 05 N and long. 33° 20 - 33° 25 E.

Geologically, it is covered by Precambrian basement rocks, comprising gneisses and schists intruded by diorites, granodiorites and granitic bodies. These are nonconformably overlain by Paleozoic sediments.

The Paleozoic sediments were classified into Lower Sandstone Series, Middle Carbonate Series, and Upper Sandstone Series, (Barron, 1907). Ball, 1916, mapped the area. The Middle Carbonate Series was found to contain economic Mn-ores which draw the attention to study its stratigraphy in detail. The Carboniferous age was assigned by (Issawi and Jux, 1982). Weissbroad (1969) applied the term Um Bogma Formation to the Middle Carbonate Series, which was adopted by (Soliman and Fetouh, 1969; Said, 1971; El Shazly, et al, 1974; Kora 1984; El Agami,1996 and Al Shami 2003). However, Omara and Conil (1965) classified the Um Bogma Formation into lower dolomitic member, middle dolomitic limestone member and upper dolomitic member, which was adopted by (Weissbroard, 1969; Kora, 1984; El Sharkawy et al, 1990; Mansour, 1994), with some difference in detail.

Since, El Sokkary (1963) reported some radioactive anomalies discovered in the limestone unit of Um Bogma Formation , more anomalies were discovered at several other localities Allouga, El Sahu, Abu Thor where some yellow and green secondary uranium mineralization were identified (El Aassy, et al. 1986), and more geologic investigations, were carried out.

The detailed stratigraphy of Um Bogma Formation at six localities (Talet Selim, Nasib, Abu Thor, Allouga, Abu Hamata and El Sahu), will be discussed and correlated. The uranium mineralization at these localities will be investigated in relation to the sedimentary facies hosting it. It is intended to discuss the paragenesis of the uranium mineralization using the results of the mineralogical investigation as well as their chemical analyses of uranium and associated trace elements. Also, the REEs data will be used to discuss the provenance of the sediments as well as the tectonic setting of the sedimentary basin.

GEOLOGIC SETTING

The Um Bogma Formation exposed in the study area (Fig.1), is characterized by the pres-

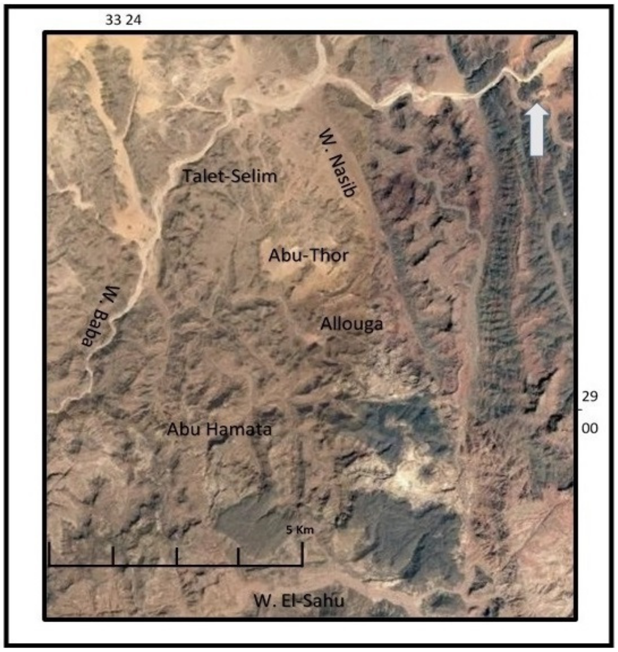


Fig.1: Google earth image of study area at SW, Sinai, Egypt

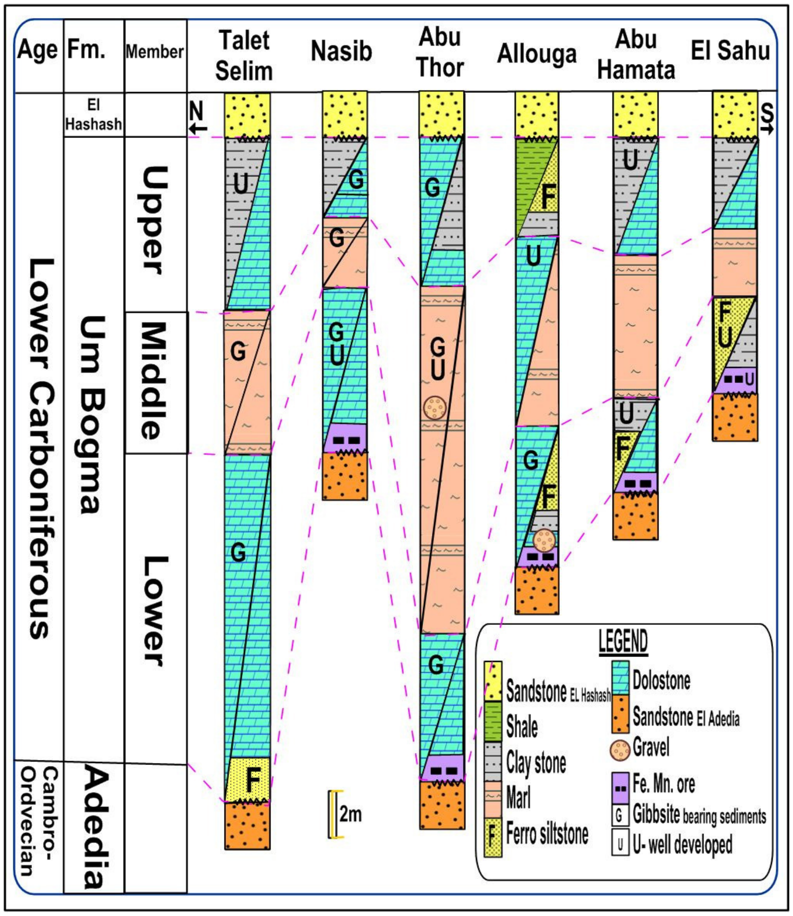
ence of paleosol layer at the bottom unconformably overlying the Adedia Formation of Cambro-Ordovician age. The upper boundary of Um Bogma Formation is marked by sandstones of brownish colour of the overlying El Hashash Formation, also of Lower Carboniferous age, Table (1).

The formation reached its maximum thickness in the study area at Talet Selim locality reaching (28) m at N and decrease in all other directions: reaching (13) m at wadi Nasib at E, (27) m at Abu Thor, (18) m at Allouga at center, (15) m at Abu Hamata (W), and (15) at El Sahu at S. The stratigraphic sections of Um Bogma Formation as measured at the above studied localities are shown in (Fig.2). The sedimentary rocks of the Lower Carboniferous Um Bogma Formation comprise the sedimentary rock types: gibbsite bearing sediments, shales, ferruginous siltstone, marl, dolostone, claystone, and (Mn-Fe) ore.

Table 1: Lithostratigraphic succession of the Paleozoic sediments

Age	Formation	Member	Lithology	Environment
Triassic			Basaltic sheet or/and sill	
Lower Carboniferous	Abu Zarab	___________	Glass sand with siltstone intercalations.	Fluviatile
	Magharet El Maiah	___________	Carbonaceous shale withLepidodendron Sp.and Sigillaria Sp.	Swamp
	El Hashash	___________	Brownish to yellow sandstone with ripple marks.	Aeolian
	Um Bogma	Upper Member	Dolostone, ferruginous siltstone, claystone, carbonaceous shale and gibbsite bearing sediments.	Shallow open marin
		Middle marly dolostone	Marl (yellow bed), dolostone, shale and gibbsite bearing sediments.	
		Lower Member	Karstified dolomitic rocks, ferruginous siltstone, claystone, Fe-Mn ore, shale, and gibbsite bearing sediments.	
Cambro-Ordovician	Adedia	___________	Sandstone, fine to medium grained, cross-bedded.	Fluviatile
	Abu Hamata	___________	Reddish sandy shale, green sandy shale	Shallow marine
	Sarabit El Khadim	___________	Alternating conglomerate with sandstone	Braided stream
Pre-Cambrian				Basement Complex

Fig.2: Stratigraphic correlation of facies of Um Boga Formation of the study area



These sediment types are well represented in the central parts of the study area (Allouga and Abu Thor), but the southern parts are characterized by more development of the ferruginous siltstone type. In the following paragraphs, stratigraphic section exposed in the studied area will be described in details from bottom upwards, with some correlation in between the various investigated localities. The facies and the horizons hosting the U-mineralization will be pointed out.

Lower Member

The Fe-Mn ore type

It is mostly confined to the lower member of Um Bogma Formation, and exposed wright above the basal unconformity. The associated high U-content is found at El Sahu and Allouga localities appearing at the unconformity surface. The ferromanganese ore bodies are often overlain by clastic sediments having sharp contact and gentle dip (0^0-10^0), Fig. (3).

Fig.3: Manganese ore, overlain by ferruginous siltstone of lower member of Um Bogma Fm., SW, Sinai

It is widely distributed in the Allouga, Abu Hamata, Abu Thor and El Sahu localities. The ferromanganese ore bodies are zoned with the Mn-concentrated towards the center and Fe-mainly concentrated at the margin. The U appears in the margins of the Fe-Mn bodies showing close relationship with Fe.The thickness of the lenses of Fe-Mn ore ranging from 1m at Nasib area to 5m at Abu Hamata area. However, the Fe-Mn ore is well developed at center and south of the studied area, but at north (Talet Selim) and east (Nasib), it is poorly developed.

The Ferruginous siltstone type

It is considered very important unit because it is the largest exposed type in the lower member all over the studied area. The southern part of the area is characterized by the lateral change to carbonate rocks. It is well developed at some parts of El Sahu locality. The average thickness is about (3m) and it is associated with uraniferous minerals at Allouga area.

Ferruginous siltstone is well developed at El Sahu (4m) at the south. Allouga (3m) Abu Hamata (4m), Talet Selim (2m), (Fig.3).

The dolostone

It is well developed at Talet Selim (15m) and decrease to the south at El Sahu (4m). It is 7m, 6m, 6m, 4m at Nasib, Allouga, Abu Thor and Abu Hamata, respectively.

The claystone

It is a very important sediment type because it contains high U- content and associated elements.. The thickness of the claystone at Allouga is (4m) and is unconformably overlain by marl. The claystone at Abu Hamata is about 5m thick and enriched in U, where the uranyl phosphate (phurcalite) was detected for first time at this locality (this work), (Figs.7-10), Table(2). The claystone of lower member is well developed at Allouga (6m), Abu Hamata (6m) and El Sahu(4m)

The shales

These are represented by three types. The first is the variegated shale exposed at the top of the lower member of Um Bogma Formation, which sometimes is changed laterally into carbonaceous shale.

The gibbsite bearing sediments

They are indicative of two processes that occurred in the past, karstification and lateritization. In warm humid climates of tropical and equatorial zones, dissolution of limestone produces deep grooves and sink holes,(karst topography) which when deepened lead down into limestone caverns. As caverns are enlarged and deepened surface collapse occurs on large scale leaving rock arches. At this stage of advanced karst development surface streams occupy valleys which become filled with shales and clays. These are the products of the hydrolysis and oxidation of igneous and metamorphic rocks, (lateritization) which is a mixture of clay minerals and heavy minerals. The general term for laterite deposits is bauxite comprising the minerals gibbsite, boehmite and diaspore, but only gibbsite was identi-

Table 2: X-ray diffraction data of phurcalite, Abu Hamata locality,(ASTM)=29-391

dA^0	I/Io	dA^0	I/Io
7.95	100	8.05	100
4.53	8	4.53	10
4.24	10	4.24	30
3.99	24	4.00	30
3.83	16	3.83	25
3.39	19	3.39	50
3.09	23	3.10	80
2.88	21	2.878	70
2.61	9	2.608	10
2.58	8	2.572	10
2.45	4	2.439	10
2.15	5	2.148	10
2.09	4	2.090	15
1.84	4	1.841	25

fied in the studied area. There are two varieties of gibbsite, the black and white ones, but the black one is much more developed. The lower gibbsite is well developed at Abu Thor and Talet Selim, and considered a uraniferous sediment.

Middle Member

The marl type

It is called the yellow bed and belongs to the middle member of Um Bogma Formation. It is characterized by predominant copper mineralization. The marl is exposed at all localities of the study area, but well developed at Abu Thor, Allouga and Abu Hamata, attaing nearly 10 m thickness. It is also associated with evaporates, sediments including gypsum, anhydrite and halite, (Fig. 4).

The shale

It is intercalated with the marl of the middle member as thin beds, almost of the variegated type with little exposures of the carbonaceous type especially at Allouga, (Fig. 4).

The gibbsite

It is present in all the studied localities expect at El Sahu where it is El Sahu (3m). At Abu Thor it is well developed associated with marl, exposed within the wadi floor and attains a thickness at Abu Thor (15m), Allouga (8m), Talet Selim(6m), Abu Hamata (6m), Nasib (3m), and absent at El Sahu.

The dolostone

It is represented by lenses within the marl and variegated shale. At Allouga, the middle member as a whole is completely changed into uraniferous dolostone in some parts.

Fig.4: marl of middle member of Um Bogma Fm., SW, Sinai.

Upper Member

The dolostone

It is represented in all localities with variable thickness. The maximum thickness is found at Abu Thor and Abu Hamata more than (10m) and poorly represented at Nasib and El Sahu. It is overlying the marl bed showing unconformable relationship at some places.

The claystone

It exposed is classified with the upper member if it overlies the marl beds such as at Talet Selim locality as opposite to Allouga locality where it is classified with the lower member. The claystone is well developed at Talet Selim at the north (7m), whereas at Nasib (3m), Abou Thor (6m) Abu Hamata (6m), El Sahu (4m).

The gibbsite

It is represented at Abu Thor (6m) and Nasib (3m) being well developed at Abu Thor, (Fig. 5).

The shale

It is of the carbonaceous type which is more developed at Allouga and Abu Thor. The distribution of upper shale is very clear (4m) at Allouga and Abu Thor and extended tens of meters. It is associated with sulphur, (Fig. 6)

On the other hand, the Figs. from (3 to 8) shows the facies at the field, while Figs.(9,10) shows the Phurcalite mineral .

STRUCTURE

The Paleozoic rocks of the southwestern Sinai were subjected to several faulting systems that vary in throw from few centimeters to hundreds of meters. Also, they vary in trends where the most common ones are NW, NE, NS and EW. They comprise step and

Fig.5: carbonaceous shale of Um Bogma Fm. SW, Sinai

Fig.6: Gibbsite bearing sediments, upper member of Um Bogma Fm., SW Sinai

Fig.7: Uraniferous claystone, lower member of Um Bogma Formation at Abu Hamata locality

Fig.8: Phurcalite within claystone, at Abu Hamata locality, first record

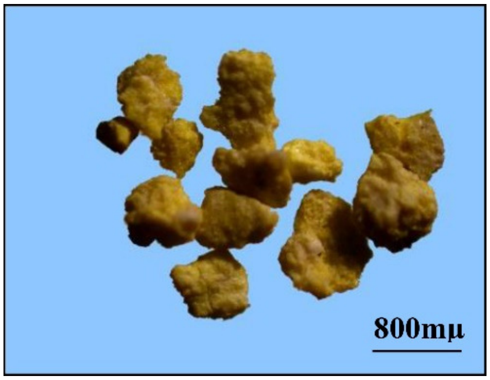


Fig.9: Uranium mineral (Phurcalite) grains picked from sandy claystone of Um Bogma Formation.

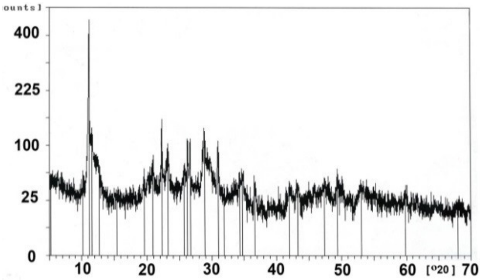


Fig.10: X- ray diffraction pattern of Phurcalite

strike-slip types.

A low basinal shaped area was developed between the Nasib fault system on the east and Baba fault system on the west. However the studied area comprises a mosaic of faulted blocks within and outside the identified basinal area, (Fig.11). The sediments associated with high uraniferous anomalies are located within this basin. It has been observed that a dolerite dike localized U-mineralization at Abu Thor. Also, the NW-trending faults controlled the high U- concentration at wadi Nasib, Talet Selim, Moreid and Abu Hamata, whereas the NE- trending faults controlled the U-concentrations at Baba. The EW-trending faults controlled the U-concentration at El Sahu. The Allouga locality is located within the down thrown block of the Nasib fault system, and its high U- anomalies are controlled by structure.

The southwestern Sinai district was affected by two volcanic episodes. The early one belongs to the Permo-Triassic age and was manifested by the basaltic sheet or / and sill at the top of the Post-Miocene age and resulted in abundant dolerite and basaltic dikes

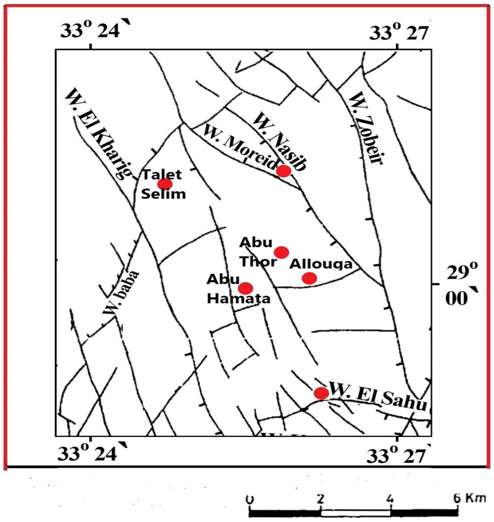


Fig. 11: Major faults of SW Sinai from field investigations

(El Shazly and Saleeb, 1969).

DISTRIBUTION OF U-MINERALIZATION

In the study area the U-mineralization is concentrated at the center of the study area at Allouga and Abu Thor where it is found as visible spots or thin layers at the surface of rocks along joints and disseminated in the rocks. The siltstone, shale and claystone are considered the main facies hosting the U mineralization especially at the lower member of Um Bogma Formation. The U minerals found within these facies comprise oxides, oxyhydroxides, carbonates, silicates, phosphates, arsenates,

Table 3: Distribution of uranium mineralization at the study area

Group	Minerals	Authors	Facies	Member	Locality
Uran oxides	**Uraninite (UO_2)**	**Bishr (2012)**			
	Coffinite ($USiO_4.nH_2O$)	**Bishr (2012)**	**Dolostone**	**Middle**	**Allouga**
	Brannerite ($U_{4+}Ti_2O_6$)	**Shata (2006)**			
Alkali and Alkaline earth (uranyl oxide hydrates)	**Clarkeite $(Na, Ca,)(U_2O)\ U_2\ (O\ OH)_7\ (H_2O)_n$**	**Amer (1997)**	**Gravels**	**----------**	**Abu Thor**
	Metacalciouranoite(Ca,Na,Ba) $U_2O_7\ .2H_2O$	**Bishr (2015)**	**Dolostone**	**Middle**	**Allouga**
Uranyl Carbonates	**Liebigite $Ca_2\ (UO_2)\ (CO_3)_3.\ 11\ H_2O$**	**Dabbour ,Mahdy(1988)**	**Siltstone**	**Lower**	**Allouga**
Uranyl Silicates	**Uranophane $Ca(UO_2)_2(SiO_3.OH)_2.(H_2O)_5$**	**Dabbour, Mahdy (1988),**	**Gravels**	**----------**	**Abu Thor**
		Alshami (2003)	**Shale**	**Lower**	**Allouga**
	Beta- Uranophane $Ca(UO_2)\ SiO_3\ (OH)_2.\ H_2O$	**Amer(1993)**	**Gravels**	**----------**	**AbuThor**
	Kasolite	**Amer (1997)**	**Shale**	**Upper**	**Allouga**
	$Pb(UO_2)(SiO_3)(OH)_2$	**Dawood (2005)**	**Gravels**	**---------**	**Abu Thor**
	Sklowdowskite	**Dawood (2005)**	**Gravel**	**---------**	**AbuThor**
	$Mg(UO_2)_2(SiO_3)_2(OH)_2.6H_2O$	**Shata (2006)**	**Shale**	**Upper**	**Allouga**
	Boltwoodite	**AbuBakr (1997)**	**Gravels**	**---------**	**Abu Thor**
	$K(UO_2)(SiO_3.OH).(H_2O)_{1.5}$		**Siltstone**	**Lower**	**Allouga**
	Soddyite	**Shata(2013)**	**Dolostone**	**Middle**	**Abu Thor**
	$(UO_2)_5(SiO_4)_2(OH)_2.5H_2O$	**Nasr (2015)**	**Gibbsite**	**Lower**	
Uranyl Phosphates & Arsenates	**Autunite $Ca(UO_2)_2(PO_4)_2.10\text{-}12H_20$**	**Dabbour,Mahdy (1988)**	**Siltstone**	**Lower**	**Allouga**
	Meta-Autunite $Ca(UO_2)_2(PO_4)_2.8H_20$	**Dabbour,Mahdy (1988),**	**Siltstone**	**Lower**	**Allouga**
		Shata (2013)			**Marl Abu Hamata**
	Sodium Meta-autunite $(Na_2,Ca)(UO_2)_2(PO_4).8H_2O$	**Shata (2013)**			**Abu Hamata**
	Hydrogen-Autunite	**Dabbour,Mahdy (1988)**	**Siltstone**	**Lower**	**Allouga**
	Meta-torbernite $Cu(UO_2)_2(PO_4)_2.8H_20$	**Dabbour,Mahdy (1988)**	**Siltstone**	**Lower**	**Allouga**
		Alshami (2003)	**Marl**	**Middle**	**Allouga**
		El Aassy and El Sawey (2010)	**Claystone**	**Lower**	**El Sahu**
	Bassetite	**Alshami (1995)**	**Carb. Shale**		**Allouga**
	$Fe\ (UO_2)_2\ (PO_4)_2.\ 8H2O$	**Alshami (2003)**	**Carb. Shale**	**Lower**	**Abu Hamata**

Table 3: Continued

Group	Minerals	Authors	Facies	Member	Locality
Uranyl Phosphates & Arsenates		**Shata & Mira (2010)**	**Black Shale**		**Abu Thor**
	Uranphite $(NH_4)_2(UO_2)_2(PO_4)_2.4\text{-}6\ H_2O$	**El Agami (1996)**	**Shale**	**Upper**	**Allouga**
	Meta-uranocircite $Ba(UO_2)_2(PO_4)_2.8H_2O$	**Abdelmonem et al. (1997)**	**Shale**	**Upper**	**Allouga**
	Meta-zeunerite **Cu(UO2)2(AsO4)2.8H2O**	**Dabbour, Mahdy (1988)**	**Siltstone**	**Lower**	
		El Agami (1996)	**Shale**	**Upper**	
	Phosphuranylite $Ca(UO_2)_4(PO_4)_2(OH)_4.7H_2O$	**AbuBakr(1997)**	**Gravels**	**----------**	**Abu Thor**
		Shata(2006)			**Allouga**
	Phurcalite $Ca_2(UO_2)_3(PO_4)_2(OH)_4.4H_2O$	**Shata & El Bilkassy (20102)**	**Claystone**	**Lower**	**El Sahu**
		Alshami (inpress)			**Abu Hamata**
	Renardite $Pb(UO_2)_4(PO_4)_2(OH)_4.7H_2O$	**Abdella (2014)**	**Claystone**	**Lower**	**Abu Hamata**
Uranyl–Vanadates	**Carnotite** $K_2(UO_2)_2(VO_4)_2.1\text{-}3H_20$	**Dabbour,Mahdy (1988)**	**Siltstone**	**Lower**	**Allouga**
		Amer (1997)	**Gravels**	**----------**	**Abu Thor**
		Dawood(2005)	**Shale**	**Upper**	**Allouga**
		Shata (2006)	**Claystone**	**Lower**	**El Sahu**
	Rb-Carnotite	**Dabbour,Mahdy (1988)**	**Siltstone**	**Lower**	**Allouga**
	Meta-tyuyamunite $Ca\ (UO_2)_2(VO_4)_2.3\text{-}5H_20$	**Dabbour,Mahdy(1988)**	**Siltstone**	**Lower**	**Allouga**
	Strelkinite $Na_2(UO_2)_2(V_2O_8)(H_2O)_6$	**Shata (2006)**	**Dolostone**	**Middle**	**Allouga**
Uranyl molybdates	**Moluranite** $H_4U(UO_2)_3.(MoO_4)_7$	**Shata&Mira (2010)**	**Carb. shale**	**lower**	**Abu Thor**
	Sedovite $U(MoO_4)_2$				
	Umohoite $(UO_2)(MoO_2)(OH)_4.2H_2O$	**Shata (2006)**			**Talet Selim**
		Shata&Mira (2010)	**Carb. shale**	**Lower**	**Abu Thor**
Uranyl Sulphates	**K-Zippeite**	**Dabbour,mahdy(1988),**	**Gravels**	**--------**	**AbuThor**
		Afifi (1992)	**Siltstone**	**Lower**	**Allouga**
	Zn Zippeite $Zn(UO_2)_4(SO_4)_3(OH)_{10}.16H_2O$	**Shata (2013)**	**Gibbsite**		**Abu Thor**
	Zippeite $2UO_3.SO_3.5H_2O$	**Mansour(1994)**	**Siltstone**	**Lower**	**Allouga**
	uranopilite $(UO_2)(SO_4)(OH)_{10}.12H_2O$	**Shata (2013)**	**Gibbsite**	**Middle**	**Abu Thor**

vanadates, molybdates and sulphates, Table (3), summaries the recorded U-mineral species observed in the studied area, and shows the distribution of U –minerals within different facies, as well as the various members of Um Bogma Formation

GEOCHEMISTRY AND PARAGENESIS OF U-MINERALS

The geochemistry of U at low temperature (> 100^0c) showed that its solubility is controlled by the presence of anions such as F^-, Cl^- , CO^{2-}, SO^{2-}, PO_4^{3-}, the oxidation potential of the fluids (fugacity of O_2) and pH. At low pH (>4), U is very soluble and fluoro complexes are stable.

At higher fugacity of O_2 levels and pH (4-7.5) uranyl-phosphate complexes are dominant, whereas at pH< 7.5 uranyl-carbonate complexes are important (Langmuir, 1978; Romberger, 1984). At low to near neutral pH and S concentrations < 100 ppm, uranyl sulfate complexes are significant and can transport U-long distances. However, uranyl-phosphate complexes will dominate over all other complexes in oxidizing fluids with 0.1 ppm PO_4^{3-} at intermediate pH (Kojima et al, 1994; Kyser and Cuney, 2009).

In reducing fluids and at low pH, uranyl-fluoride complexes can transport U, whereas at high pH uranyl-hydroxide complexes dominate. at near neutral pH and reduced environments U is immobile and precipitates as the U minerals, uraninite (UO_{2+x}) and coffinite ($USiO_4$), (Langmuir, 1978).

Several mechanisms can cause U to precipitate from U-bearing fluids. These include: 1) adsorption, 2) reduction-oxidation, 3) microbial activity, 4) evaporation, changes in pH, 5) decrease in ligand concentration. In sedimentary environments, it is fixed by reduction of U^{6+} to U^{4+} and precipitation of oxide minerals or by adsorption onto clay mineral surfaces, organic matter and oxides (Langmuir, 1978; Bruno et al 1995, Duff et al 1997, 1999; Moyes et al, 2000). In oxidizing conditions, fixation of U can occur with K and V ions to form a variety of U-K-V minerals (Hostetler and Garrels, 1962).

Most common U- ore minerals: uraninite (UO_{2+x}), coffinite $USiO_4$. Uraninite contains impurities such as Pb, Ca, Si, Th, Zr, Fe, S, Ti and REE, which can affect thermodynamic properties of uraninite and the rate of alteration. The nature of alteration products are controlled by these impurities ad the chemistry of the fluids associated with alteration of uraninite. Therefore, uraninite commonly alters to autunite [$Ca (UO_2)_2(PO_4)_2.10H_2O$]. or uranophane [$Ca (UO_2)_2 SiO_3 (OH)_2 .5H_2O$]. Under reducing conditions, uraninite is altered through dissolution or silicification to coffinite ($USiO_4.nH_2O$), with loss of Pb, Y and REE.

Coffinite is the most important ore mineral for U after uraninite. Commnly it contains some water and the correct formula is $USiO_{4.}$ nH_2O, (Speer, 1982). The most common impurities in coffinite are P and REE, suggesting some solid solution with xenotime(YPO_4) which is isostructural with coffinite, (Janeczek and Ewing,1992). Coffinite is the major U-bearing mineral in many low-temperatures sandstone-hosted U-deposits, where it commonly occurs intermixed with organic matter. Coffinite is also a common alternation product of uraninite in Si-rich reducing environment, (Janeczek and Ewing, 1996).

Brannerite ($U^{4+}Ti_2O_6$) is the most important U-ore mineral after uraninite and coffinite, typically metamict. It is a common accessory mineral in numerous uraninite and coffinite U deposits, and has been identified in both unconformity and hydrothermal-vein U deposits, (Finch, 1996). Sometimes it may form following adsorption of U onto oxides, (McCready and Parnell, 1997, 1998).

The uranyl oxyhydroxides (clarkeite and metacalciouranoite) form in U-rich aqueous solutions and develop early during the oxidation and corrosion of uraninite bearing ore deposits, most commonly at or near the surface of corroded uraninite. The formation and alternation of uranyl oxyhydroxides can, in part, determine reaction paths and uranyl mineral paragenesis at weathered U-deposits, which help to control dispersion and fixation of U in many dilute groundwaters.

The uranyl carbonates represented by liebigite, are important in near neutral to alkaline waters (pH<7) and may precipitate where evaporation is significant or where the fugacity of CO_2 is greater than atmospheric. Uranyl di- and tri- carbonates tend to form only where evaporation is high. Precipitation of uranyl tricarbonate minerals usually reflects evaporation of alkaline water.

The uranyl silicates are represented by uranophane, beta-uranophane, kasolite, sklowdowskite, boltwoodite and soddyite. They are moderately insoluble in most natural groundwaters and because of the ubiquity of dissolved Si in most groundwaters, they are the most abundant group of uranyl minerals. Uranophane, the most common uranyl mineral and probably the most common U mineral after uraninite, precipites from near neutral to alkaline groundwaters that contain dissolved Si and Ca. When exposed to dilute meteoric water (low CO_3: pH>7), uranophane may be replaced by soddyite (Finch, 1994), Sklodowskite is replaced by kasolite when radiogenic Pb that accumulates within Sklodowskite reaches enough level to be exolved and reprecipitated as kasolite (Isobe et al 1992). However, uranophane and soddyite can persist in some environments for long times. (Finch et al, 1996).

Uranyl phosphates and arsenates represented by autunite, meta-autunite, sodium meta-autunite, hudrogen autunite, uranphite, meta-uranocircite, phosphuranylite, phurcalite, renardite and meta-zeunerite, They help control U concentrations in many natural waters. They generally have solubilites below those of uranyl silicates and associated with a wide range of weathered U deposits. They are known to precipitate from groundwater with U concentrations in the range $10^{-8} – 10^{-9}$ mol/kg values that approach the solubility of uraninite in some reducing environments. Uranyl phosphates may occur well removed from any U source (Frondel, 1958). In groundwaters where log $([PO_4^{3-}]_T/[CO_3^{2-}]) < 3.5$ uranyl phosphate complexes predominate over uranyl carbonate complexes, (Sandino and Bruno, 1992). Apatite controls the phosphate concentrations necessary to precipitate uranyl phosphates in many natural waters keeping phosphate activity below10^{-7} mol/kg. Uranyl phosphates are typically most stable below pH nearly 5 where apatite solubility tends to increase (Sandino, 1991; Stumm and Morgan, 1981).

Uranyl vanadates represented by carnotite, Rb-carnotite, meta-tyuyamunite and strelkinite, They are the most insoluble of uranyl minerals and so stable that they will form wherever dissolved U comes in contact with waters containing dissolved U-ions. The uranyl vanadates occur where reduced U minerals (uraninite, coffiinite or brannerite) and reduced V minerals. (montroseite) are undergoing oxidation. The V^{5+}- ions may also be derived from rocks that contain reduced V such as organic-rich shales and other clay-rich rocks. They are very stable and exist for long time, (Garrels and Christ, 1959, Langmuir, 1978; Smith, 1984).

The uranyl molybdates represented by moluranite, sedovite and umohoite, are important ore minerals and occur where uraninite and Mo-bearing minerals are being weathered. The Mo in these minerals occurs as Mo^{6+} and U may be of mixed value U^{4+} and U^{6+}.

Uranyl sulphates represented by K-zippeite, Zn zippeite, zippeite and uranopilite, are only important where sulphides are being oxidized providing dissolved SO_4^{2-} to groundwater that can complex with UO_2^{2+}. Evaporation is required to precipitate uranyl sulphates. Waters from which uranyl sulphates precipitate tend to be somewhat acidic with pH value nearly >6. A slow decrease in solution pH is required from the precipitation of zippeite-group minerals, otherwise uranyl oxyhydroxides tend to form, decreasing the activates of dissolved U-species. (Frondel et al., 1976; Brindley and Bastanov, 1982).

REE Provenance

Because REE are not easily fractionated during sedimentation, the REE patterns of sedimentary rocks, (facies), may provide an index to the average provenance composition. Hence, reinvestigation of sedimentary rocks may explain sedimentary processes (weathering, digenesis … etc.), or relationship between sedimentation and plate tectonics, crustal evolution and paleogeography, (McLennan, 1989).

Six samples representing the different sedimentary rock facies in the studied area were analyzed for the REE and some other trace elements. the analytical results are shown in Table (4), the REE patterns of the individual rock facies are demonstrated, as normalized to chondritic abundances (Schmidt et el., 1964) and normalized to north American Shales Composite (NASC) abundances (Haskin et al.,1968, Gormet et el.1984), (Figs.12-13) for siltstone, (Figs.14-15) for gibbsite, (Figs.16-17) for marl, (Fig.18-19) for dolostone and (Figs.20-21) for shale.

The analytical data indicate that the gibbsite facies contain the highest REE (x7 NASC, x40 chondrites). The gibbsite is followed by the claystone, shale, marl, ferroginous siltstone and dolostone showing REE in a decreasing order. The general features of the REE pattern show the presence of (-ve) Ce-anomalies and (-ve) Eu-anomalies. Also the REE patterns show some LREE variably enriched with some fractions and semi-flat HREE patterns which can be considered as somehow parallel to the upper continental crust REE pattern, (Tayolr and McLennan, 1981,1985)

The presence of the (-ve) Ce-anomaly has been explained as due to the oxidation of Ce^{3+} to Ce^{4+} under oxidizing conditions which may only happen on large scale in the marine environment in the open ocean associated with the formation of Mn-nodules and the other mineral phases precipitated in equilibrium with sea water, hence, Ce is highly depleted in ocean water (Elderfield and Greaves, 1982). Similarly under reducing conditions such as those found within the lower crust Eu may exist as Eu causing an increase in its ionic radius (1.25A) becoming very similar to Sr (1.26 A) and consequently Eu substitutes in feldspar notably Ca-plagioclase . This might show up as (+ve) Eu-anomaly in sediments rich in volcanogenic components, otherwise it exhibits, (-ve) Eu-anomaly in other sediments as the studied sedimentary rocks. The level of LREE enrichment is similar to that observed for the upper crust (Taylor and McLennan, 1985), suggesting further upward enrichment of (LIL) elements within the crust itself. The flat HREE pattern suggests no control on crustal composition from a HREE – fractionating phase such as garnet.

From the above discussion, it can be suggested that for terrigenous sedimentary rocks, the REE patterns generally reflect the average compositions of the provenance. The uniformity of REE distribution in terrigenous sedimentary rocks has been attributed to the efficient mixing of sources lithology during sedimentary processes, especially sedimentary recycling history, (Veizer and Jansen, 1979, 1985), which facilitates mixing, and homogenization of REE and other geochemical signatures

As for the tectonic setting, continental margins may be classified into passive and active types. The active continental margins are distinguished into island arcs or continental arcs. The sediments deposited at continental margins generally show REE intermediate between typical andesite pattern and NASC. These most active continental margin sediments display intermediate REE abundances, variable LREE enrichment and variable (-ve) Eu-anomalies. However, the gibbsite sample

Table 4: Chemical analyses of REE and U of some facies of Um Bogma Formation.

	Shale	**Dolos.**	**marl**	**Clay.**	**gibbsite**	**Ferr. Siltstone**	**Mn-Fe ore**	**Nasc**	**C1**
	S-6	**D-5**	**M-4**	**AH**	**G-3**	**Ferr-2**	**Mn-1**		
La								**32**	**0.46**
Ce	**200**	**49**	**178**	**240**	**480**	**110**	**N.D.**	**73**	**1.20**
Pr	**34**	**29**	**40**	**40**	**300**	**24**	**40**	**7.9**	**0.18**
Nd	**92**	**23**	**200**	**112**	**1460**	**42**	**40**	**33**	**0.85**
Sm	**16**	**2**	**60**	**10**	**340**	**2**	**N.D.**	**5.7**	**0.27**
Eu	**N.D.**	**N.D.**	**10**	**N.D.**	**60**	**N.D.**	**N.D.**	**1.24**	**0.099**
Gd	**24**	**10**	**100**	**40**	**200**	**40**	**90**	**5.2**	**0.34**
Tb	**N.D.**	**N.D.**	**10**	**4**	**26**	**2**	**8**	**0.85**	**0.06**
Dy	**1.2**	**6**	**42**	**12**	**100**	**110**	**N.D.**	**5.8**	**0.40**
Ho	**N.D.**	**N.D.**	**N.D.**	**N.D.**	**2**	**N.D.**	**N.D.**	**1.04**	**0.089**
Er	**10**	**2**	**16**	**12**	**26**	**6**	**N.D.**	**3.4**	**0.26**
Tm	**N.D.**	**N.D.**	**N.D.**	**N.D.**	**N.D.**	**N.D.**	**N.D.**	**0.50**	**0.039**
Yb	**6**	**N.D.**	**8**	**8**	**12**	**2**	**4**	**3.1**	**0.25**
Lu	**N.D.**	**N.D.**	**N.D.**	**N.D.**	**4**	**N.D.**	**N.D.**	**0.48**	**0.038**
Y	**100**	**28**	**134**	**104**	**220**	**54**	**10**		**4.33**
U	**78**	**2209**	**190**	**22**	**706**	**80**	**N.D.**		

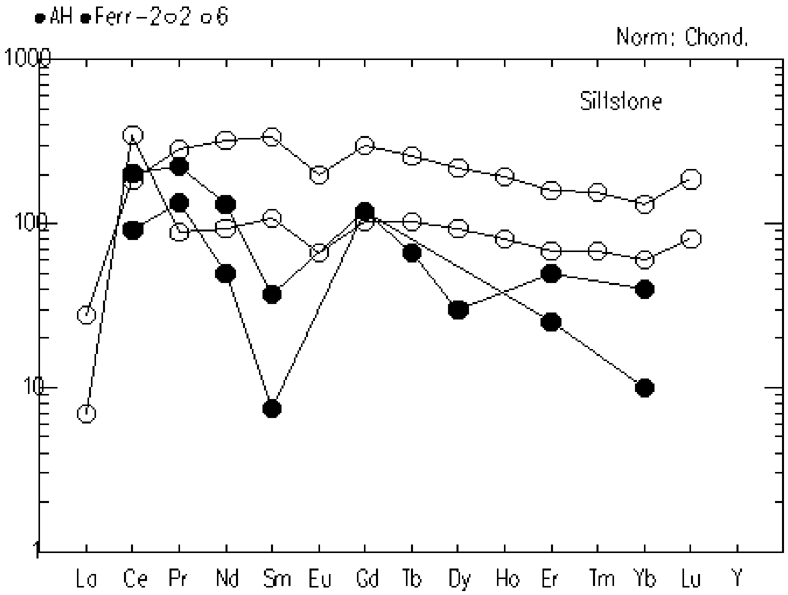


Fig. 12: REE pattern normalized with condrite.

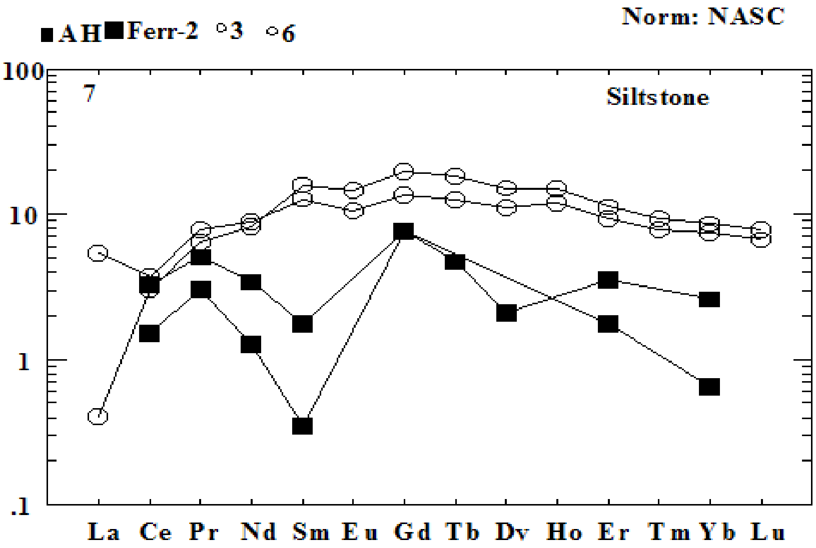


Fig.13: REE pattern normalized with NASC.

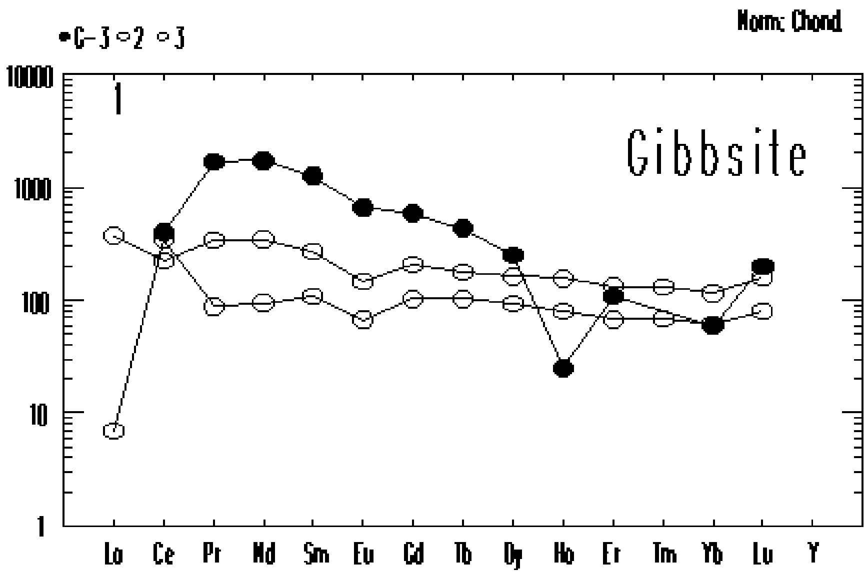


Fig.14: REE pattern normalized with condrite

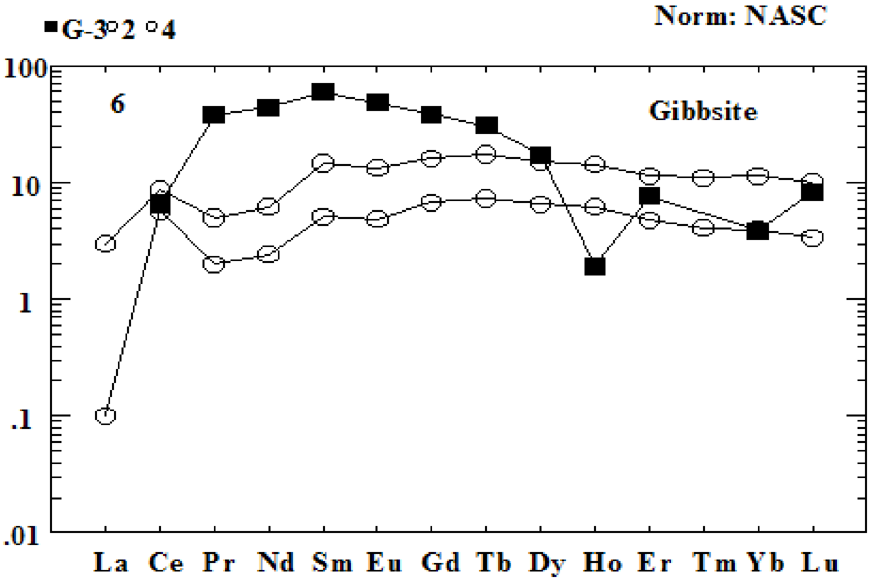


Fig. 15: REE pattern normalized with NASC.

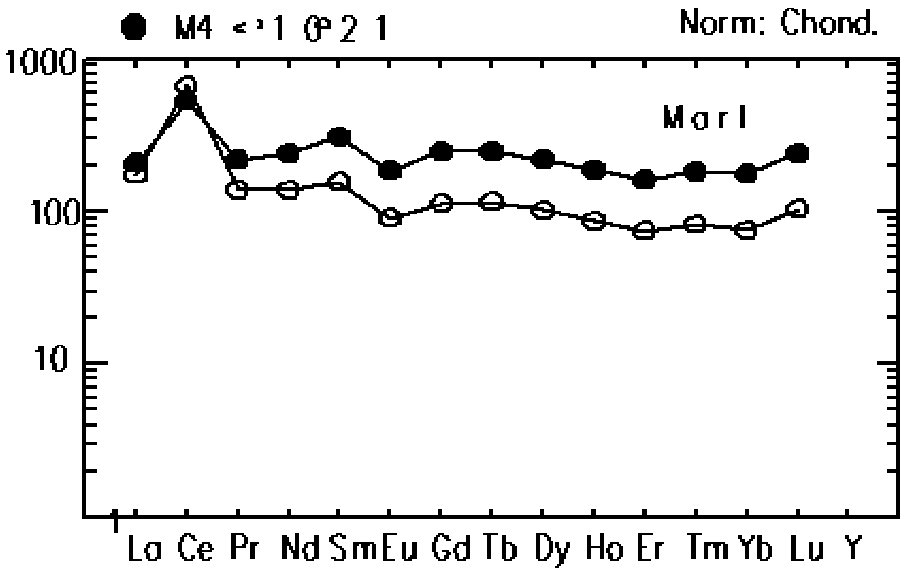


Fig. 16: REE pattern normalized with condrite.

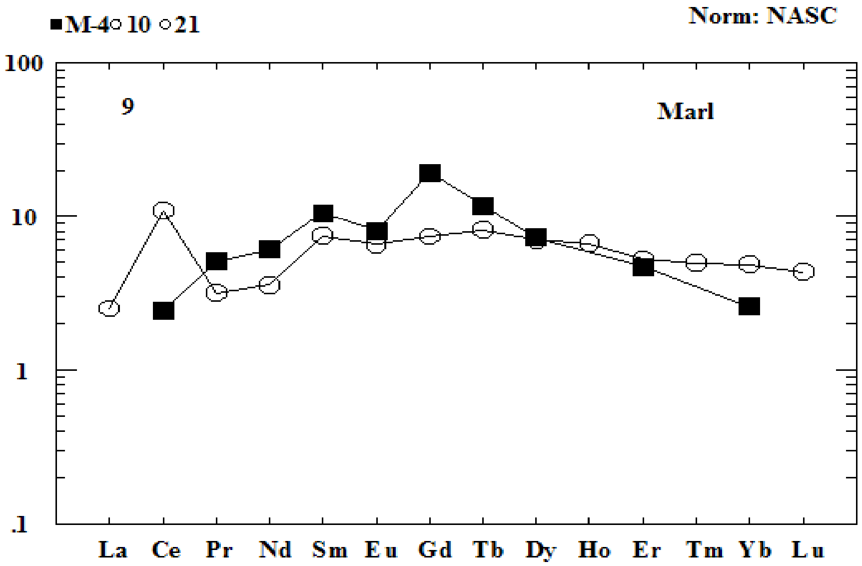


Fig.17: REE pattern normalized with NASC

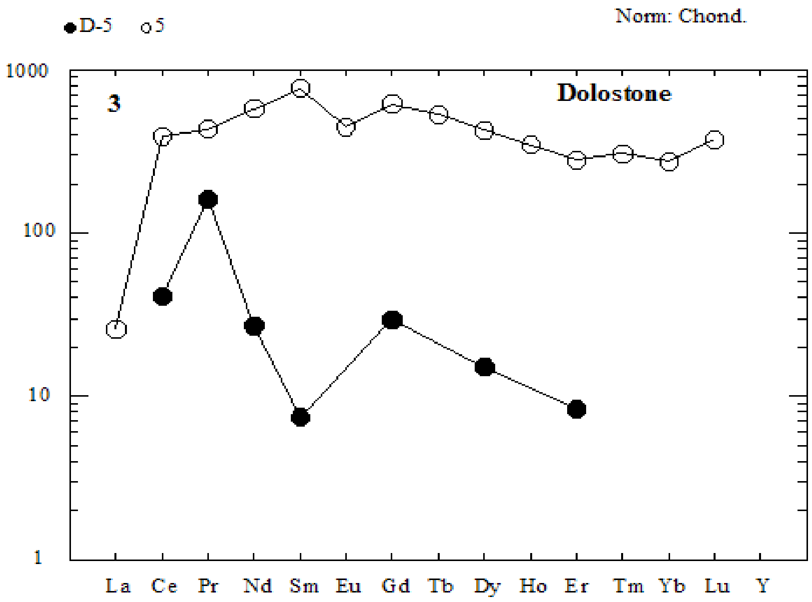


Fig. 18: REE pattern normalized with condrite

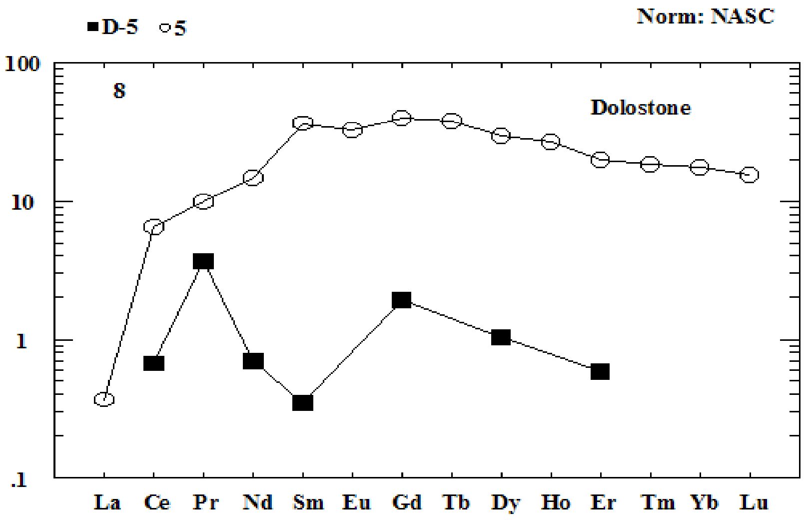


Fig. 19: REE pattern normalized with NASC.

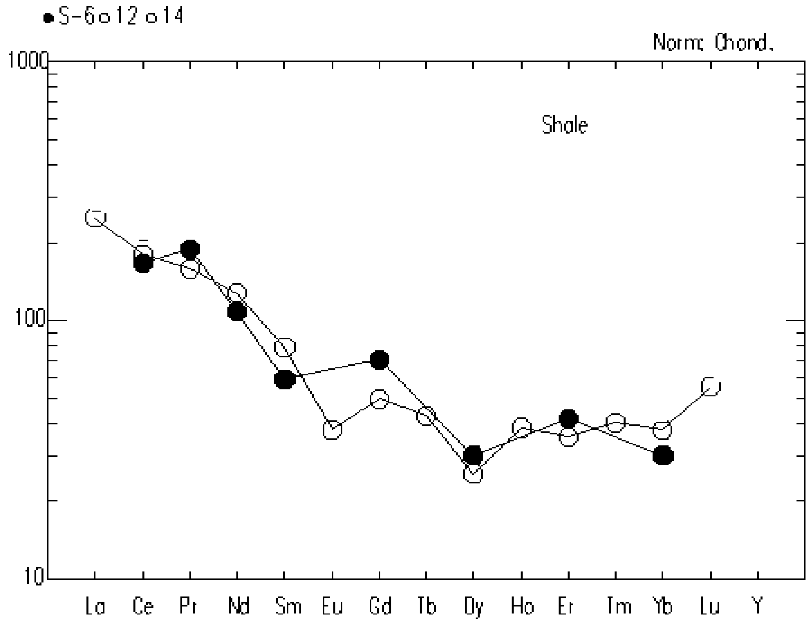


Fig. 20: REE pattern normalized with condrite

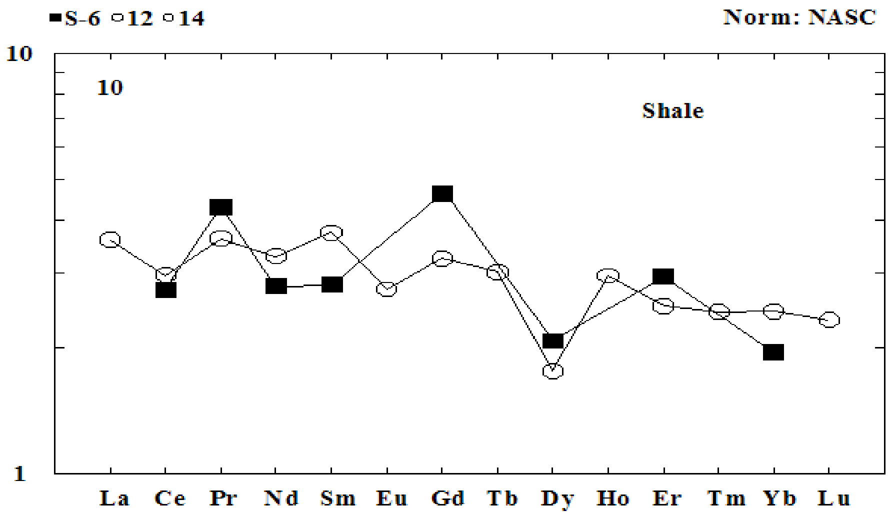


Fig.21: REE pattern normalized with NASC.

is excluded from this general characterization, probably these sediments might contain some heavy accessary minerals that control its REE pattern as well as their abundance.

There are at least three major source components for sediments deposited at active continental margins. One component is old upper continental crust which may lay either old igneous/metamorphic terranes or old recycled sedimentary rocks which likely have REE patterns fairly similar to upper continental crust. A second major source is a young component derived from the island arc or continental arc itself. If the igneous materials is less fractionated it will display less fractionated REE patterns with no Eu-anomalies. But the fractionated igneous components (felsic volcanics/plutonics rocks), effectively show REE patterns similar to upper continental crust with (–ve) Eu-anomalies .This last third that source may be added into the sediments is during explosive volcanism, or more likely when the arc is in the matured stage and dissected to expose its root zones displaying variable REE patterns and the fractionation is documented by the (–ve) Eu-anomalies , (McLennan et al, 1989,1990). In general, the REE patterns of the studied sediments suggest provenance comprising a mixture of components one and two explained above, however, dominated by recycled old sediments.

DISCUSSION AND CONCLUSIONS

The lower Carboniferous Um Bogma Formation, SW Sinai, is classified into lower, middle-and upper members, where the lower member hosts the (Mn-Fe) ores; the middle member dominated by dolostone and marls, and the upper member dominated by siltstone and gibbsite. The formation comprises seven lithologic units: (Mn-Fe) ores, gibbsite bearing sediments, ferruginous siltstone, claystone, shales (variegated, carbonaceous), marl and dolostone. The (Mn-Fe) ore and the terruginous siltstone are mainly exposed in the lower member, while the marl (yellow bed) is mainly exposed in the middle member. The variegated shale occurs in the lower member while the carbonaceous type shale autcrops in the upper member. The claystone, the gibbsite bearing sediments and dolostone occur in all members.

Nearly all lithologies described show some association with U-minerals, however, the siltstone, claystone and shale are considered the main facies hosting the U-minerals. The structure (faulting), lithology, topography and biogenic effects are the main factors that controlled the localization of the U-minerals within the sediments, especially in the lower member of Um Bogma Formation. The mineralogy of uranium comprises 33 minerals as follows: U^{44}-oxides (3 minerals), uranyl/oxyhydroxides (2 minerals), uranyl silicates (6 minerals), uranylphosphates and arsenates (10 minerals), uranyl/vanadates and molybdates (7 minerals), uranyl sulphates (4 minerals) and uranyl carbonates (one minerals). The U^{4+} oxides and silicates were precipitated under reducing environment at low temperature <100ºc, as uraninite and coffinite probably associated with carbonaceous shale. The uranyl oxyhydroxides are important because they form early during the dissolution of U^{4+}-oxides, however, continued interaction between groundwater and the oxyhydroxides results in their replacement by uranyl silicates (and carbonates). Also, during the early of uraninite weathering, uranyl vanadates and malybdates may be formed if reduced, and Mo-minerals are undergoing oxidation. But, the Pb-rich uranyl oxyhydroxides persist, (clarkeite). In such highly oxidizing environment and pH 4-7.5 uranyl phosphate complexes are dominant over all other complexes with 0.1 ppm PO_4^{3-} at intermediate pH. The autunite group uranyl phosphate complexes form first, while the phospho-uranylite group will not precipitate until the pH becomes alkaline >7.5, the presence of phurcalite is an evidence for the environment becoming alkaline. The formation of uranyl/sulpahte complexes indicates significant evaporation processes as indicated by the presence of evaporites associated with the studied sediments as well as slightly acidic environment, pH <6. Also, the uranyl carbonate complexes, (liebigite) require such high evaporation but when the fluids become neutral or alkaline.

The REE patterns of sedimentary rocks have been used to indicate the average provenance composition. The studied REE pattern exhibit variable slight LREE enrichment with both (-ve) (ee-, and (-ve) Eu-anomalies, and semi-flat HREE pattern. This is similar to average continental crust, which might suggest efficient mixing of terrigenous materials from different sources during sedimentation processes. The source of the terrigenous is suggested to be a mixture old recycled sedimentary rocks and younger component from the continental arc. The tectonic setting of the sedimentary basin have been suggested to be an active continental margin as indicated by the intermediate REE abundances, variable LREE enrichment and variable (-ve) Eu-anomalies.

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توزيع اليورانيوم و العناصر الارضيه النادره في متكون ام بجمه, جنوب غرب سيناء – مصر

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تحتوى صخور العصر الكربوني السفلي جنوب غرب سيناء على 4 متكونات هي من الاقدم: أم بجمه, الحشاش , مغاره المياة, أبو زراب.

يعتبر متكون أم بجمة من أهم الصخور الموجودة في المنطقة وذلك لوجود اليورانيوم والعناصر المصاحبه له مثل الفانديوم, الكروم, الكوبلت ,الباريوم ,البورون ,الاتريم ,الزركون ,الرصاص ,الزرنيخ ,النتنجستن الاسترنشيوم ,النيكل والنحاس .

وقد قسمت هذه الدراسة هذا المتكون الواعد (أم بجمه) الي ٧ أنواع من الصخور هي:
١- خام الحديد والمنجنيز ٢- الرواسب الحاملة للجبسيت ٣- حجر السيلت الغني بالحديد
٤- الصخور الطينيه ٥- صخور الطفله ٦- صخور المارل
٧- الدولوستون

-تم أكتشاف معدن يورانيوم جديد في منطقة أبو حماطه لأول مره وهو (الفيركولايت) وذلك في منطقة أبو حماطه في الصخور الطينية الحاملة لليوانيوم حيث أنه يمتد حوالي ١٥ متر طولاً 5 متر عرضاً لكل عدسة ويظهر في عدسات غير متصله مما يعطى تصوراً لوجود صخور حاملة لليورانيوم بكميات كبيرة وهذا يزيد من أهمية هذه الاكتشاف كما أنه مكان سهل الوصول اليه و يمكن عمل محاجر لتتبع هذا الخام ويعلو هذه الصخور, صخورالعصر الكربون الأسفل التي تعلو متكون أم بجمة بحوالي (٤٠متر).

-يحتاج هذا الأكتشاف حفر وعمل ترنشات ومحاجر لتتبع الخام والحصول عليه.