IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 6, June 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

Geology and Radioactivity of the Paleozoic Rocks of Wadi El-Sahu Area, Southwestern Sinai, Egypt.

Abu Bakr, M. A.[1]; El Mezayen, A. M.[2]; Sherif, H. M. Y.[3]; El Nahas, H. A.[4] and Ali, H. H.[5]

[1,3,4,5] Nuclear Materials Authority, Cairo, Egypt. [2] Al Azhar University, Egypt.

Abstract

Wadi El Sahu area consists of basement rocks and Paleozoic sedimentary cover. The Paleozoic rocks are represented from base to top by Sarabit El Khadim, Abu Hamata, Adediya, Um Bogma, El Hashash, Magharet El Miah and Abu Zarab Formations respectively. Basaltic sills (Late Triassic-Early Jurassic) cover the top most part of these Formations. The chemical and radiometrical studies of the Paleozoic rocks revealed that most of radioactive, trace and rare earth elements are mainly enriched in the organic matters of Um Bogma Formation. The organic matters hosted in the fissures and fractures in Um Bogma Formation are due to the seepage of oil after the tectonic events. The volatiles evaporated by the high thermal effects of the basaltic volcanicity leaving the rest of organic matters as asphalt-like materials. The structural and lithological features controlling the redistribution of most radioactive, trace and rare earth elements leached from asphalt-like materials are taken into consideration.

Introduction

Wadi El Sahu area is located in the southwestern part of Sinai Peninsula to the east of Abu Zeneima Town by distance of about 30 km and occupies approximately 260 km^2. It is delineated by Longitudes 33^o 21′ and 33^o 28′ E and Latitudes 28^o 52′ and 29^o 05′ N, (Fig.1). The study area is covered by basement and Paleozoic sedimentary rocks. The basement rocks are represented by gneisses and younger granites. These rocks are overlain by Paleozoic sedimentary rocks started with the Cambrian succession (Sarabit El Khadim, Abu Hamata, Nasib and Adediya Formations) which are unconformably overlain by Carboniferous shallow marine facies of Um Bogma Formation and deltaic to fluviomarine facies of Abu Thora Formation (Soliman and Abu El Fetouh, 1969; Kora, 1984 and El Agami, 1996). Alshami (2003) clarified that Abu Thora Formation is composed of El Hashash, Maghert El Miah and Abu Zarab Formations. Basaltic sills (Late Triassic-Early Jurassic, Weissbored 1969) cut through the top of Abu Thora Formation.

Omara and Schultz (1965) divided Um Bogma Formation into three members; namely: the Lower dolomitic member, the Middle dolomitic limestone and marl member and the Upper dolomitic member. El Sharkawi et al., (1990a) paid a special attention to the Lower member and considered it as a karst profile. Morsy et al., (1995) summarized the diagenetic history of Um Bogma carbonate rocks in southwestern Sinai. They described diagenetic processes mostly; dolomitization, dedolomitization, formation of calcite veins, dissolution and replacement. Alshami

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 6, June 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

(2003) subdivided Um Bogma Formation into three members; Lower siltstone, dolostone, claystone member associated with manganese iron ore, Middle marl dolostone member and Upper siltstone, dolostone, claystone member.

Soliman and Abu El Fetouh (1969) classified the Ataqa Series of Kostandi (1959) into the three formations (from base to top): El-Hashash, Magharet El Miah and Abu Zarab and introduced the name El Hashash Formation for the first time.

The Paleozoic rocks outcropped at Wadi El Sahu and the surrounding areas attracted the attention of many authors since it contains several mineral deposits especially Um Bogma Formation which is considered as poly metallic horizon. For example, manganese-iron deposits (Mart and Sass, 1972 and Abu El Hassan and Baioumy, 2003), copper deposits (Hilmy and Mohsen, 1965; El Sharkawi et al., 1990b and Amer, 1997), silver deposits (Amer, 1993 and El Agami, 1996), uranium deposits (El Aassy et al., 1986; Dabbour and Mahdy, 1988; El Reedy et al., 1988; Hussein et al., 1992; Abdel Monem et al., 1997; Amer, 1993 and 1997, NMA, 1999a, Alshamy, 2003 and Abdel- Azeem, 2014) and some transitional elements like Zn, Sn, Ni, Mo and Pt (Ahmed, 2003). These discovered sites were subjected to extensive studies from the geological, mineralogical, geochemical and even hydrometallurgical points of view.

Geologic outline

A geologic map (Fig. 1) of the studied area was modified after Alshami, (2003). The area is covered with basement and Paleozoic rocks. The basement rocks are represented by gneisses and younger granites overlain by the Paleozoic sedimentary cover. The Paleozoic rock succession, exposed in most parts of the mapped area, consists of seven formations (Fig.2); namely: Sarabit El Khadim, Abu Hamata, Adediya, Um Bogma, El Hashash, Magharet El Miah and Abu Zarab respectively.

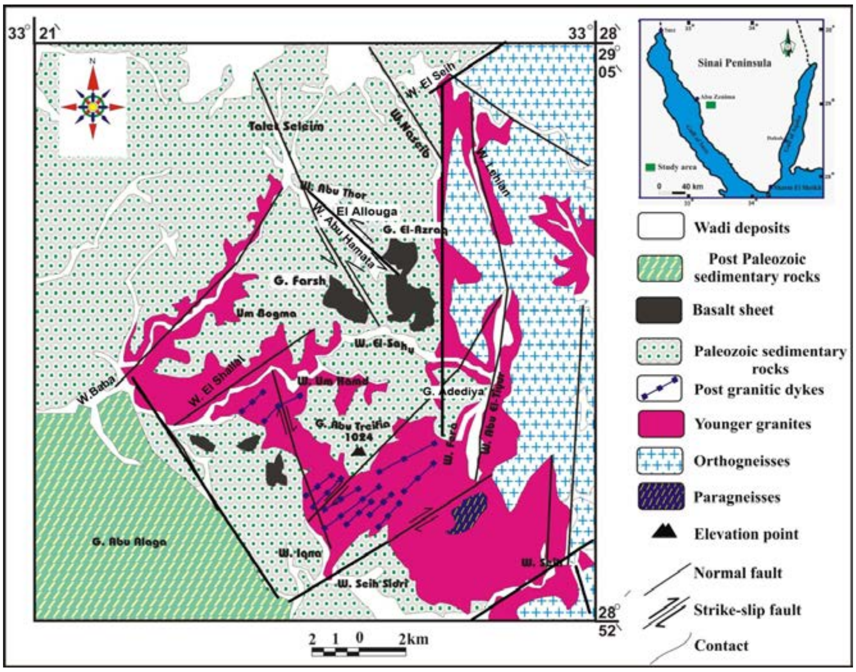

Figure-1: Location and geologic maps of Wadi El Sahu area, modified after Alshami, (2003).

ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

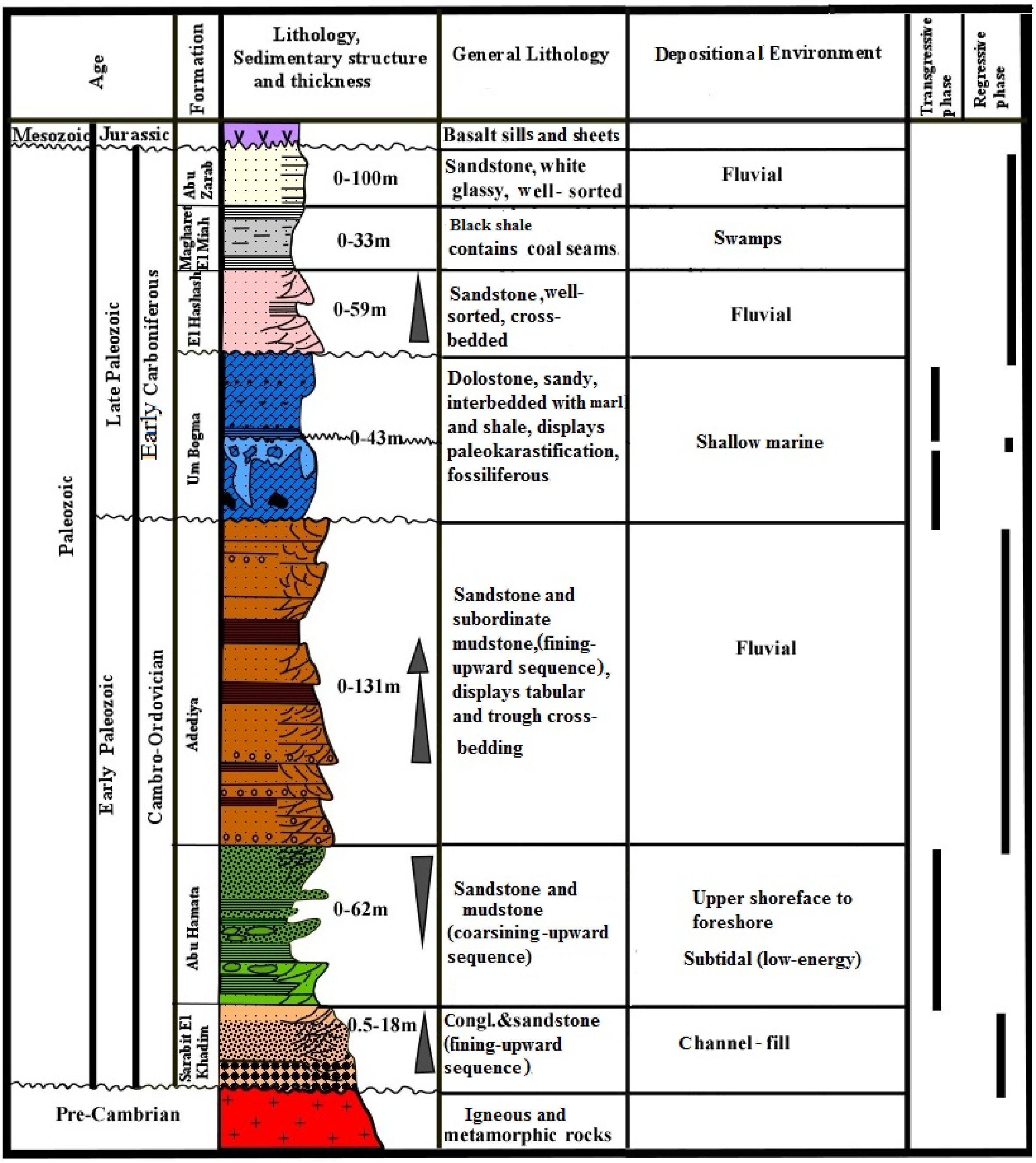

Figure-2: Lithostratigraphic section of southwestern Sinai after Aita, (1996). Thicknesses are not to scale**.**

Sarabit El Khadim Formation

Sarabit El Khadim Formation unconformably overlies the basement rocks in the studied area (Fig.3). The thickness of this formation varies laterally and reaches (~18m) at its type locality (G. Sarabit El Khadim). The formation is composed mainly of thick, cross-bedded sandstones which are medium-grained and contain intercalations of conglomeratic and pebbly sandstones. The pinkish to brownish color is dominant due to the abundance of iron and manganese oxides that occur as batches or bands.

Abu Hamata Formation

Abu Hamata Formation conformably overlies Sarabit El Khadim Formation. This formation has a maximum thickness (~62m) at its type locality (G. Abu Hamata). It consists mainly of two members, the lower member is characterized by reddish color and composed of sandstone, siltstone and fissile shale, while the upper member has greenish color which can be used as a marker horizon in the field and composed of fissile greenish shale, siltstone and very fine-grained sandstone (Fig.4).

Adediya Formation

Adediya Formation conformably overlies Abu Hamata Formation and unconformably underlies Um Bogma Formation. This formation has a maximum thickness (~131m) at its type locality (G. Adediya).

Adediya Formation consists of fine-to coarse-grained sandstones containing thin intercalations of shales and ferruginous siltstones (Fig.5A). The uppermost part of this formation is highly ferruginated and shows signs of paleosol. Different types of cross bedding are displayed by the Adediya sandstone beds (Figs.5B&C). The topmost part of the rock unit has abnormally high radioactivity.

Um Bogma Formation

Um Bogma Formation unconformably overlies Adediya Formation and unconformably underlies El Hashash Formation. The maximum thickness of this formation (~43m) is recorded at its type locality (G. Um Bogma).

The Lower member of Um Bogma Formation is represented in the field as fossiliferous dolostone with manganese lenses overlain by ferruginous siltstone (Fig.6A). The Middle member is represented by marl interbedded with dolostone and overlain by the Upper member which is represented by dolostone interbedded with siltstone and claystone (Fig.6B). This formation is characterized by dominance of black organic matter filling the fissures (Fig.7A). It is also present as thin layer lining the cavities in ferruginous siltstone; marked by presence of carbonate and associated with anomalous radioactivity (Fig.7B).

El-Hashash Formation

El Hashash Formation unconformably overlies Um Bogma Formation. The type section is located at El-Hashash area, western side of Wadi El Sahu, where it attains (~59m) thick (Soliman and Abu El Fetouh, 1969). It is overlain by Magharet El Miah and Abu Zarab Formations (Fig.8). The rock unit consists of brownish cross-laminated sandstone beds intercalated at the base with thin shale and siltstone beds. Ripple marks are observed in this formation (Fig.9).

Magharet El Miah Formation

It conformably overlies El Hashash Formation (Fig.8), easily identified in the field by its dark appearance. The formation is relatively thick (~33m) and recorded at its type locality (Magharet El Miah area). It is composed of shale, siltstone, sandstone, kaolin, clay and carbonaceous shale and characterized by presence of plant remains or coal seems which contain rare earth elements. El Aassy et al., (2006) considered the carbonaceous shale and thin coal seams as low-grade resources for REEs. Kora (1984) and Temraz (2005) suggested a fluvial origin for these carbonaceous shales.

Abu Zarab Formation

It conformably overlies Magharet El Miah Formation (Fig.8) and acquires a thickness of ~26m at its type locality (Abu Zarab area), while it is ~100m thick at El Hashash locality (Soliman and Abu El Fetouh, 1969) and (~93m) thick in G. Homiyer (El Aassy et al., 1997). This formation consists mainly of white sandstone (known as glass sand) and different grades of brown sandstones containing grayish and black shale and siltstone interbeds. The rocks are intruded by basaltic sills where their thermal effects changed the sandstone along their contacts to quartzite.

Figure-3: Photograph showing Sarabit El Khadim Formation which unconformably overlies the basement rocks, Wadi El Sahu area.

Figure-4: Photograph showing Abu Hamata Formation with reddish and greenish members overlain by Adediya Formation, Wadi El Sahu area.

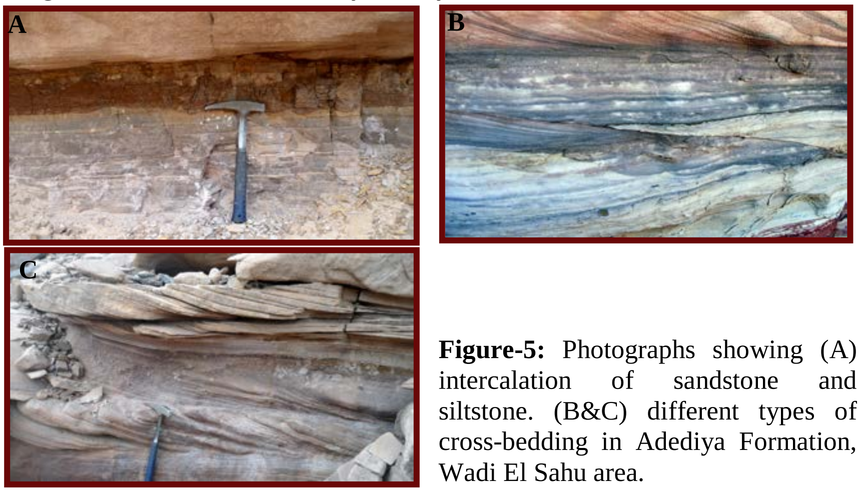

Figure-5: Photographs showing (A) intercalation of sandstone and siltstone. (B&C) different types of cross-bedding in Adediya Formation, Wadi El Sahu area.

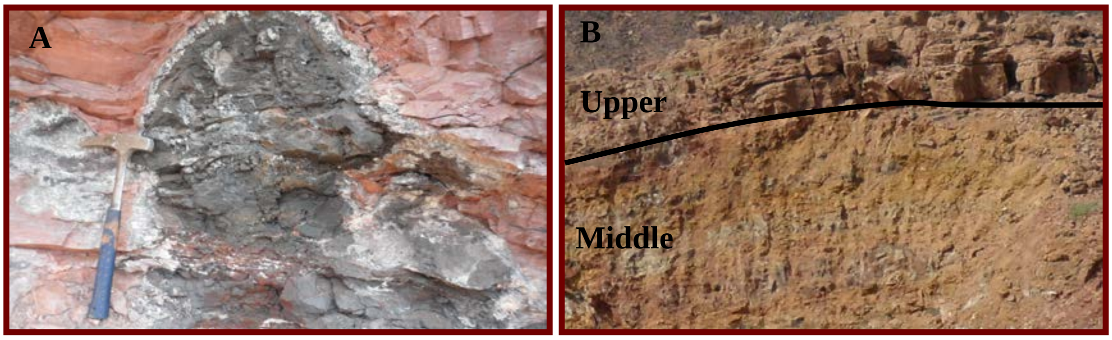

Figure-6: Photographs showing Um Bogma Formation at Wadi El Sahu area. (A),Lower member with lense of Mn; overlain by ferruginous siltstone.(B), Middle and Upper members of Um Bogma Formation.

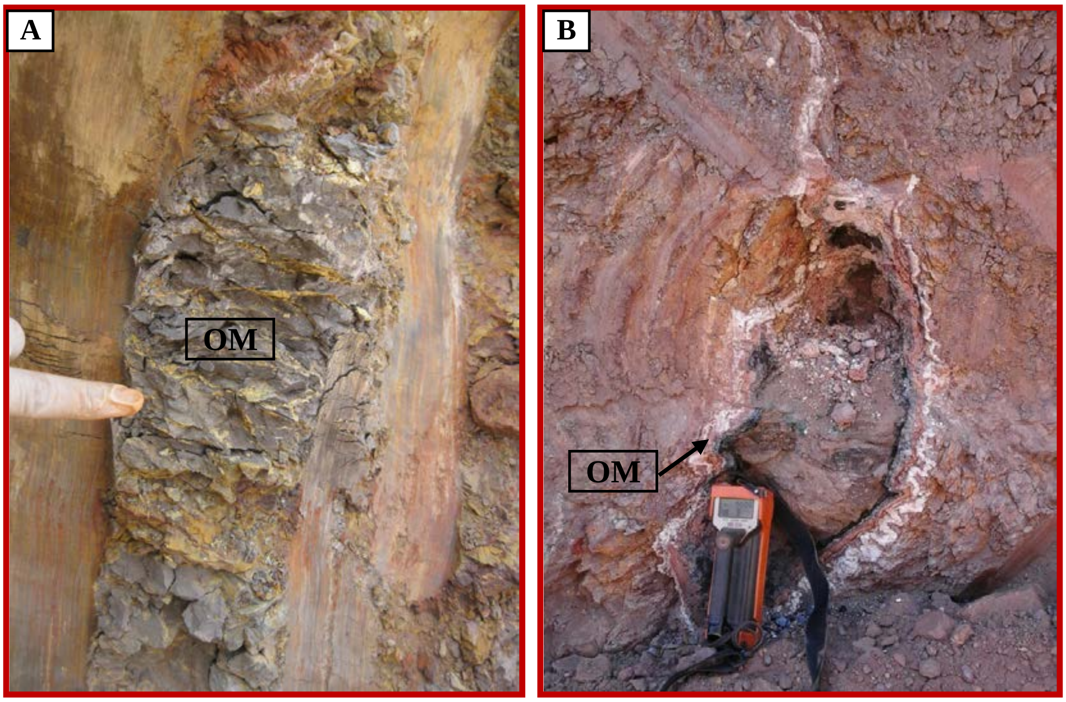

Figure-7: Photographs showing black organic matter (OM) (A) filling fissure in Um Bogma shale and (B) lining cavity in Um Bogma ferruginous siltstone.

Figure-8: Photograph showing (A) El Hashash, (B) Magharet El Miah and (C) Abu Zarab Formations, Wadi El Sahu area.

Figure-9: Photograph showing ripple marks in sandstone of El Hashash Formation.

The Paleozoic rocks in the studied area are dissected by several normal faults having N-S, NNW-SSE and NW-SE trends as well as strike-slip faults with NW-SE and NE-SW trends; Alshami (2003).

Chemical characteristics

A chemical comparison is preformed among the studied Paleozoic rocks based on their contents of major oxides, trace and rare earth elements. The samples were collected from sandstone beds representing Paleozoic sedimentary rocks (seven samples) away from hot radioactive spots at both of El Allouga and Abu Thor localities that contain huge number of secondary uranium minerals recorded by many authors (Dabbour and Mahdy, 1988; Amer, 1993; El Agami, 1996; Abdel Monem et al., 1997; Abu Bakr, 1997; Amer, 1997; Alshami, 2003 and Bishr, 2015). This is also reported by NMA, (1999b) through spectrometric filled-color contour map of the apparent surface eU concentration of Abu Zeneima-Al Tur area revealing that the highest eU concentration falls in El Allouga and Abu Thor localities (Fig.10). In addition to the seven samples, another two samples having special characteristics where they are mainly organic matters hosted in Um Bogma Formation were collected from El Allouga locality; named H1;sampled from deep seated part about 5 meters from the exposed surface and H4; sampled from exposed surface. The prepared samples were analyzed in the ACME Lab of Vancouver in Canada by using the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The analytical results of major oxides, trace and rare earth elements are given in table-1.

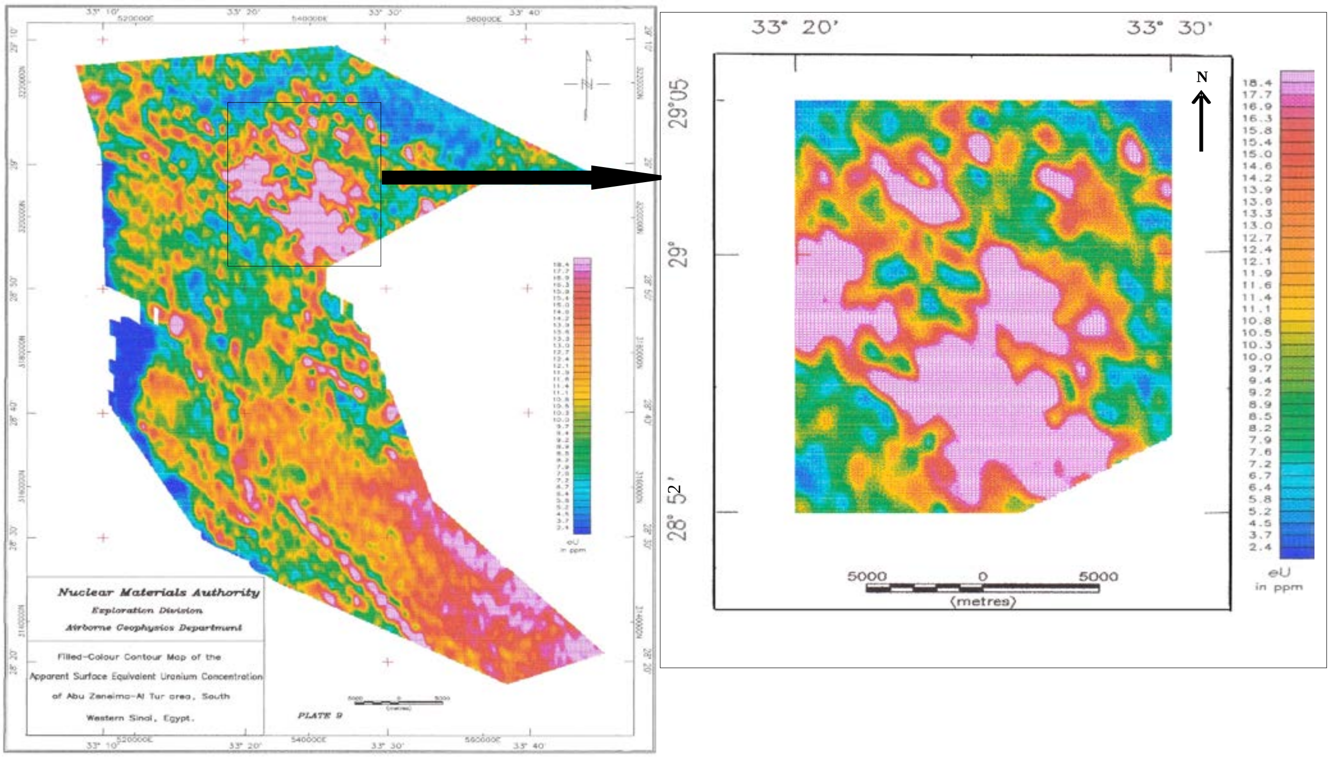

Figure-10: Spectrometric filled-color contour map of the apparent surface eU concentration of the studied area, modified after NMA, (1999).

Table-1: Major oxides (%), trace and rare earth elements (ppm) for the studied sandstone in the seven formations and organic matters represented by H1 &H4.

	Sarabit El Khadim Fm.	Abu Hamata Fm.	Adedyia Fm.	Um Bogma Fm.	H1	H4	El Hashash Fm.	Magharet El Miah Fm.	Abu Zarab Fm.
Oxides (%)									
SiO_2	92.69	72.09	79.47	33.82	4.81	0.57	64.47	76.34	98.45
Al_2O_3	3.84	11.49	5.39	7.5	6.27	2.32	3.04	10.79	0.44
TiO_2	0.1	0.54	0.22	0.43	0.18	0.15	0.16	0.87	0.03
Fe_2O_3	0.23	4.43	10.07	37.3	6.56	3.06	21.26	0.9	0.1
MgO	0.08	0.5	0.12	2.74	0.65	15.19	0.13	0.13	0.03
MnO	0.03	1.3	0.05	1.3	1.3	0.36	1.3	0.01	0.003
CaO	0.6	0.74	0.7	4.3	0.62	22.33	2.41	1.26	0.31
Na_2O	0.04	0.18	0.8	0.16	0.91	0.04	0.16	0.28	0.03
K_2O	0.31	3.19	0.11	0.48	0.54	0.31	0.1	0.36	0.02
P_2O_5	0.04	0.15	0.32	0.25	0.03	0.03	0.1	0.05	0.01
SO_3	0.2	0.62	0.38	0.22	0.3	5.72	2.47	1.67	0.1
L.O.I	1.84	4.77	3.09	12.8	78.83	49.92	4.4	7.37	0.48
Total	100	100	100	100	100	100	100	100	100
Total Alk.	0.35	3.37	0.91	0.64	1.45	0.35	0.26	0.64	0.05
Trace elements (ppm)									
V	15	65	88	324	112	64	105	161	9
Cr	3	28	45	249	82	61	32	56	1
Co	0.8	19.4	10.3	85.7	4000	807	64	3.7	1.4
Ni	2.4	21	23.7	179.1	1702.8	526.5	45.4	10.8	3.6
Cu	16.36	68.4	25.03	470.44	10000	10000	953.58	345.38	15.56
Zn	21.3	179.2	104.2	3108.5	1951.5	1171.5	394.3	44.6	28.2
Ga	5.61	17.07	9.05	16.69	6.92	3.02	5.32	20.78	0.45
As	1.5	6.6	20.4	121.1	61.5	54.2	34.3	13.6	0.9
Rb	14.6	100.8	3.6	19.5	18.4	11.3	3.7	12.4	0.8
Sr	224	334	439	460	131	63	259	197	22
Y	12.4	23.3	1169.9	904	112.9	16.3	294	37	2.9
Zr	76.8	104.8	53.8	136.6	77.7	43.7	73.4	276.8	35.6
Nb	5.14	11.63	7.15	26.59	10.73	5.8	7.18	40.68	1.58
Ba	1406	1633	123	2310	522	27	118	146	25
Pb	16.59	499.14	124.14	634.26	87.08	1559.96	402.11	230.24	1.99
U	2.9	5.3	57.8	162.7	3321.3	19.5	87.4	52.6	1.9
Th	7.9	13.3	3.6	10.7	9	4	3.7	14.5	0.8
Rare Earth elements (ppm)									
La	9.6	30.8	22.6	90	32.9	20.8	23.9	47	6.1
Ce	21.98	65.32	47.52	149.52	77.06	35.26	44.94	97.78	12.64
Pr	3.1	7.4	6.5	23.7	9.8	5.1	6.5	12.5	1.5
Nd	12.8	26.7	34.8	102	51.1	19.8	36.7	48.2	5.3
Sm	3.8	5.3	24.1	25.4	22.3	3.6	12.2	9.4	0.9
Eu	0.2	1	8.2	5.5	4.8	0.7	3.2	1.6	0.1
Gd	3.7	4.8	87	52.3	22.4	3.6	27.7	7.6	0.6
Tb	0.4	0.8	22	15.3	4.6	0.5	6.5	1.2	0.1
Dy	2.3	4.5	152	131.7	26.1	3.1	45.4	7.6	0.3
Ho	0.4	0.8	41	33.1	4.9	0.6	10.9	1.5	0.1
Er	1.1	2.7	103.6	100.8	14.3	1.5	36	4.5	0.2
Tm	0.2	0.3	15.8	14.3	2.3	0.2	4.7	0.6	0.1
Yb	1.5	2.3	76.7	82.9	14.2	1.4	26.8	4.1	0.2
Lu	0.2	0.3	11.2	11.7	1.9	0.2	4	0.6	0.1
∑LREE	51.48	136.52	143.72	396.12	197.96	85.26	127.44	216.48	26.54
∑HREE	9.8	16.5	509.3	442.1	90.7	11.1	162	27.7	1.7
∑REE	61.28	153.2	653.02	838.22	288.66	96.36	289.44	244.18	28.24

Depending on the chemical analyses of trace and rare earth elements of the analyzed samples, the Paleozoic rocks are classified into three groups as following:

Group 1: Sarabit El Khadim and Abu Zarab Formations.

Group 2: Abu Hamata, Adediya, El Hashash and Magharet El Miah Formations.

Subgroup 2.1: Abu Hamata and Magharet El Miah Formations.

Subgroup 2.2: Adediya and El Hashash Formations.

Group 3: Um Bogma Formation and the organic matter samples (H1&H4).

Subgroup 3.1: Um Bogma Formation.

Subgroup 3.2: The organic matter samples (H1&H4).

The comparisons of major oxides, trace and rare earth elements of the three groups are given in tables 2, 3 and 4 respectively.

Table-2: Comparison of major oxides.

Major oxides	Group 1	Group 2		Group 3	
		Subgroup 2.1	Subgroup 2.2	Subgroup 3.1	Subgroup 3.2
SiO_2% Mean	92.96-98.45 95.71	72.09-76.34 74.23	64.47-79.47 71.97	33.82	0.57-4.81 2.69
Al_2O_3% Mean	0.44-3.84 2.14	10.79-11.49 11.14	3.04-5.39 4.22	7.5	2.32-6.27 4.30
TiO_2% Mean	0.03-0.1 0.07	0.54-0.87 0.71	0.16-0.22 0.19	0.43	0.15-0.18 0.17
Fe_2O_3 % Mean	0.1-0.23 0.17	0.9-4.43 2.67	10.07-21.26 15.67	37.3	3.06-6.56 4.81
MgO% Mean	0.03-0.08 0.06	0.13-0.5 0.32	0.12-0.13 0.13	2.74	0.65-15.19 7.92
MnO% Mean	0.003-0.03 0.02	0.01-1.3 0.66	0.05-1.3 0.68	1.3	0.36-1.3 0.83
CaO% Mean	0.31-0.6 0.91	0.74-1.26 1	0.7-2.4 1.55	4.3	0.62-22.33 11.48
Total alk.% Mean	0.05-0.35 0.2	0.64-3.37 2.01	0.26-0.91 0.59	0.64	0.35-1.45 0.9
P_2O_5% Mean	0.01-0.04 0.03	0.05-0.15 0.1	0.1-0.32 0.21	0.25	0.03
SO_3% Mean	0.1-0.2 0.15	0.62-1.67 1.15	0.38-2.47 1.43	0.22	0.3-5.72 3.01
L.O.I.% Mean	0.48-1.84 1.16	1.84-7.37 4.61	3.09-4.4 3.75	12.8	78.83-49.92 64.38

Table-3: Comparison of trace elements.

Trace elements	Group 1	Group 2		Group 3	
		Subgroup 2.1	Subgroup 2.2	Subgroup 3.1	Subgroup 3.2
V **Mean**	9-15 12	65-161 113	88-105 96.5	324	64.112 88
Cr **Mean**	1-3 2	28-56 42	32-45 38.5	2.49	61-82 71.5
Co **Mean**	0.8-1.4 1.1	3.7-19.4 11.55	10.3-64 37.15	85.7	807-4000 2403.5
Ni **Mean**	2.4-3.6 3	10.8-21 15.9	23.7-45.4 34.55	179.1	526.5-1702.8 1114.65
Cu **Mean**	15.56-16.36 15.96	68.4-345.38 206.89	25.03-953.58 489.31	470.44	10000
Zn **Mean**	21.3-28.2 24.75	44.6-179.2 111.9	104.2-394.3 249.25	3108.5	1171.5-1951.5 1561.5
Ga **Mean**	0.45-5.61 6.06	17.07-20.78 18.93	5.32-9.05 7.19	16.69	3.02-6.92 4.97
As **Mean**	0.9-1.5 1.2	6.6-13.6 10.1	20.4-34.3 27.35	121.1	54.2-61.5 57.85
Rb **Mean**	0.8-14.6 7.7	12.4-100.8 56.6	3.6-3.7 3.65	19.5	11.3-18.4 14.85
Sr **Mean**	22-224 123	197-334 265.5	259-439 349	460	63-131 97
Y **Mean**	2.9-12.4 7.65	23.3-37 30.15	294-1169.9 731.95	904	16.3-112.9 64.6
Zr **Mean**	35.6-76.8 56.2	104.8-276.8 190.8	53.8-73.4 63.6	136.6	43.7-77.7 60.7
Nb **Mean**	1.58-5.14 3.36	11.63-40.68 26.16	7.15-7.18 7.17	26.59	5.8-10.73 16.53
Ba **Mean**	25-1406 715.5	146-1633 889.5	118-123 120.5	2310	27-522 274.5
Pb **Mean**	1.99-16.59 9.29	230.24-499.14 364.69	124.14-402.11 263.13	634.26	87.08-1559.96 823.52
U **Mean**	1.9-2.9 2.4	5.3-52.6 28.95	57.8-87.4 72.6	162.7	19.5-3321.3 1670.4
Th **Mean**	0.8-7.9 4.35	13.3-14.5 13.9	3.6-3.7 3.65	10.7	4-9 6.5

Table-4: Comparison of rare earth elements.

Rare earth elements	Group 1	Group 2		Group 3	
		Subgroup 2.1	Subgroup 2.2	Subgroup 3.1	Subgroup 3.2
La **Mean**	6.1-9.6 7.85	30.8-47 38.9	22.6-23.9 23.25	90	20.8-32.9 26.85
Ce **Mean**	12.64-21.98 17.31	65.32-97.78 81.55	44.94-47.52 46.23	149.52	35.26-77.06 56.16
Pr **Mean**	1.5-3.1 2.3	7.4-12.5 9.95	6.5	23.7	5.1-9.8 7.45
Nd **Mean**	5.3-12.8 9.05	26.7-48.2 37.45	34.8-36.7 35.75	102	19.8-51.1 35.45
Sm **Mean**	0.9-3.8 2.35	5.3-9.4 14.7	12.2-24.1 18.15	25.4	3.6-22.3 12.95
Eu **Mean**	0.1-0.2 0.15	1-1.6 1.3	3.2-8.2 5.7	5.5	0.7-4.8 2.75
Gd **Mean**	0.6-3.7 2.15	4.8-7.6 6.2	27.7-87 57.35	52.3	3.6-22.4 13
Tb **Mean**	0.1-0.4 0.25	0.8-1.2 1	6.5-22 14.25	15.3	0.5-4.6 2.55
Dy **Mean**	0.3-2.3 1.3	4.5-7.6 6.05	45.4-152 98.7	131.7	3.1-26.1 14.6
Ho **Mean**	0.1-0.4 0.25	0.8-1.5 1.15	10.9-41 25.95	33.1	0.6-4.9 2.75
Er **Mean**	0.2-1.1 0.65	2.7-4.5 3.6	36-103.6 69.8	100.8	1.5-14.3 7.9
Tm **Mean**	0.1-0.2 0.15	0.3-0.6 0.45	4.7-15.8 10.25	14.3	0.2-2.3 1.25
Yb **Mean**	0.2-1.5 1.7	2.3-4.1 3.2	26.8-76.7 51.75	82.9	1.4-14.2 7.8
Lu **Mean**	0.1-0.2 0.15	0.3-0.6 0.45	4-11.2 7.6	11.7	0.2-1.9 1.05
∑LREE **Mean**	26.54-51.48 39.01	136.52-216.48 176.5	127.44-143.72 135.58	396.12	85.26-197.96 141.61
∑HREE **Mean**	1.7-9.8 5.75	16.5-27.7 22.1	162-509.3 335.65	442.1	11.1-90.7 50.9
∑REE **Mean**	28.24-61.28 44.76	153.2-244.18 198.69	289.44-653.02 471.23	838.22	96.36-288.66 192.51

Comparison of major oxides in the different groups:

The average of SiO_2% in the first group is 95.71% whereas it ranges from 71.97% to 74.23% in the second group and reaches to 33.82% in Um Bogma Formation of the third group; to be about 2.69% in the organic asphaltic matter of the same formation. The average of Al_2O_3% in the first group is 2.14% whereas it ranges from 4.22% to 11.14% in the second group and reaches to 7.5% in Um Bogma Formation of the third group; to be about 4.3% in the organic asphaltic matter of the same formation. The average of Fe_2O_3% in the first group is 0.17% whereas it ranges from 2.67% to 15.67% in the second group and reaches to 37.3% in Um Bogma Formation of the third group; to be about 4.81% in the organic asphaltic matter of the same formation. The average of MgO% in the first group is 0.06% whereas it ranges from 0.13% to 0.32% in the second group and reaches to 2.74% in Um Bogma Formation of the third group; to be about 7.92% in the organic asphaltic matter of the same formation. The average of CaO% in the first group is 0.91% whereas it ranges from 1% to 1.55% in the second group and reaches to 4.3% in Um Bogma Formation of the third group; to be about 11.48% in the organic asphaltic matter of the same formation. The average of total alkalis% in the first group is 0.2% whereas it ranges from 0.59% to 2.01% in the second group and reaches to 0.64% in Um Bogma Formation of the third group; to be about 0.9% in the organic asphaltic matter of the same formation. The average of L.O.I. % in the first group is 1.16% whereas it ranges from 3.75% to 4.61% in the second group and reaches to 12.8% in Um Bogma Formation of the third group; to be about 64.38% in the organic asphaltic matter of the same formation.

Comparison of trace elements in different groups:

The average of V content is 12 ppm in the first group whereas it ranges from 96.5 ppm to 113 ppm in the second group and reaches to 324 ppm in Um Bogma Formation but it equals to 88 ppm in the organic asphaltic matter of the same formation. The average of Cr content is 2 ppm in the first group and ranges from 38.5 ppm to 42 ppm in the second group whereas it reaches to 2.49 ppm in Um Bogma Formation and equals to 71.5 ppm in the organic asphaltic matter of the same formation. The average of Co content is 1.1 ppm in the first group but it ranges from 11.55 ppm to 37.15 ppm in the second group whereas it reaches to 85.7 ppm in Um Bogma Formation and equals to 2403.5 ppm in the organic asphaltic matter of the same formation. The average of Ni content is 3 ppm in the first group but it ranges from 15.9 ppm to 34.55 ppm in the second group whereas it reaches to 179.1 ppm in Um Bogma Formation and equals to 1114.65 ppm in the organic asphaltic matter of the same formation. The average of Cu content is 15.96 ppm in the first group whereas it ranges from 206.89 ppm to 489.31 ppm in the second group but it reaches to 470.44 ppm in Um Bogma Formation and equals to 10000 ppm in the organic asphaltic matter of the same formation. The average of Zn content is 24.75 ppm in the first group whereas it ranges from 111.9 ppm to 249.25 ppm in the second group but it reaches to 3108.5 ppm in Um Bogma Formation and equals to 1561.5 ppm in the organic asphaltic matter of the same formation. The average of As content is 1.2 ppm in the first group whereas it ranges from 10.1 ppm to 27.35 ppm in the second group but it reaches to 121.1 ppm in Um Bogma Formation and equals to 57.85 ppm in the organic asphaltic matter of the same formation. The average of Y content is 7.65 ppm in the first group whereas it ranges from 30.15 ppm to 731.95 ppm in the second group but it reaches to 904 ppm in Um Bogma Formation and equals to 64.6 ppm in the organic asphaltic matter of the same formation. The average of Zr content is 56.2 ppm in the first group whereas it ranges from 63.6 ppm to 190.8 ppm in the second group but it reaches to 136.6 ppm in Um Bogma Formation and equals to 60.7 ppm in the organic asphaltic matter of the same formation. The average of Ba content is 715.5 ppm in the first group whereas it ranges from 120.5 ppm to 889.5 ppm in the second group but it reaches to 2310 ppm in Um Bogma Formation and equals to 274.5 ppm in the organic asphaltic matter of the same formation. The average of Pb content is 9.29 ppm in the first group whereas it ranges from 263.13 ppm to 364.69 ppm in the second group but it reaches to 634.26 ppm in Um Bogma Formation and equals to 823.52 ppm in the organic asphaltic matter of the same formation. The average of U content is 2.4 ppm in the first group whereas it ranges from 28.95 ppm to 72.6 ppm in the second group but it reaches to 162.7 ppm in Um Bogma Formation and equals to 1670.4 ppm in the organic asphaltic matter of the same formation. The average of Th content is 4.35 ppm in the first group whereas it ranges from 3.65 ppm to 13.9 ppm in the second group but it reaches to 10.7 ppm in Um Bogma Formation and equals to 6.5 ppm in the organic asphaltic matter of the same formation.

The trace elements of the first group (Sarabit El Khadim and Abu Zarab sandstones) are normalized by continental crust (Weaver and Tarney 1984). Sarabit El Khadim sandstone resembles Abu zarab sandstone for V, Cr, Co, Ni, Cu, Zn and As concentrations, while the other elements are higher in Sarabit El Khadim sandstone if compared with the corresponding of Abu Zarab sandstone. Sarabit El Khadim sandstone is characterized by radioelements concentrations higher than the continental crust (more than the unity), (Fig.11).

The trace elements of the second group (sandstones of Abu Hamata, Adediya, El Hashash, and Magharet El Miah Formations) are graphically plotted as spider diagram (Fig.12). The four spiders are nearly identical characterized by general depletion of V, Cr, Co. Ni, Zn, Ga, Rb, Sr, Zr, Nb and Ba. On the other hand, they are enriched by Cu, As, Y, Pb and U. it is clear that, Adediya sandstone is higher than the other sandstones of the above mentioned formations in Y content, while El Hashash sandstone is higher than the other sandstones of the above mentioned formations in U content. The Th content approaches the unity in the four sandstones.

The spider diagram of the trace elements of Um Bogma sandstone clarified that, it is enriched in most of the trace elements if compared with the corresponding values of the continental crust. One of the organic matter samples is enriched in most of trace elements and higher than Um Bogma sandstone for Co, Ni and U (3321.3 ppm). The other organic matter sample is depleted in most of the trace elements rather than the continental crust and enriched in Co, Ni, Cu, Zn, As, Pb and U. It is generally lower than the corresponding elements of Um Bogma except for Cu, Ni and Co (Fig.13).

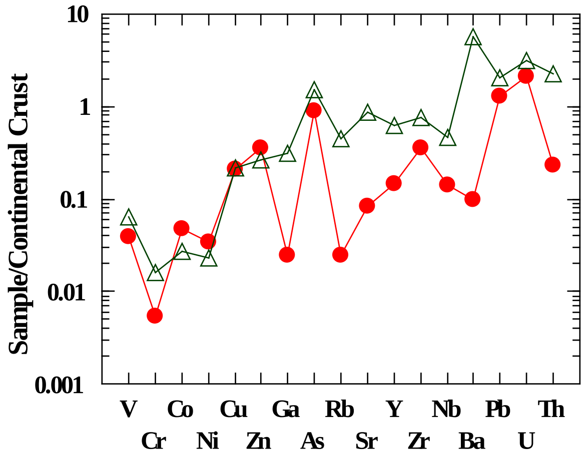

Figure-11: Continental crust-normalized trace elements for Sarabit El Khadim and Abu Zarab Formations (first group).

Sarabit El Khadim Fm. =△ and Abu Zarab Fm. =●

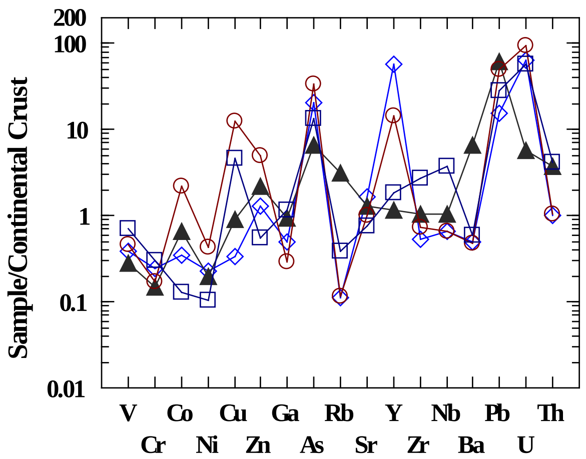

Figure-12: Continental crust-normalized trace elements for Abu Hamata, Adediya, El Hashash and Magharet El Miah Formations (second group).

Abu Hamata Fm. =▲ Adediya Fm. =◊

El Hashash Fm. = ○ Magharet El MiahFm. = □

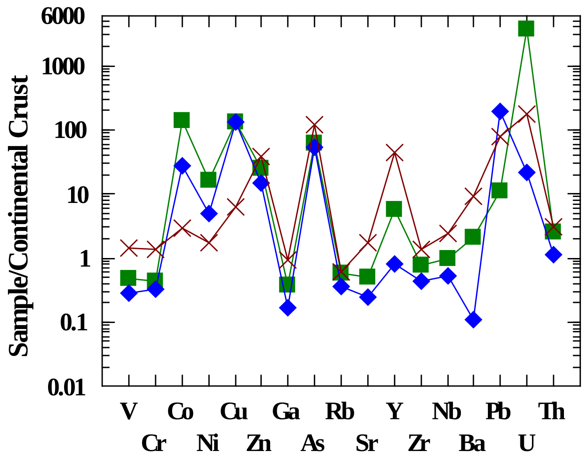

Figure-13: Continental crust-normalized trace elements for Um Bogma Formation and organic matter samples (third group).

Um Bogma Formation =× H1= ■ H4= ♦

Comparison of rare earth elements in different groups:

The average of ∑REE in the first group is 44.76 ppm with an average of ∑LREE and ∑HREE are 39.01 ppm and 5.75 ppm respectively. In the second group, the average of ∑REE ranges between 198.69 ppm to 471.23 ppm, while the average of ∑LREE ranges between 135.58 ppm to 176.5 ppm and the average of ∑HREE ranges between 22.1 ppm to 335.65 ppm. Um Bogma Formation exhibits an average of ∑REE= 838.22 ppm with an average of ∑LREE= 396.12 ppm and an average of ∑HREE= 442.1 ppm while the organic asphaltic matters of the same formation exhibit an average of ∑REE= 192.51 ppm with an average of ∑LREE= 141.61 ppm and an average of ∑HREE= 50.9 ppm.

Spiders of the rare earth elements established for the first group (Sarabit El Khadim and Abu Zarab sandstones) are identical with general increasing for Sarabit El Khadim sandstone. Both of them are depleted in most of the elements rather than the corresponding values of continental crust and characterized by negative Eu anomaly, (Fig.14).

The rare earth elements patterns of the second group (sandstones of Abu Hamata, Adediya, El Hashash, and Magharet El Miah Formations) are above the line of unity. They are nearly identical in LREE. On the other hand, HREE bifurcates into two subgroups. The first subgroup comprises Magharet El Miah and Abu Hamata sandstones approaching the line of unity, while the second subgroup comprising Adediya and El Hashash sandstones is strongly higher than the continental crust especially in HREEs (Fig. 15).

The rare earth elements of Um Bogma sandstone are characterized by noticeable enrichment for all elements especially HREE rather than LREE. The organic matter sample that shows high enrichment in trace elements is also enriched in rare earth elements (H1) and the sample that depleted in trace elements is also depleted in rare earth elements (H4) (Fig.16).

The above mentioned results and comparisons of major oxides, trace and rare earth elements for the three groups revealed that the first group comprises Sarabit El Khadim and Abu Zarab sandstones is the highest in silica contents(mean= 95.71%), while the subgroup comprises Abu Hamata and Magharet El Miah sandstone is the highest in Al_2O_3, TiO_2 and total alkalis. Um Bogma sandstone is characterized by higher Fe_2O_3 content rather than the mentioned groups, while the organic matter samples are the highest in L.O.I. and CaO contents.

The third group which comprises Um Bogma and organic matter samples is more enriched in most of trace elements contents except for Y which is higher in Adediya sandstone. It is clear that, the organic matter sample (H1) is more enriched in uranium content rather than the other mentioned groups. On the other hand, the organic matter sample (H4) is more enriched in Pb content which may suggest decay of uranium in this exposed sample.

The REEs are more concentrated in Um Bogma sandstone, while Adediya sandstone is slightly higher in HREEs than Um Bogma sandstone.

The comparison between average of some trace elements in the sandstone beds in the six formations (Sarabit El Khadim, Abu Hamata, Adedyia, El Hashash, Magharet El Miah and Abu Zarab), Um Bogma Formation and the organic matter samples indicate that, the majority of trace elements concentrations are highly enriched in Um Bogma Formation and organic matter samples (especially in H1) more than the average formations. It is clear to state that, the organic matter which is represented by H1 is highly enriched in U, Cu, Co and Ni more than the Um Bogma Formation (Fig.17).

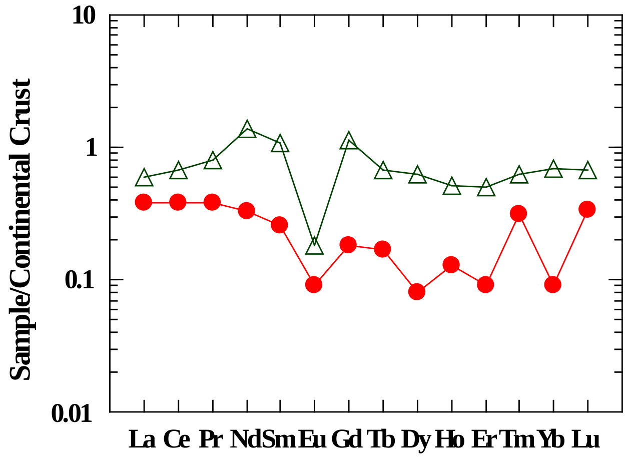

Figure-14: Continental crust-normalized rare earth elements for Sarabit El Khadim and Abu Zarab Formations (first group). *Symbols as in Fig. 11*

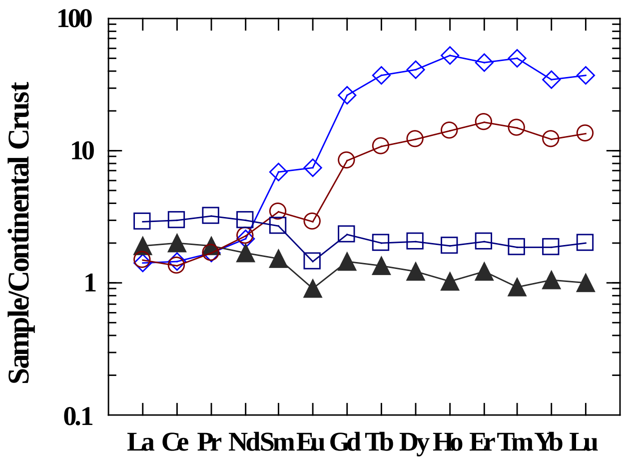

Figure-15: Continental crust-normalized rare earth elements for Abu Hamata, Adediya, El Hashash and Magharet El Miah Formations (second group).
Symbols as in Fig.12

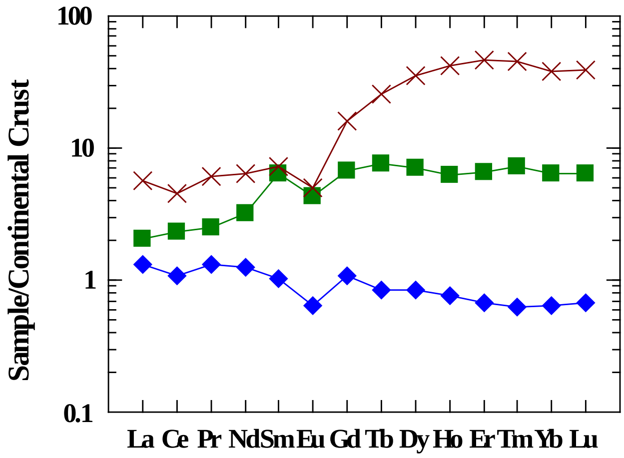

Figure-16: Continental crust-normalized trace elements for Um Bogma Formation and organic matter samples (third group). *Symbols as in Fig.13*

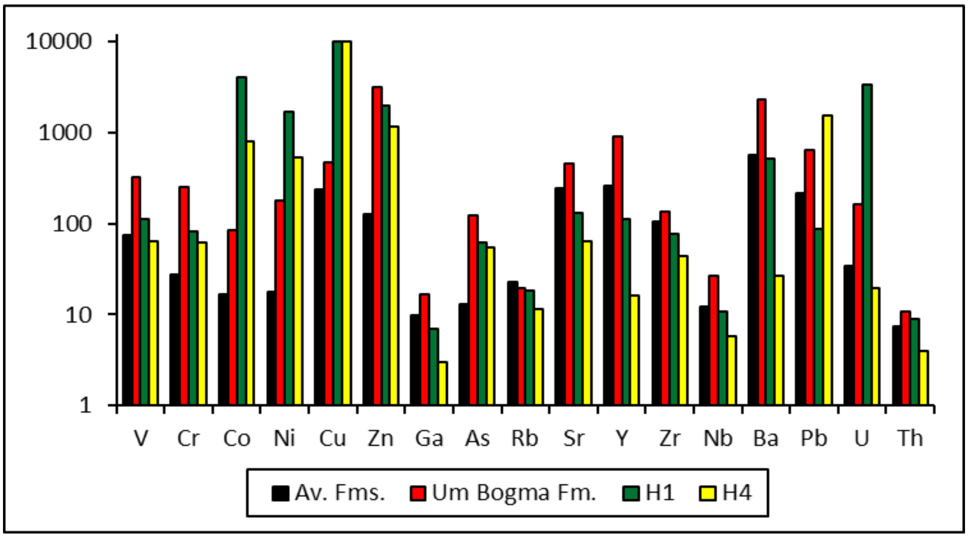

Figure-17: Bar diagram showing comparison between av. Formations, Um Bogma Fm. and organic matters versus trace elements.

Radiometric study

Thirty four samples representing all Paleozoic Formations in the studied area are collected in addition to two samples named H1 and H4, are prepared for the radiometric measurements (Table-5). In this stage, the rock samples were subjected to grinding in order to obtain crushed samples of about 0.5 mm grain size. The obtained samples were packed in plastic containers, tightly sealed and stored for thirty days to be ready for the radiometric measurements.

Bicron scintillation Detector NaI (TI) 76×76 mm (NMA Lab.) is used to determine equivalent uranium, equivalent thorium, radium (ppm) and potassium percents contents of the studied samples representing the different rock units.

The results of radiometrical analyses in addition to calculated ratios between these results are tabulated in table-5.

Table-5: Radioactivity measurement and ratios for the studied Paleozoic rocks.

Formation	Sample No.	eU (ppm)	eTh (ppm)	Ra (eU) (ppm)	K%	eTh/eU	eU/Ra	Uc	D-factor
Sarabit El Khadim	1	8.3	11.3	1.5	1.1	1.36	5.53	**2.9**	**0.35**
	2	9.2	13.1	2.7	1.6	1.42	3.41		
	3	7.2	16.2	3.2	1	2.25	2.25		
	Average	**8.23**	**13.53**	**2.47**	**1.23**	**1.68**	**3.73**		
Abu Hamata	4	8	5	4	4.03	0.63	3	**5.3**	**0.57**
	5	13	6	9	4.1	0.46	1.89		
	6	7	3	10	2.09	0.43	0.7		
	Average	**9.33**	**4.67**	**7.67**	**3.41**	**0.51**	**1.86**		
Adedyia	7	135	43	355	0.2	0.32	0.38	**57.8**	**0.77**
	8	87	32	244	0.32	0.37	0.36		
	9	76	29	251	0.3	0.38	0.3		
	10	35	13	235	0.35	0.37	0.15		
	11	41	15	185	0.1	0.37	0.22		
	Average	**74.8**	**26.4**	**254**	**0.25**	**0.37**	**0.28**		
Um Bogma	12	35	29	84	0.39	0.83	0.42	**162.7**	**1.42**
	13	79	12	70	2.95	0.15	1.13		
	14	125	34	248	0.1	0.27	0.5		
	15	397	147	535	0.2	0.37	0.74		
	16	151	23	350	1.1	0.15	0.43		
	17	122	18	49	0.29	0.15	2.49		
	18	95	40	98	0.1	0.42	0.97		
	19	120	35	158	0.9	0.29	0.76		
	20	83	8	37	0.35	0.1	2.24		
	21	42	6	25	0.29	0.14	1.68		
	22	11	19	15	0.8	1.73	0.73		
	Average	**114.6**	**33.7**	**151.7**	**0.68**	**0.42**	**1.1**		
	H1	**682**	**39**	**286**	**0**	**0.06**	**2.38**	**3321.3**	**4.87**
	H4	**16**	**4**	**10**	**0.16**	**0.25**	**1.6**	**19.5**	**1.22**
El Hashash	23	130	22	165	0.12	0.17	0.79	**87.4**	**1.19**
	24	112	33	203	0.5	0.29	0.55		
	25	58	27	180	2.3	0.47	0.32		
	26	27	18	45	1.4	0.67	0.6		
	27	39	16	61	0.8	0.41	0.64		
	Average	**73.2**	**23.2**	**130.8**	**1.02**	**0.4**	**0.58**		
Magharet El Miah	28	30	47	10.2	1.7	1.57	2.94	**52.6**	**1.79**
	29	23.8	37.9	9.4	1.3	1.59	2.53		
	30	22	25	7.1	0.7	1.14	3.1		
	31	42	50	14.5	1.4	1.19	2.9		
	Average	**29.45**	**39.9**	**10.28**	**1.28**	**1.37**	**2.87**		
Abu Zarab	32	5.2	6.3	2.1	0.1	1.21	2.48	**1.9**	**0.27**
	33	6.4	12	1.6	0.9	1.88	4.63		
	34	9.5	11	3.4	0.4	1.16	2.5		
	Average	**7.03**	**10.43**	**2.37**	**0.47**	**1.86**	**3.2**		

The above mentioned data revealed that Um Bogma Formation is characterized by high uranium content with an average 114.6 ppm reaching up to 397 ppm in the anomalous samples, while the average thorium content is 33.7 ppm with an average eTh/eU ratio of about 0.42. The two samples enriched in organic matters (H1&H4) are excluded from the average where H1 exhibits uranium content about 682 ppm, thorium content about 39 ppm and eTh/eU ratio of about 0.06. The other sample (H4) exhibits eU= 16 ppm, eTh= 4 ppm and eTh/eU ratio= 0.25.

Abu Bakr, (1997) applied α-particles tracing technique on separated black grains resemble asphaltic materials that is lighter than bromoform (2.8 gm cm^3); and strongly react with hydrogen peroxide. These grains were separated from the exposed sediments at El Allouga and Abu Thor localities belonging to Um Bogma Formation. These particles are organic materials most probably of hydrocarbon origin. These grains gave condense homogeneous to nonhomogeneous α-tracks (Fig. 18).

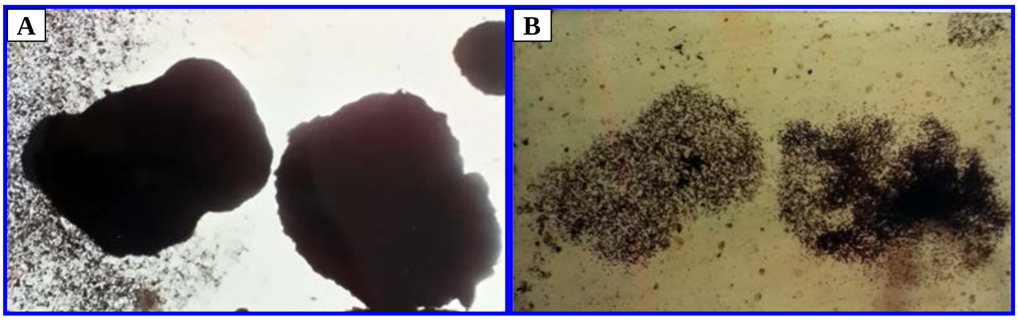

Figure-18: Microphotograph showing separated cluster particles of asphaltic material of Um Bogma Formation (A) and their α-tracks (B).

In Adedyia Formation, the average uranium content is 74.8 reaching up to 135 ppm in the anomalous samples, while the average thorium content is 26.4 ppm with an average eTh/eU ratio of about 0.37. In El Hashash Formation, the average uranium content is 73.2 ppm reaching up to 130 ppm in the anomalous samples, while the average thorium content is 23.2 ppm with an average eTh/eU ratio of about 0.4. In Magharet El Miah Formation, the average uranium content is 29.45 ppm, while the average thorium content is 39.9 ppm with an average eTh/eU ratio of about 1.37.

In Abu Hamata Formation, the average uranium content is 9.33 ppm reaching up to 13 ppm, while the average thorium content is 4.67 ppm with an average eTh/eU ratio of about 0.51. The average uranium content in Sarabit El Khadim Formation is 8.23 ppm reaching up to 9.2 ppm, while the average thorium content is 13.53 ppm with an average eTh/eU ratio of about 1.68. In Abu Zarab Formation, the average uranium content is 7.03 ppm reaching up to 9.5 ppm, while the average thorium content is 10.43 ppm with an average eTh/eU ratio of about 1.86.

The average of eU and eTh for the studied formations beside the two samples enriched in organic matters are represented graphically in figures 19&20 respectively. The two figures clarify that, the enriched organic matter sample (H1) is characterized by the highest uranium content, while Magharet El Miah Formation is characterized by the highest thorium content.

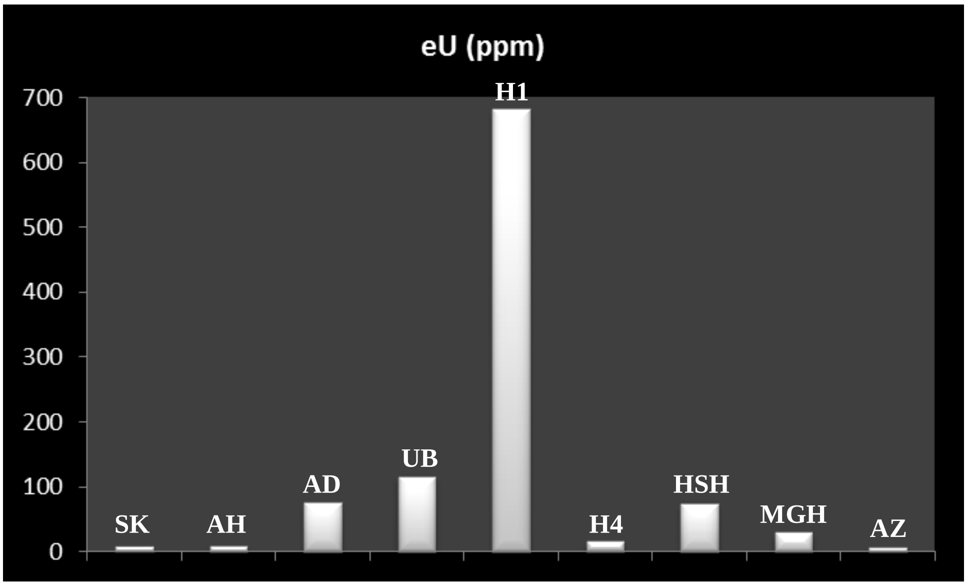

Figure-19: Bar diagram showing average content of eU for (SK) Sarabit El Khadim, (AH) Abu Hamata, (AD) Adediya, (UB) Um Bogma, (H1&H4) enriched organic matter samples, (HSH) El Hashash, (MGH) Magharet El Miah and (AZ) Abu Zarab Formations.

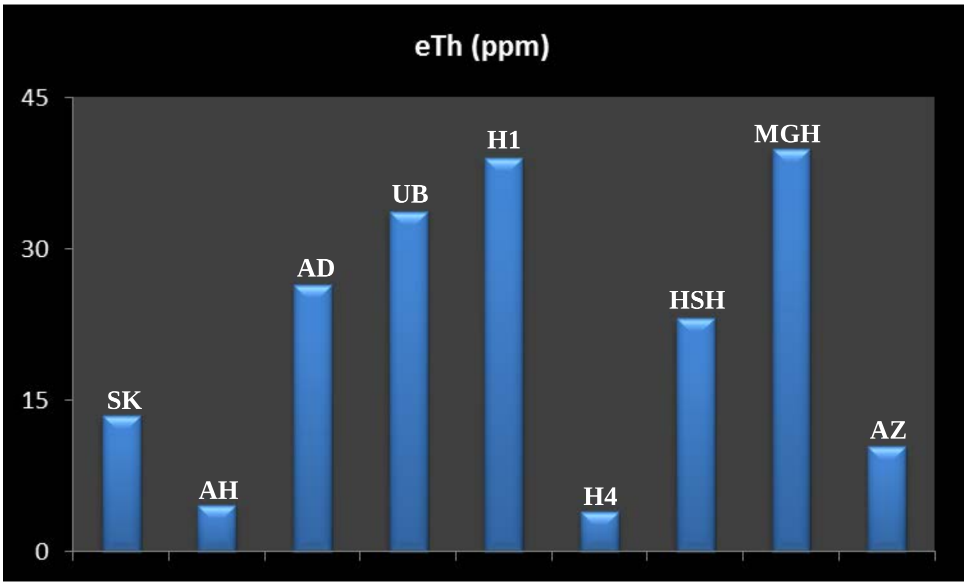

Figure-20: Bar diagram showing average content of eU for (SK) Sarabit El Khadim, (AH) Abu Hamata, (AD) Adediya, (UB) Um Bogma, (H1&H4) enriched organic matter samples, (HSH) El Hashash, (MGH) Magharet El Miah and (AZ) Abu Zarab Formations.

Radioactive Equilibrium

The radioactive equilibrium/disequilibrium study is considered as an essential part in the radiometric investigation of U-ore deposits and U-bearing rocks; it can be used as a tool for U-exploration processes. In nature, the equilibrium state is controlled by different geologic processes such as weathering, alteration, groundwater, meteoric water, circulating fluids through fractures and fault planes.

According to the chondritic value (3-3.5) for eTh/eU ratio stated by Rogers and Adams (1969), the eTh/eU ratios for the above mentioned formations beside the two samples enriched in organic matters clarify the addition of uranium content.

In the present study, the equilibrium/disequilibrium state was discussed through calculation both of the equilibrium factor (P) which is defined as: P = eU/Ra (Hussein, 1978 and El Galy, 2003) and D-factor (U_c/U_r) where U_c = chemically measured uranium and U_r = radiometrically measured uranium The equilibrium state is reached, if the eU/Ra and U_c/U_r ratios is equal to unity .

Um Bogma, Adedyia, El Hashash and Magharet El Miah Formations are characterized by disequilibrium state where Adedyia and El Hashash possess P-factor less than the unity (0.28 and 0.58 respectively) referring to high Ra (eU) content. On the other hand, Um Bogma and Magharet El Miah Formations and the samples enriched in organic matters (H1&H4) have P-factor more than the unity (1.1, 2.87, 2.38 and 1.6 respectively) referring to low Ra content.

Sarabit El Khadim, Abu Hamata and Abu Zarab Formations are characterized by disequilibrium state where the three formations have P-factor more than the unity (3.73, 1.86 and 3.2 respectively) referring to low Ra content.

Adedyia, Um Bogma, El Hashash and Magharet El Miah Formations are characterized by disequilibrium state where Adediya Formation possess D-factor (U_c/U_r) less than the unity (0.77) referring to loss of uranium content. On the other hand, Um Bogma, El Hashash and Magharet El Miah Formations and the organic matter samples (H1&H4) have D-factor more than the unity (1.42, 1.19, 1.79,4.87 and 1.22 respectively) referring to addition of uranium content.

Sarabit El Khadim, Abu Hamata and Abu Zarab Formations are characterized by disequilibrium state where the three formations have D-factor less than the unity (0.35, 0.57 and 0.27 respectively) referring to loss of uranium content.

Discussion

The chemical and radiometrical studies of the Paleozoic rocks revealed that most of radioactive, trace and REEs are enriched in Um Bogma Formation hosted the organic matters, while the top most part of Adediya Formation is enriched in HREE especially Y. Um Bogma Formation hosting the organic matters is the most responsible zone for radioactive mineralization in the studied area (U_c for Um Bogma Fm. =162.7 ppm and U_c for H1=3321.3ppm). The above mentioned results agree with the occurrence of secondary uranium mineralizations in Um Bogma Formation enriched with organic matters especially in El Allouga and Abu Thor localities recorded by many authors (Dabbour and Mahdy, 1988; Amer, 1993; El Agami, 1996; Abdel Monem et al., 1997; Abu Bakr, 1997; Amer, 1997; Alshami, 2003 and Bishr, 2015).

Abdelaziz, (2011) studied the gamma-ray spectral data covering the area of Southwestern Sinai, Egypt; and indicated the presence of characteristic normalized potassium and uranium anomalies above Belayiem petroleum oil fields. The result of his study showed positive correlation between radio-spectrometry favorable areas and the known oil and gas fields. These oil fields lie around the study area especially to west direction.

Gott et al., (1952), mentioned that uranium may be extracted to form metallo-organic compounds in petroleum where (Erickson et al., 1954) added that the asphalt like carbonaceous materials have been found closely associated with some of the uranium deposits.

Arthur et al., (1955) stated that the uranium and associated metals may be present in the petroleum as colloidal-sized impurities derived from the interstitial parts of the reservoir rocks, or they may be present as organometallic complexes soluble in the petroleum. If the metals occur as organometallic complexes, they probably concentrated in a surface-active fraction of petroleum which tends to adhere to the pore walls of the reservoir rock. Uranium has been redistributed and concentrated within the interstices of rocks through which petroleum has migrated or in which it has accumulated. The concentration and redistribution of uranium has been associated in time with structural and diagenetic events including recrystallization, solution, cementation, and adsorption of metalliferous surface-active fractions of migrating petroleum.

The lithologic nature of Um Bogma Formation played a very important role in the localization of the various mineralization of Mn-Fe, U and REEs. El Aassy et al., (1990) concluded that the Um Bogma region is highly tectonized and affected by different faulting trends represented by N-S, ENE-WSW, NE-SW and NNW-SSE. The effect of high tectonic event causes the seepage of crude oil through fractures and fissures. Um Bogma Formation is characterized by the presence of dolomite which may act as sealing for the seepage of crude oil except through fractures and fissures. The high thermal effect of the volcanicity evaporated the light hydrocarbons from the crude oil and remained the asphalt-like materials enriched in uranium and trace elements. The later on digenetic events play its rules in redistribution and concentration of uranium in association with trace and REEs. The presence of unconformity surface between Um Bogma and Adediya Formations represents a suitable place to form many kinds of secondary uranium mineralization as a result of redistribution of uranium and trace elements from the asphaltic materials.

The analyzed asphaltic samples show radio and trace elements signature comparable with the results of Erickson et al., (1954); which match well with our study case.

Abu Bakr, (1997) detected α-particles emitted from the organic matters occupying the fissures and interstices of the sediments exposed at El Allouga and Abu Thor localities and belong to Um Bogma Formation. The homogeneous to nonhomogeneous α-tracks indicate the solubility of uranium from the organic matters under supergene processes to form secondary uranium mineralization.

Gott and Erickson, (1952) stated that several sources have been postulated for the uranium in the sandstone ores, one of them is the migrating petroleum or solutions derived from petroleum source beds where crude oil has been suggested as a transporting medium for uranium.; that is agree with this interpretation.

Conclusion

The chemical and radiometrical studies of the Paleozoic rocks revealed that most of radioactive, trace and LREE are enriched in Um Bogma Formation hosted the organic matters, while the top most part of Adediya Formation is enriched in HREE especially Y. The hosted organic matter sample (H1) is enriched in most of trace elements and higher than Um Bogma Formation for Cu, Co, Ni and U (up to 3321 ppm).

In the present study, the organic matter hosted in the fissures and fractures as asphaltic materials in Um Bogma Formation may be due to the seepage of oil after the tectonic events where the volatiles evaporated. The evaporation was taken by the high thermal effects of the volcanicity leaving what so called asphaltic materials. These asphaltic materials contain high concentration of uranium that redistributed forming different secondary minerals. From the above discussion and conclusion, the high anomalous in the present study agrees with the concept of Gott and Erickson, 1952.

References

Abdel- Azeem, M., (2014): Genesis and Potentiality of Radioactive Minerals and Rare Metals in the Adediya Formation, Southwestern Sinai, Egypt. Ph.D. Thesis, Ain Shams University, Egypt. 2014.

Abdelaziz, A. M. S. (2011): The use of aero-gamma-ray spectrometric survey data, as a corroborative direct indicator for surface hydrocarbon occurences. J. Appl. Geophys., Vol. 10, No. 1, March 2011, pp: 37-49.

Abdel Monem, A. A., El Aassy, I. E., Hegab, O. A., El-Fayoumy, I. F. and El-Agami, N.L. (1997): Gibbsite, uranium and copper mineralization, Um Bogma area, Southwestern Sinai, Egypt. J. Sedimentology. Egypt Vol. 5, pp. 117-132.

Abu Bakr, M. A. (1997): Uranium mineralization associated with copper occurrences in Sinai, Egypt. Ph. D. Thesis, Faculty of Sciene, Ain Shams University. 202 P.

Abu El Hassan, M. M. and Baioumy, H. M. (2003): Origin of Carboniferous manganese bearing dolomite of the Um Bogma Formation, SW Sinai, Egypt. In: The Third International Conf. on the Geol. of Africa, Vol. 2, Assiut Univ., Egypt, pp. 307-319.

Ahmed, F. Y. (2003): Contribution to the crystal chemistry of the mineralized Paleozoic dolostone of Um Bogma, Southwestern Sinai, Egypt. J. Geol. Vol. 47 (1), pp. 527-540.

Aita, S. K. (1996): Geological, mineralogical and geochemical studies on some radioactive anomalies of the Paleozoic sediments of Um Bogma area, west central Sinai, Egypt. M. Sc. Thesis, Fac. Sci., Cairo Univ., 262p.

Alshami, A. S. (2003): Structural and lithologic controls of uranium and copper mineralization in Um Bogma environs, southwestern Sinai, Egypt, PhD Thesis, Fac. Sci., Mansoura Univ., Egypt, 134p.

Amer, T. E. (1993): Physical and chemical studies on the uranium copper mineralization of uraniferous Paleozoic sediments, west central Sinai, Egypt. Unpublished M. Sc. Thesis, Cairo Univ.

Amer, T. E. (1997): Geochemistry and extraction of uranium, copper and manganes from the ore materials of the uraniferous Paleozoic sedimentary rocks, west central Sinai, Egypt. Unpublished Ph.D. Thesis, Cairo Univ.

Arthur P. Pierce, J. W. Mytton, and Garland B. Gott. (1955): Contributions to the Geology of Uranium and Thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland. GEOLOGICAL SURVEY PROFESSIONAL PAPER 300.

Bishr, H. A., (2015): An assessment of radioactive mineralization of representative samples from the Um Bogma uranium ore, Southwestern Sinai, Egypt. Twelfth Arab Conf. on the peaceful uses of atomic energy, Sharm El-Sheikh, Arab Republic of Egypt, 16-20 May 2015.

Dabbour, G. M. and Mahdy, M. A. (1988): Mineralogical studies on the lower uraniferous sediments of W. Naseib, Sinai, Egypt. In: C.N.S.A. Conference, Cairo.

El Aassy, I. E.; El Rakaiby, M. L. and Botros, N. H. (1990): Geology and radioactivity of East Abu Zeneima area, Sinai, Egypt. Ann. Geol. Surv. Egypt, v. 16, pp. 285-288.

El Aassy, I. E., Botros, N. H., Abdel Razik, A., Alshamy, A. S., Ibrahim, S. K., Sherif, H. Y., Attia, K. E. and Moufei, A. A. (1986): Report on proving of some radioactive occurrences in west central Sinai. Int. Rept. N.M.A., Cairo, Egypt.

El Aassy, I. E; Ahmed, F. Y; Alshamy; A. S, and Shata, A. E, (1997): Contribution to the uranium distributions in the Paleozoic section in Gabal Homiyer. Egypt. J. Geol., v. 41/2A, pp. 205-218.

El Aassy, I. E., Ahmed, F. Y., Mohammed, G. A.; Alshami, A.S.; Gabr, M.M. and Rabboh, A.A. (2006): New resource of rare earth elements in Sinai, Egypt. 7^{th} Int. Conf. Geochem., Fac. Sci., Alex. Univ., Egypt, v. 3, pp 177 – 184.

El Agami, N. L. (1996): Geology and radioactivity studies on the Paleozoic rock units in the Sinai Peninsula, Egypt. Ph.D. Thesis, Fac. Sci, Mansoura Univ., pp. 302.

El Galy, M. M. (2003): Review article in application of equilibrium-disequilibrium phenomena of the U-Th decay series in exploration for uranium ore deposits. Nuclear Materials Authority.

El Reedy, M. W., Mahdy, M.A., El Aassy, I. E., and Dabbour, G. M. (1988): Geochemical studies of some uraniferous sedimentary rock varieties of West Central Sinai, Egypt. In: Fourth Conference on Nuclear Sciences and Applications, Cairo, Egypt, Vol. I, pp. 224-229.

El Sharkawi, M. A., El-Aref, M. M. and Abdel Motelib, A. A. (1990a): Manganese deposits in a Carboniferous paleokarst profile, Um Bogma region, West Central Sinai, Egypt. Mineralium Deposita, v. 25, 343p.

El Sharkawi, M. A., El Aref, M. M. and Abdel Motelib, A. A. (1990b): Syngenetic and paleo karstic copper mineralization in Paleozoic platform sediments of west central Sinai, Egypt. BL: sediment hosted mineral deposits. Spec. Publ. Int. Assoc. Sedimentol., pp. 159-170.

Erickson, R. L., Myers, A. T., and Horr, C. A. (1954): Association of uranium and other metals with crude oil, asphalt, and petroliferous rock: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 2200-2218.

Gott, G. B., and Erickson, R. L., (1952): Reconnaissance of uranium and copper deposits in parts of New Mexico, Colorado, Utah, Idaho, and Wyoming: U. S. Geol. Survey Circ. 219, 16 p.

Gott, G. B., Wyant, D. G., and Beroni, E. P., (1952): Uranium in black shales, lignites, and limestones in the United States: U. S. Geol. Survey Circ. 220, p. 31-35.

Hilmy, M. E. and Mohsen, I. A. (1965): Secondary copper minerals from west central Sinai, Egypt. J. Geol. Vol. 9, pp.1-12.

Hussein A. H. (1978): Lecture Course in Nuclear Geology, 101p., NMA, Egypt.

Hussein, A. H., Abdel Monem, A. A., Mahdy, M. A., El Aassy, I. E. and Dabbour, G. M. (1992): On the genesis of surficial uranium occurrences in west central Sinai, Egypt. Ore, Geol. Rev. Vol. 7.

Kora, M., (1984): The Paleozoic outcrops of Um Bogma area, Sinai. Ph.D. Thesis, Mansoura Univ., Egypt. 280pp.

Kostandi, A. B. (1959): Facies maps for the study of the Paleozoic and Mesozoic sedimentary basins of the Egyptian regions, U.A.R. First Arab Petroleum Congress, 16p.

Mart, S. and Sass, E. (1972): Geology and origin of the manganese ore of Um Bogma Sinai. Econ. Geol., v. 67, pp.145-155.

Morsy, A.M.; EL-Fawal, F.M.; EL-Aassy, I.E. and Mansour, M. Gh. (1995): Sedimentology of the Um Bogma Formation, west central Sinai. Proc. 4th Conf. Geol. Sinai Develop., Ismailia, pp. 121-139.

Nuclear Materials Authority (1999a): Uranium evaluation in Abu Zeneima area, Sinai, Egypt. Part I: Geology, Mineral Resources and Geochemistry. Internal Report**.**

Nuclear Materials Authority (1999b): Airborne Magnetic and Gamma-Ray Spectrometric Survey Flown over Abu Zeneima-Al Tur Area, Southwestern Sinai, Egypt. NMA-ED-SIR 1/99. Internal report.

Omara, S. and Schultz, G. (1965): A Lower Carboniferous microflora from southwestern Sinai, Egypt. Palaeontographica, Abt. B, v. 117, pp. 47-58.

Rogers, J. W. and Adams, J. S. S., (1969): Uranium. In: Wedepohl, K.H. (ed.), Handbook of Geochemistry, New York, springer-Verlag, 4, 92B-1 to 92C.

Soliman, M. S., and Abu El Fetouh, M. A. (1969): Petrology of Carboniferous sandstone in west central Sinai, J. Geol. U. N. R., v. 13 (2), pp. 61-143.

Temraz, M. G. (2005): Mineralogical and geochemical studies of carbonaceous shale deposits from Egypt. M.Sc. Thesis, Berlin. pp105.

Weaver B. and Tarney J. (1984): Empirical approach to estimating the composition of the continental crust. Nature, 310, 575-57.

Weissbroad, T. (1969): Paleozoic outcrops in south Sinai and their correlation with those of southern Palestine. In: The Paleozoic of Israel and adjacent countries. Bull. Geol. Surv., v. 17(2), 32p.