IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 6, June 2015.
www.ijiset.com
ISSN 2348 – 7968

Radioactive Mineralization of El-Missikat Granite; one of Most Important Occurrence, Eastern Desert, Egypt.

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Abstract

El-Missikat granite pluton represents one of the most promising radioactive mineral occurrence in the Eastern Desert of Egypt. Radioactive mineralization of El-Missikat granite represents a good example of fracture filling uranium type, associated within red, black and jasperoid silica veins, dissecting NE – SW shear zone. Alterations represent the common feature; indicated as greisenization, silicification, hematitization, kaolinization and fluoritization. However silicification is the most important alteration process of hosting uranium mineralization. Measurement of radioactive elements suggests uranium – bearing granite of El-Missikat pluton as well as red, black and jasperoid silica veins. The mineralizations are considered either as syngenitic uranium leaching origin for granite or post magmatic association for different silica veins. Most of the radioactive minerals are represented by uranophane, autonite, kasolite, monazite and zircon.

Key words: El-Missikat area, radioactive minerals and mineralization.

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1-Introduction

El - Missikat area represents one of the most important uranium occurrence in the Eastern Desert of Egypt. The area is located in the Central Eastern Desert between latitude 26° 23´ and 26° 33´ N and longitudes 33° 15´ and 33° 30´ E. It covers about 350 km^2, composed essentially of the Neoproterozoic rocks and the Phanerozoic Nubian Sandstone (Fig. 1). The area under study was considered as radioactive anomaly by the airborne radiometric and magnetic survey of Wadi El-Gidami area (**Ammar, 1973**), however the El- Missikat and the El Eridiya granite plutons host significant uranium mineralization (**Hussein et al. 1986; Hussein and Sayyah, 1992; Abu Dief, 1992**). The uranium mineralization is structurally controlled, restricted essentially along NE - SW shear zone, traversing the northern part of El- Missikat younger granites. The uranium-bearing minerals are associated essentially with the hydrothermal alteration and represented mainly by uranophane, beta-uranophane, soddyite and retardate (**Attawiya, 1983 and 1984**), whereas the primary uranium minerals are represented by uraninite (**Mohamed, 1995**) and pitchblende (**Ibrahim, 2002**). The present study deals mainly with the radioactive mineralization of the northwestern part of Gabal El-Missikat shear zone that represents the main mineralized zone of the study area. A modified geologic map at scale 1: 100,000 is given, (Fig. 1).

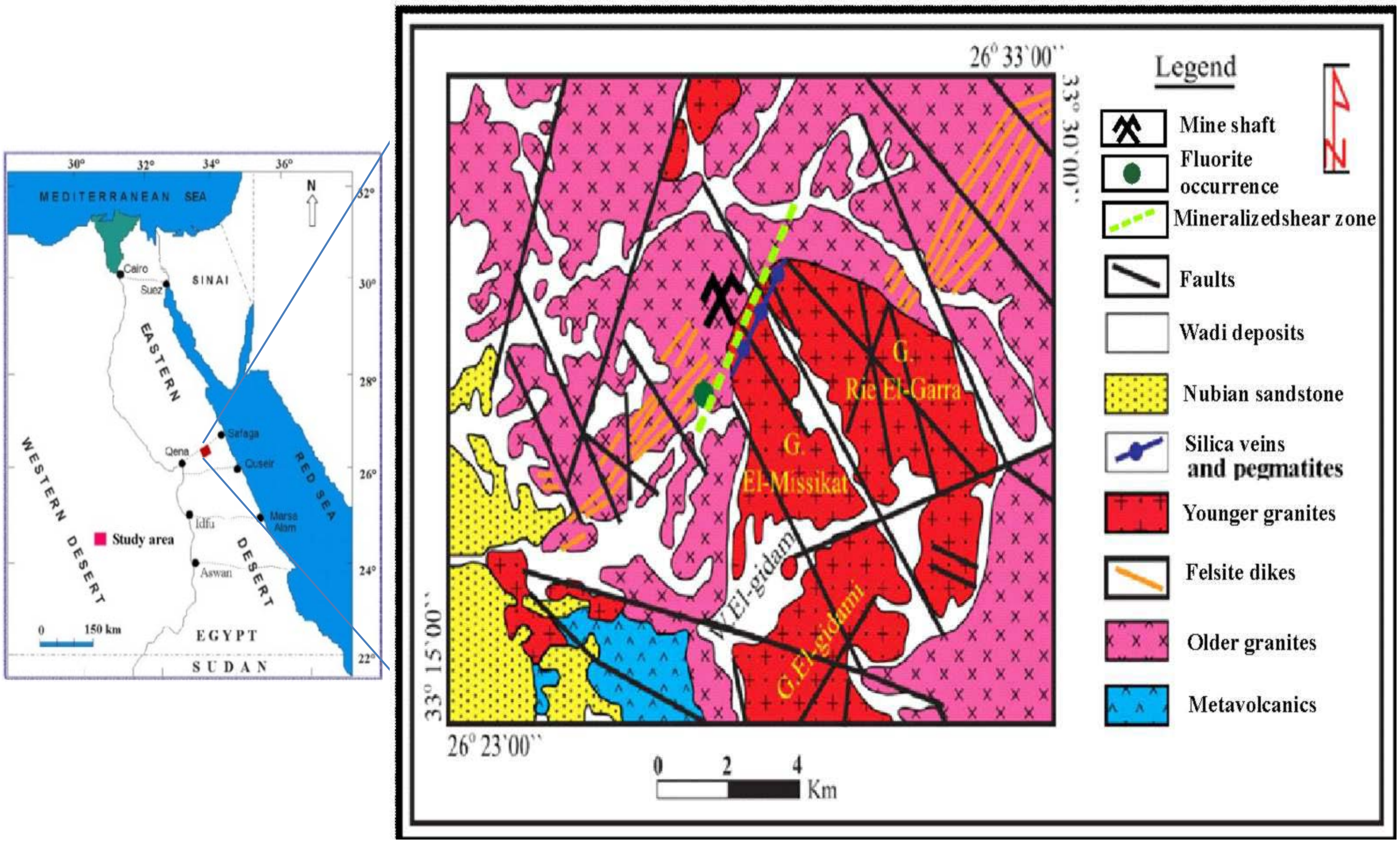


Fig. (1): Geologic map of El-Missikat area, (modified after Abu Deif, 1992).

Actually, 87 samples were collected from different rock units (13 samples from older granites, 13 samples from monzogranite, 5 samples from syenogranite, 2 samples from white silica veins and 54 samples from red and black silica veins) and radiometrically analyzed to determine the content of eU, eTh, Ra eU in ppm and K % (Tables.1,2,3). Uranium, thorium, radium and potassium contents are determined radiometrically by using a multichannel analyzer of γ -ray detector (Gamma- Spectrometer technique). The instrument used in determination of the four radioactive elements consists of a Bicom scintillation detector NaI (TI) 76 mm X 76 mm, hermetically sealed with the photomultiplier tube in aluminum housing. The tube is protected by a copper cylinder of thickness 0.6 cm against induced X ray and a chamber of lead bricks against environmental radiation. Uranium, thorium, radium and potassium were measured by using four energy regions representing 234 Th, 212 Pb, 214 Pb and 40 K at 93 K, 239 K, 352 KV and 1460 KV for uranium, thorium, radium and potassium respectively. The measurements were carried out in sample plastic containers, cylindrical in shape, 212.6 cm in volume with 9.5 cm average diameter and 3 cm height. The rock sample was crushed as fine as about 1 mm in grain size and the container was then filled with about 300 – 400 gm of the crushed sample sealed well and left for at least 21 days to accumulate free radom to attain radioactive equilibrium. The relation between the percentage of 222 Rn accumulations and time increased till reaching the steady stage after about 38 days (**Matoline, 1991**).

2- Geologic Setting

El – Missikat area is mainly covered by the Neoproterozoic rock units represented by island arc metavolcanics, syntectonic older granites and felsite dikes, as well as post tectonic younger granites (monzogranite, syenogranite and altered rich quartz granites) in addition to aplite, granite porphyry and basal dikes, pegmatite, silica and quartz veins. The syntectonic older granites represent a past of huge pluton extending westward and north ward beyond the limits of the area with an age ranging from 930 – 850 Ma (**Meneisy, 1972 and Hashad, 1980**) to 711 Ma (**Greenberg,1981**). They are uncomfortably capped by the Nubian Sandstones and invaded by NE- SW syntectonic felsite dike swarms and post tectonic younger granites. The felsite dikes cut only through the older granite ranging from few meters to more than 10 Km length and up to 5 meters width, to suggest that they had been emplaced before the emplacement of the younger granites. Generally, the older granites from low to moderate outcrops, characterized by exfoliation and gneissose texture, sometimes they occur as migmatized rocks of well alternated dark and white bands, particular at the northern side of the area. According to the mineral composition, the older granites are classified into quartz diorite, tonalite and granodiorite. Actually, the quartz diorite has the less quartz content (8 %), high plagioclase content (38 %) and less K- feldspars content (2 %) mafic minerals are represented by hornblende (18 %) augite (13 %) and biotite (12 %). Both tonalite and granodiorite have moderate quartz content up to 38 % and 39 % respectivelly, K – feldspars are varying from 6 % to 12 %. Plagioclase content up to 58 % is restricted in tonalite, while it decreases to 39 % in the granodiorite. Also biotite decreases from 20 % in tonalite to 13 % in the granodiorite. Hornblende is relatively rare up to 1 % for both.

The younger granites are represented by oval like pluton comprising essentially the monzogranite and syenogranite, in addition to high quartz altered granites, with an age dated 568 ±17 Ma (**Fullagar, 1980**) and 603 – 575 Ma (**Greenberg, 1981**). They had been emplaced during the post tectonic episode of the Eastern Desert. They form moderate to high NW – SE granites pluton traversed by some NW – SE faults in addition to NE – SW mineralized shear zone. These granites are more or less suffered alteration, particular along the fault planes and shear zone, represented by silicification, sericitization, hematization, greisenization, kaolinization and fluoritization either as patches or altered granite zones, as well as they are talented by manganese mineralization as dendritic like forms.

The NE – SW shear zone represents the main mineralized zone for the radioactive mineralization. It is represented by tabular and elongated NE – SW crushed and brecciated granites, displaced by parallel fractures and joints traced over 2 Km in length and 4 Km in width.

The younger granites intrude directly the older granites with sharp contact along several hundred of meters (500 – 750 m), characterized by presence of some oval dark color xenoliths and some lenticular pegmatite bodies, siliceous and quartz veins as well as aplite sheets and dikes. The smoky and jasperoid NE –SW silica veins show often radiometric anomalies due visible secondary uranium mineralization. Quartz veins are generally milky – white and occasionally grayish or reddish in color, commonly include vugs, some of which filled with iron, carbonates and clay minerals.

The younger granite varieties show a quite difference in the main minerals constituents. The monzogranite has the less quartz content (51 %), followed by the syenogranite (59 %) and altered granite (82 %). Plagioclase gradually decreases from the monzogranite (39 %) to the syenogranite (16 %) and altered granite (5 %), as well as biotite decreases from the monzogranite (6 %) to the syenogranite (1 %). Muscovite is recorded only in the syenogranite and altered granite with content up to (3 %).

3. Radioactive inspections

From data given of the analyzed 87 samples (Tables 1, 2, 3), it is clear that U content ranges from ULD to 19 ppm with an average of 4.3 ppm. Th content ranges from 2 to 32 ppm with an average of 6.6 ppm. Ra (eU) increases with increasing U content. Generally, its average concentration is 4.58 ppm. K% content ranges from 0.92% to 4.58%with an average value.

U and Th contents in the older granites are up to 1.9% (Table 1). However eU and eTh contents are compared with the value of **Clark et al** (**1966**), **Rogers and Adams** (**1969**), indicate that El-Missikat older granitoids are characterized by higher uranium content. The higher radioactivity is mainly attributed to the presence uranium bearing minerals such as apatite, sphene, zircon, allanite, in addition to iron oxides. eTh/eU ratio ranges from 0.22 to 5 with 1.5 as an average. The theoretically expected eTh/eU ratio of the normal continental crust is about 4 (**Ȍrgün et al., 2005**). This indicates that El-Missikat older granitoids slightly had been underwent alteration, weathering and metasomatic processes. **Cambon** (**1994**) stated that, the U content of the different rock types is variable. The types which contain most of the U are the younger granitic rocks. eU content in El Missikat monzogranite ranges from 1 to 43 ppm with an average up to 22.3 ppm, while its Th content ranges from 14 to 42 ppm with an average up to 28.5 ppm. Ra (eU) content has values ranging from2 to 26 ppm with an average up to 14.3 ppm. On the other hand, the average content of K is 3.3 %. For syegranites, values of eU, eTh, Ra and K change from 5 to 19 ppm, from 18 to 28 ppm, from 5 to 13 ppm and from 2.51 % to 4.43 %, respectively. The study monzogranite and syenogranite are hence considered uraniferous granites according to **Darnely** (**1982**) and **Darnely and Ford** (**1989**) since their uranium content greatly exceeds the Clark value of U (4 ppm). Relatively high uranium content is attributed to the presence of accessory and secondary minerals, such as allanite, zircon and kazolite. The range of eTh/eU ratio is wide (0.60 to 14.00 ppm) for monzogranite and (1.32 to 3.60 ppm) for syenogranite (Table.2). eTh/eU ratio averages of monzogranite and syenogranite are approx. 3.27 and 3.6, respectively, often lower than the average continental crust value of approx. 3.8 (**Van Schmus 1995**), suggesting that these rocks are enriched in U. Moreover, the arithmetic mean of eU (18.32 ppm) of El Missikat younger granites is more than that of the orogenic granites of Saudi Arabia, (5.6 ppm) given by **Stuckless et al.** (**1984**), as well as, common granitic rocks (4.5 ppm) quoted by **Killen** (**1979**) and normal granites (4.75 ppm) given by **Rogers and Adams** (**1969**).

Table (1): Radionuclide contents in the studied older granites.

Older granites								
Sample No:	**eU (ppm)**	**Th (ppm)**	**Ra (ppm)**	**K%**	**eTh/eU(ppm)**	**eU/Th (ppm)**	**U/Ra (ppm)**	**Uch/Ur (ppm)**
2	19	32	13	4.6	1.7	0.6	1.5	0.62
3	17	22	11	3.6	1.3	0.8	1.5	0.61
17	3	3	1	0.9	1.0	1.0	3.0	0.4
20	2	3	3	1.8	1.5	0.7	0.7	1.0
26	0	2	3	2.0	-	0.0	0.0	-
16	1	5	2	1.5	5.0	0.2	0.5	0.9
23	0	2	1	1.4	-	0.0	-	-
24	3	3	2	1.6	1.0	1.0	1.5	1.2
25	0	4	1	1.8	-	0.0	-	-

27	2	3	2	1.7	1.5	0.7	1.0	1.0
36	0	3	2	1.3	-	0.0	-	-
37	0	2	3	1.5	-	0.0	-	-
34	9	2	9	1.2	0.2	4.5	0.1	0.83
Max	19	32	13	4.58	5	4.5	3.0	1.2
Min	0	2	1	0.92	0.2	0	-	0.4
Av	4.3	6.6	4.1	1.9	1.5	0.7	0.8	0.82

Table (2): Radionuclide contents in the studied younger granite.

Monzogranite								
Sample No	**eU(ppm)**	**Th (ppm)**	**Ra (ppm)**	**K%**	**eTh/eU(ppm)**	**eU/Th (ppm)**	**U/Ra (ppm)**	**Uch/Ur (ppm)**
4	19	27	16	2.09	1.42	0.70	1.19	0.52
5	16	25	12	3.13	1.56	0.64	1.33	0.51
6	19	27	14	3.58	1.42	0.70	1.36	0.53
7	20	34	17	3	1.70	0.59	1.18	0.55
8	17	16	11	4.31	0.94	1.06	1.55	0.55
10	32	31	18	2.81	0.97	1.03	1.78	0.54
11	36	42	19	4.07	1.17	0.86	1.89	0.55
12	31	38	16	2.32	1.23	0.82	1.94	0.55
14	43	26	26	1.54	0.60	1.65	1.65	0.54
19	9	24	7	3.91	2.67	0.38	1.29	0.51
21	11	24	7	3.88	2.18	0.46	1.57	0.5
22	15	29	9	3.77	1.93	0.52	1.67	0.49
32	1	14	2	3.48	14	0.07	0.50	2.9
Max	**43**	**42**	**26**	**4.31**	**14**	**1.65**	**1.94**	**2.9**
Min	**1**	**14**	**2**	**1.54**	**0.6**	**0.07**	**0.50**	**0.49**
Av	**22.29**	**28.50**	**14.29**	**3.3**	**3.27**	**0.8**	**1.49**	**0.71**
Syenogranite								
9	18	28	11	2.51	1.56	0.64	1.64	0.52
15a	19	25	11	2.7	1.32	0.76	1.73	0.5
39a	10	18	5	3.65	1.80	0.56	2.00	0.55
15b	19	25	13	4.12	1.32	0.76	1.46	0.51
39b	5	18	7	4.43	3.60	0.28	0.71	0.54
Max	**19**	**28**	**13**	**4.43**	**3.6**	**0.76**	**2**	**0.55**
Min	**5**	**18**	**5**	**2.51**	**1.32**	**0.28**	**0.71**	**0.5**
Av	**14.2**	**22.8**	**9.4**	**3.482**	**1.92**	**0.6**	**1.51**	**0.52**
Av.*	**4**	**18**	**-**	**-**	**3.5**	**-**	**-**	**-**

Av.*: Averages of Clark et al. (1966) and Rogers and Adams (1969).

Table (3)*:* Radionuclide contents in the studied silica veins.

Red and Black silica veins								
Sample No	**eU(ppm)**	**Th (ppm)**	**Ra (ppm)**	**K%**	**eTh/eU(ppm)**	**eU/Th (ppm)**	**U/Ra (ppm)**	**Uch/Ur (ppm)**
ms-18	193	26	237	0.73	0.13	7.4	0.8	-
ms-28	17	27	12	3.36	1.59	0.6	1.4	
ms-29	168	12	141	0	0.07	14.0	1.2	-
ms-30	296	23	291	0	0.08	12.9	1.0	-
ms-31	1	14	2	3.48	14.0	0.1	0.5	-
ms-33	1	3	3	1.95	3.0	0.3	0.3	-
An-13-1	533	45	369	0	0.08	11.8	1.4	-
An-13-2	477	41	362	0	0.09	11.6	1.3	-
An-13-3	522	32	341	0	0.06	16.3	1.5	-
An-13-4	476	46	325	0.28	0.1	10.3	1.5	
An-13-5	540	47	360	0	0.09	11.5	1.5	0.97
An-13-6	518	38	359	0.2	0.07	13.6	1.4	-
An-13-7	524	49	341	0.82	0.09	10.7	1.5	-
An-13-8	468	50	315	0	0.11	9.4	1.5	-
DI-1-1	26	29	26	0.33	1.1	0.9	1.0	-
DI-1-2	27	31	22	0.3	1.1	0.9	1.2	-
DI-1-3	31	30	25	0.82	1.0	1.0	1.2	-
DI-1-4	29	27	25	0.36	0.9	1.1	1.2	-
DI-1-5	28	31	25	0.28	1.1	0.9	1.1	-
DI-1-6	27	30	27	0.53	1.1	0.9	1.0	-
DI-1-7	27	29	23	0.43	1.1	0.9	1.2	-
DI-1-8	30	24	24	0.61	0.8	1.3	1.3	-
DI-2-1	33	31	32	0.6	0.9	1.1	1.0	-
DI-2-2	33	33	32	0.48	1.0	1.0	1.0	-
DI-2-3	35	33	30	0	0.9	1.1	1.2	-
DI-2-4	31	32	33	0.64	1.0	1.0	0.9	-
DI-2-5	36	31	35	0.34	0.9	1.2	1.0	-
DI-2-6	32	31	34	0.4	1.0	1.0	0.9	-
DI-2-7	40	33	34	0.55	0.8	1.2	1.2	-
DI-2-8	31	31	33	0.61	1.0	1.0	0.9	-
DI-3-1	46	32	32	0.61	0.7	1.4	1.4	-
DI-3-2	46	23	36	0.67	0.5	2.0	1.3	-
DI-3-3	38	27	35	0.54	0.7	1.4	1.1	-
DI-3-4	47	29	34	0.63	0.6	1.6	1.4	-
DI-3-5	39	27	34	0.39	0.7	1.4	1.1	-
DI-3-6	40	33	35	0.63	0.8	1.2	1.1	-
DI-3-7	41	30	33	0.96	0.7	1.4	1.2	-
DI-3-8	35	32	34	0.24	0.9	1.1	1.0	-
DI-4-1	78	27	64	0.61	0.3	2.9	1.2	-
DI-4-2	76	35	63	0.49	0.5	2.2	1.2	-
DI-4-3	75	30	68	0.48	0.4	2.5	1.1	-
DI-4-4	73	34	65	0	0.5	2.1	1.1	-
DI-4-5	82	30	64	0.47	0.4	2.7	1.3	1.0
DI-4-6	76	28	66	0	0.4	2.7	1.2	-
DI-4-7	79	28	67	0.27	0.4	2.8	1.2	-
DI-4-8	73	24	71	0.64	0.3	3.0	1.0	-
T2-1	125	20	110	0.45	0.2	6.3	1.1	-
T2-2	118	22	102	0.82	0.2	5.4	1.2	-
T2-3	125	17	111	1.04	0.1	7.4	1.1	-
T2-4	128	17	110	1.02	0.1	7.5	1.2	-
T2-5	133	15	105	0.77	0.1	8.9	1.3	-
T2-6	113	15	107	0.58	0.1	7.5	1.1	-
T2-7	111	15	101	0.68	0.1	7.4	1.1	-
T2-8	128	12	116	1.11	0.1	10.7	1.1	-
max	**540**	**50.0**	**369**	**3.5**	**14.0**	**16.3**	**1.5**	**1.0**
min	**1.0**	**3.0**	**2.0**	**0.0**	**0.1**	**0.1**	**0.3**	**0.97**
Av	**132.5**	**28.5**	**103.4**	**0.6**	**0.8**	**4.5**	**1.2**	**0.98**

The Egyptian uraniferous granites are defined and discussed by several authors (**Bakhit, 1987; Cambon 1994; Assaf et al. 1997; Breiter et al., 1998 and 2005**). They defined the following characteristics features:

1) High silica contents (> 73%).
2) Al_2O_3>13.38%.
3) L.O.I <0.5%.
4) Very rare ferromagnesian minerals.
5) Low CaO contents (<0.98%).
6) Low Sr contents (<98.98ppm).
7) High Rb/Sr ratios (>2.4ppm).
8) High Zr/Sr ratio (>1.65ppm).
9) High Rb contents (>184.8 ppm).
10) Low Na_2O/K_2O ratios (1.0 %).

The geochemical data of the study granites are in complete harmony with the all-previous discussions (Table 3). The study younger granites are thus considered as uraniferous granites. White silica veins are nearly barren from radioactivity where they contain uranium contents reach up to 1 ppm.

Generally, the high radioactive anomalies of the study area are recorded in the mineralized red and black silica veins hosted within the younger granites. These radioactive veins are enriched in uranium (Table 3). eU ranges from 1 to 540 ppm with an average content of 132.5 ppm and eTh (3-50 ppm) has the average of 28.5 ppm. Ra (eU) and K contents vary from 2 to 369 ppm and from 0.0 to 3.5wt% with an average of 103.4 ppm and 0.6wt%, respectively. eU and eTh values in red and black silica are higher than the average concentrations of the Earth curst, continental crust and magmatic rocks of granitic composition (**Mason and Moore, 1982; Rudnick and Gao, 2003; Tzortzis et al., 2003**). eTh/eU ratio varies from 0.1 to 14 ppm with 0.8 ppm as an average (Table 3). The average crustal Th/U ratio is nearly 3, when this ratio is disturbed; it indicates either depletion or enrichment of uranium. In these rocks, the wide range of Th/U ratios (0.1 and 14 ppm), suggesting that the enrichment of uranium and thorium is related to hypogene fluids, which cause the enrichment of uranium and thorium by the same ratio.

The disturbance of Th/U ratio (less than 3) indicates that the uranium enrichment is more than thorium due to the more stability of thorium as compared to uranium in secondary environment.

The eU/eTh ratio varies from 0.1 to 16.31 with an average up to 4.5 that can be considered as higher than the range commonly recorded for granites (0.08-0.50) given by (**Stuckless et al., 1977, Rogers and Adams 1969a**). The high eU/eTh ratio may be attributed to the fact that the study red and black silica veins are enriched in radioactive accessory minerals such as uranophane, autonite, monazite, zircon and xenotime.

3.1 Radioactive equilibrium

Radioactive equilibrium of El Missikat area can be determined by calculation of the equilibrium factor (P), defined as the ratio of radiometrically determined uranium content (U_r) to the radium content (P-factor= eU/Ra (eU)) recently applied by **El-Galy** (**1998**), **El-Feky** (**2000**), **Raslan et al., (2010) and Raslan and El-Feky (2012)**. If P- factors is more or less than one, this means addition or removal of uranium, respectively. The second method for the equilibrium study is carried out by using the data of chemically analyzed uranium (U_{ch}) and radiometrically determined uranium (U_r). Ratio between chemically and radiometrically determined uranium is known as the D-factor=U_{ch}/U_r (**Hansink, 1976**). If both P- and D-factors are more or less than one, this means addition or removal of uranium respectively. Removal and addition of uranium are argued to some certain geological processes such as alteration which causes disturbance in the equilibrium state. Also, groundwater may act on some uranium deposits and causes leaching of uranium from its original place and its redeposition in other places. Another factor controlling the equilibrium state is the loss of radon gas as one of uranium daughters. This loss occurs easily due to the solubility of radon in water and its leakage through pore spaces, as well as along faults and other fractures types. According to **Reeves and Brooks (1978)**, uranium attains equilibrium in about 1.5 m.y. **Cathelineau and Holliger (1987)** stated that uranium mineralization is affected by different stages of alteration. Stages of leaching, mobility and redeposition of uranium are affected by hydrothermal solutions and/or supergene fluids which cause disequilibrium in the radioactive decay series in the U-bearing rocks.

P- factor of the study uraniferous granitoids (older granites and younger granites), red and black silica veins was calculated (Tables 1, 2, 3). The measured eU and Ra (eU) are plotted versus each other for possible estimation of the equilibrium state and as an approximate estimate to the degree of agreement between the two values (Figs 2a, b & c). It is clear that most values of the P-factor of El Missikat samples are more than one. This refers to possible loss of radon or radium resulting in eU/Ra (eU) averages of 1.42, 1.40, 1.37 and 1.19 for older granitoids, monzogranite, syenogranite and red and black silica veins, respectively.

The use of D-factor in the determination of equilibrium state reveals that syn- and post-orogenic granites have uranium lesser than the radiometrically determined uranium in most samples reflecting a disequilibrium state characterized by uranium leaching. On the contrary, the D-factor in red and black silica is nearly in equilibrium where its value equal or close to unity (Table 3). The values of P- and D- factors may indicate recent uranium leaching from the study granites.

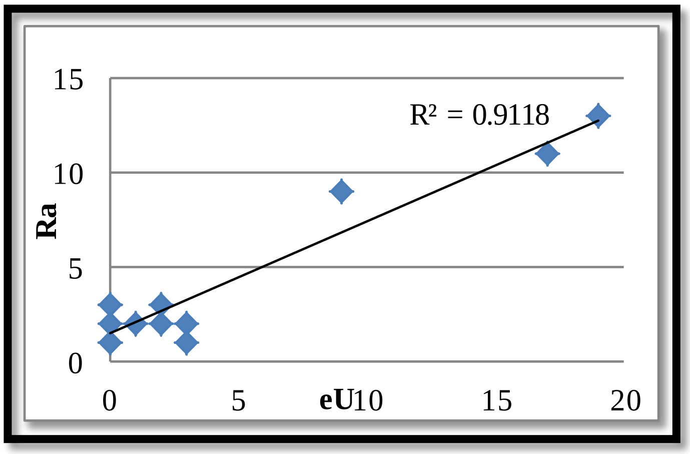


Fig. (2a): Binary diagrams showing eU vs. Ra (eU) elements in older granites of El Missikat area.

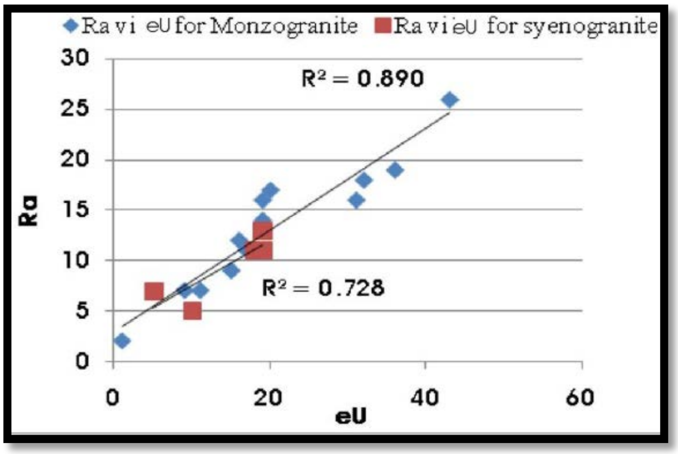


Fig. (2b): Binary diagrams showing eU vs. Ra (eU) elements in younger granites of El Missikat area.

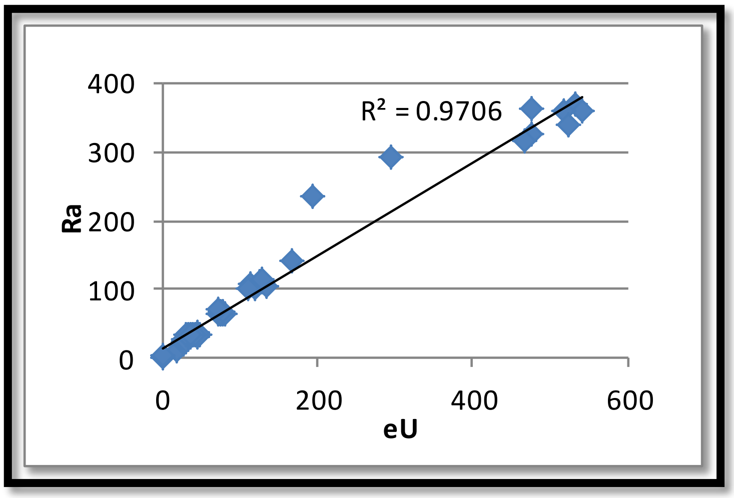


Fig. (2c): Binary diagrams showing eU vs. Ra (eU) elements in red and black silica of El Missikat area.

3.2 Geochemistry of uranium and thorium:

Distribution of uranium and thorium in minerals and rocks of igneous origin can be explained in terms of crystal chemistry of the elements (**Aswathanarayana, 1985**). The geochemical coherence of U and Th during the magmatic cycle arises out of the marked similarity in their charges and ionic radii (U^{4+}, $1.05A^{O}$&Th^{4+}, $1.10A^{O}$). There is a relationship between uranium and the volatile components of magmas; uranium tends to concentrate in an acidic melt rich fluorine and chlorine. This behavior may explain the late precipitation of uranium in many types of granite.

The geochemical behavior of U and Th in the study granitoids rocks and red and black silica veins was examined by plotting a number of variation diagrams: The eTh/eU ratio is indicative for the relative depletion or enrichment of radioisotopes. Normally, thorium is three times as abundant as uranium in natural rocks. When this ratio is disturbed, it illustrates depletion or enrichment of uranium. The relationship between U and eTh/eU ratio (Figs 3a, b & c), indicates a decreasing trend for the study granitic rocks. Scattering of data in case of the older granites, monzogranite, syenogranite and red and black silica veins indicate the effects of hydrothermal fluids.

The relationship between Th and eTh/eU (Figs 3 d, e, and f) in the study granitoids elucidate that eTh/eU ratio decreases with the enrichment of Th in monzogranite, syenogranite and there is no any correlation with older granitoids and red and black silica veins. This observed trend may suggest that distribution of uranium and thorium was at least partly controlled by post-magmatic processes.

U and Th contents of granitic rocks generally increase during differentiation although in some cases they decrease (**Ragland et al., 1967**). eTh/eU ratio can either increase (**Whitfield el al., 1959; Rogers and Ragland, 1961**) or decrease (**Larsen and Gottfried, 1960**) as it is controlled by the redox conditions, volatile contents, or alteration by endogens or supergene solutions (**Falkum and Rose-Hansen, 1978**).

The eU-eTh variation diagram indicates positive correlation between the two radioactive elements in most types of the concerned rocks (Figs 3g, h & i). This could be related to the differentiation trends suggesting the syngenitic origin of radioactivity. Weak correlation between thorium and uranium in red and black silica dikes and veins may indicate that post-magmatic processes play an important role in uranium mineralization.

U/Th ratio is an important parameter to indicate the sites of uranium mineralization. **Darnely and Ford (1989)** mentioned that U/Th ratio provides the best pointers to sites where mineralizing processes most likely occur. As a rule, productive uraniferous strata have U/Th ratio around one or more. U/Th ratio is also an important parameter in the detection of the oxidation state in which U is transported (**Naumove, 1959**). Tetravalent uranium (U^{4+}) and Th can be accommodated within the same minerals, and both will be transported in solution under reducing conditions. Under oxidizing conditions, U is transported alone in the hexavalent state (U^{6+}), and usually a high U/Th ratio can be expected at the site of deposition.

The eU/eTh of the study granitic rocks are variable, It ranges from 0.0 to 4.5 (average=0.7) in the older granites, from 0.07 to 1.65 (average=0.7) in the monzogranite, from 0.28 to 0.76(average=0.6) in the syenogranite and from 0.1 to 16.31(average=4.5) in red and black silica

veins. High U/Th ratio in the mineralized zone (red and black silica veins) also suggests that U was transported to the site of deposition under oxidizing condition more likely in the form of uranyl complexes (e.g. Uranylsilicaes) regarding to the common occurrence of uranophane and kasolite.

3.3 Secondary Alteration Features and associated mineralization in Silica Veins:

The Missikat granite is dissected by a set of NE-SW to ENE-WSW shear zones, which were rejuvenated several times causing a main faulting and fracturing followed by late meteoric and/or hydrothermal alterations. These alterations resulted locally in the partial or complete disappearance of the primary textural features in these zones (**Ibrahim, 2002**).

Silicification is the most important features accompanying alteration within the main NE-SW shear zone in the Missikat granite. In this shear zone, several generations of quartz veins 1-3m thick, extend for more than 2 km. Wall rocks suffered illitization, kaolinization and hematization (**Ibrahim et al., 2004**). It has been found that most of the radioactive veins in El Missikat pluton are of the fracture-filling type, predominantly of a NE-SW direction. Red and black silica veins are highly mineralized and associated with uranium mineralization (Fig.4). The style of alterations of El Missikat and El Eridya granites was recently studied by **Abdalla and El-Afandy (2004), Ibrahim et al., (2004) and Abu-Dief and El Taher (2008).** The common alterations are greisenization, silicification, hematitization and kaolinization (Figs5 a, b and c). Fluoritization is also present (Fig 5d). Silicification is the most important alteration process in the shear zones as it sometimes hosts U- mineralizations. These mineralizations are mainly represented by radioactive minerals (uranophane, autonite and kasolite) and U-bearing mineral zircon, (Figs.5a, b, c, e, f, g, and h).

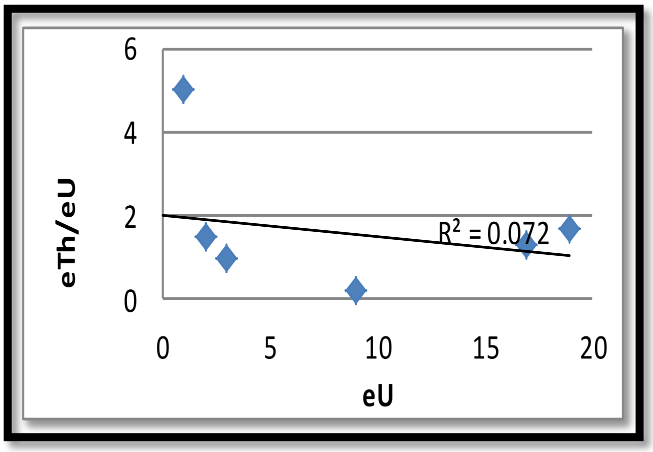


Fig (3a): Binary diagrams showing eU and eTh/ eU ratio in older granites of area.

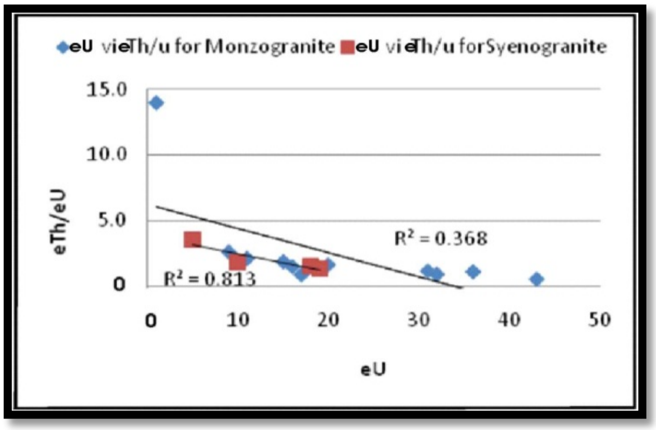


Fig (3b): Binary diagrams showing eU and eTh/ eU in younger graites of El Missikat area.

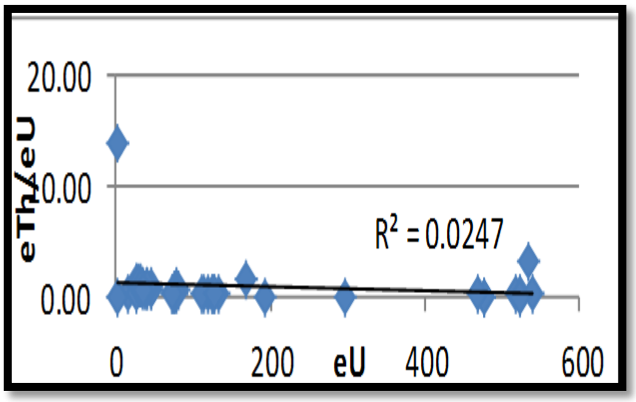


Fig. (3c): Binary diagrams showing eU and eTh / eU in red and black silica of El Missikat area.

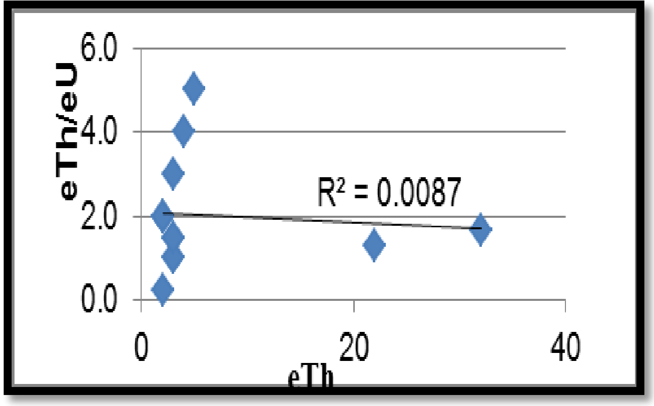
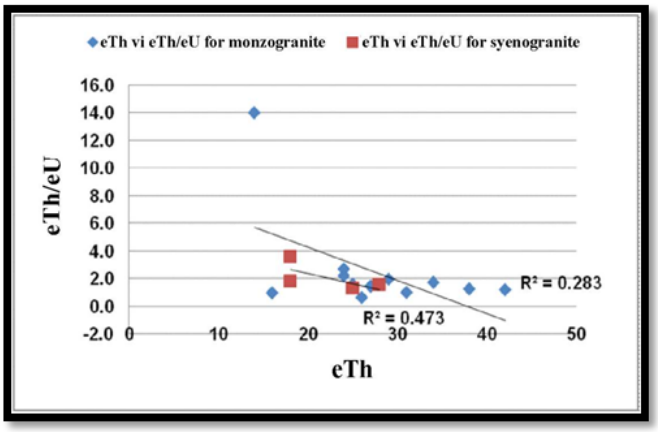


Fig (3d): Binary diagrams showing Th and eTh/ eU in older granites of El Missikat area.



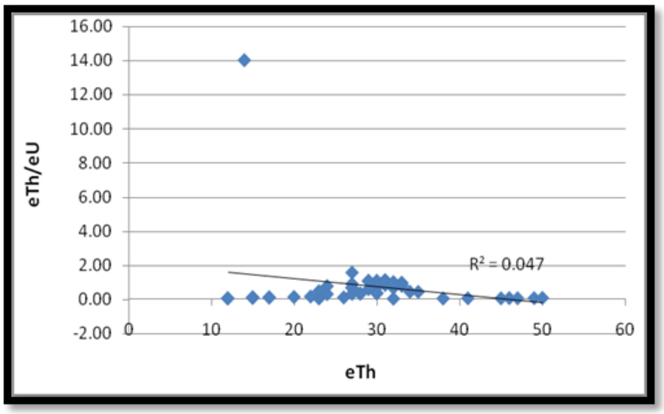


Fig (3e): Binary diagrams showing eTh and eTh/ eU elements in younger granites of El Missikat area.

Fig. (3f): Binary diagrams showing eTh and eTh / eU elements in red and black silica of El-Missikat area.

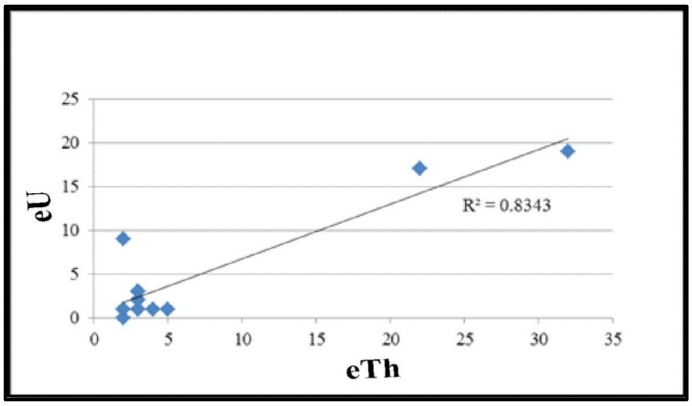


Fig (3g): Binary diagrams showing eTh and eU elements in older granites of El Missikat area.

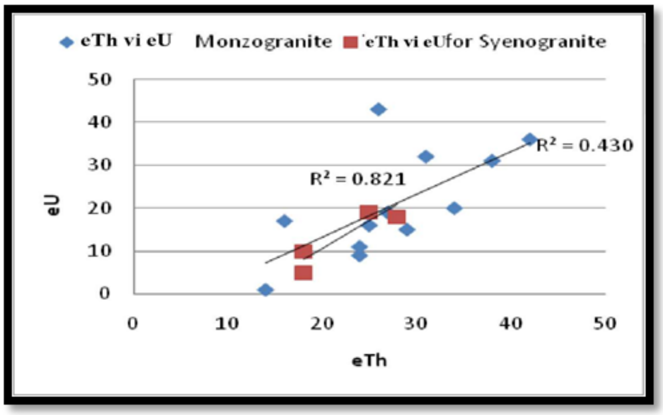


Fig (3h): Binary diagrams showing eTh and eU elements in younger granites of El Missikat area.

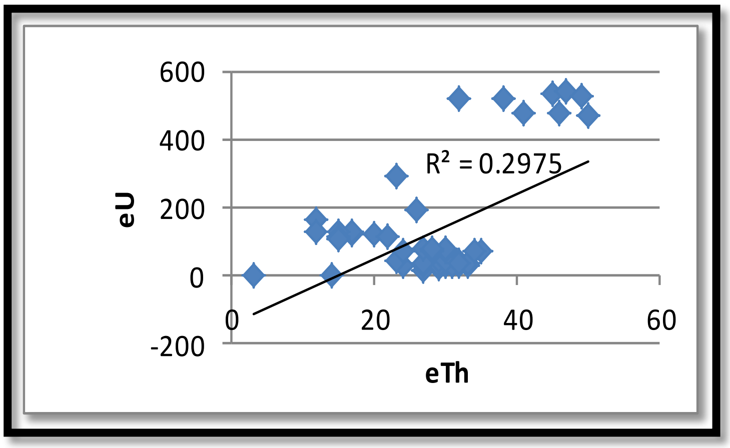
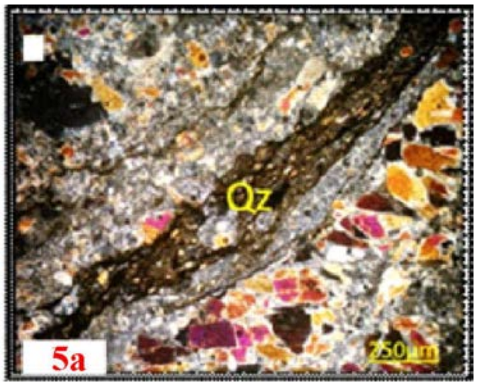
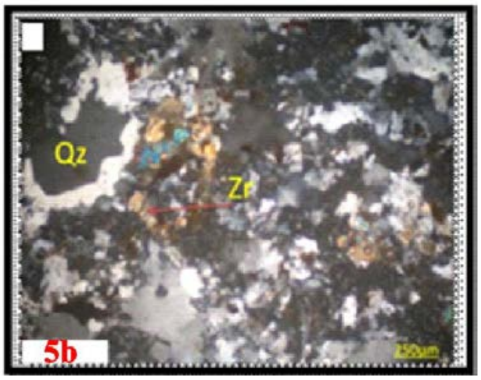
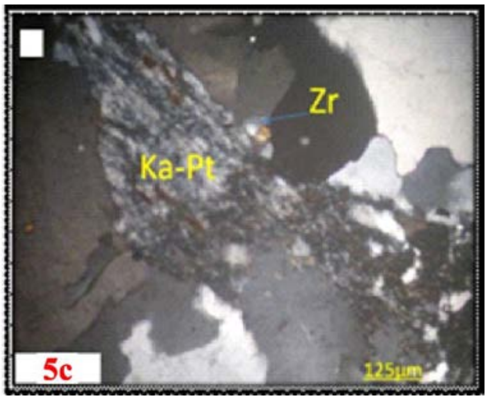


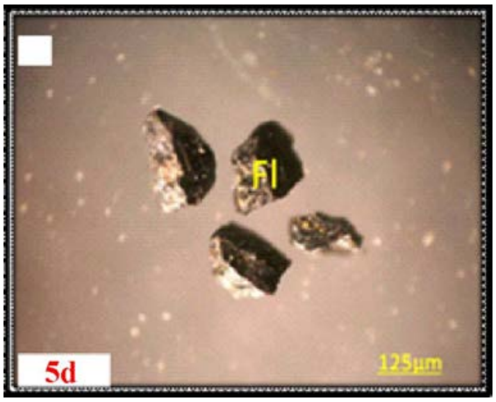
Fig. (3i): Binary relation between eTh and eU element in red and black silica of El-Missikat area.

Fig (4): Secondary uranium mineralization associating red and black silica veins.


Qz
5a
250μm

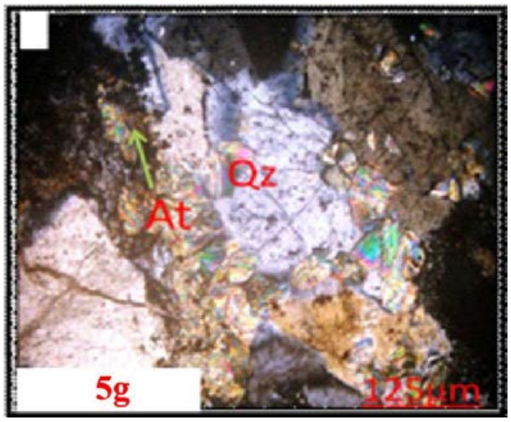

Qz
Zr
5b
250μm


Zr
Ka-Pt
5c
125μm


Fl
5d
125μm


U
5e
250μm


U
5f
250μm


Qz
At
5g
125μm

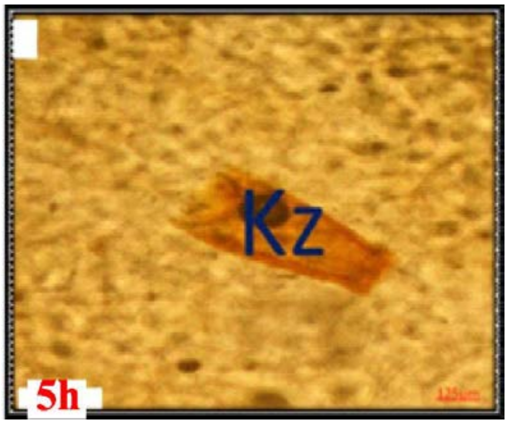

Kz
5h
125μm

Fig.(5):Photomicrograph showing: (a) fine crystals of quartz (Qz) in greisenized granite (CN). (b) Zircon (Zr) crystal enclosing in quartz. (CN). (c) Kaolinized perthite (Ka-Pt) associated with metamictic zircon. (CN). (d) black fluorite (Fl) (e) Uranophane (U) with cryptocrystalline and amorphous silica. (f) Uranophane (U) adsorbed by iron oxides. (CN). (g) Autonite (At) on the border of quartz crystal (CN). (h) Euhedral crystal of kazolite (Kz).

Conclusion

Geologic and radiometric investigations indicate that the El- Missikat area represents an important radioactive mineralized area in the Eastern Desert of Egypt. The mineralizations are concentrated essentially within the El- Missikat granite and along the dissected NE – SW shear zone .In general, the mineralizations have been considered as fracture filling, however many of fractures have been displaced by lot of thin red, black and jasperoid silica veins with visible bright ,yellow color secondary uranium – bearing minerals. Alterations are also the common features, represented by greisenization, silicification, hematitization, kaolinization and flouritization, often associated with radioactive mineralizations. Two main processes of the mineralization have been concerned, one of syengenenitic origin by recent uranium leaching of the granite and other by post magmatic processes accompanied with uranium – bearing red, black and jasperoid silica veins. The recorded minerals are uranophane, autonite, kasolite, monazite and zircon.

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