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Geochemistry and Radioactive Mineralization Inspections of the Pegmatite Bodies Associating Variable Granitic Environs, Abu Hadeida Area, North Eastern Desert, Egypt.

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Abstract

Two types of pegmatite (Mineralized and non-mineralized) pegmatite are identified in Abu Hadeida area. Mineralized pegmatite characterized by high contents of trace, rare earths, uranium, and thorium. Mineral associations include uranophane, autunite and thorite. Non mineralized pegmatite has low contents of trace and radioelements. REE patterns of the two pegmatites show M-W tetrad effects suggesting the dual effect of late stage hydrothermal solutions and surficial or underground water. Difference in pegmatite properties despite their presence in the same rocky environment may be due to the difference in the magma melt which the mineralized pegmatite emerged, where mineralized pegmatite bound to magma rich unlike normal type.

Key Words: Radioactivity, Mineralized, Non mineralized, Pegmatites, Abu Hadeida, Egypt.
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1. Introduction

Abu Hadeida area is located in the Northern Eastern Desert of Egypt at about 20 km west ward from Safaga City at the Red Sea coast. The area can be easily accessed via a newly established part of Qena–Safaga asphaltic road. The area exposure reaches up to about 26 $km^2$and bounded by latitudes 26° 43′48″ and 26° 48′36″N and longitudes 33° 35′24″ and 33° 45′E (Fig.1). It is characterized by its rugged topography and high relief and intersected by wadi Ras Abda and wadi Abu Hadeida and is bounded by the northern part of wadi Ras Baroud and the southern of wadi Um Taghir.

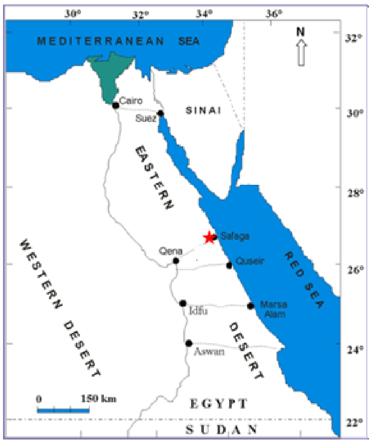


Fig (1): Location Map of the studied area.

Few radiometric and mineralogical studies were carried out on the study area [1- 2]. [3] studied in detail the highly radioactive microgranite dike-like bodies present in the studied area. He concluded that microgranites are alkali feldspar granite composed mainly of potash feldspars mainly perthites and microcline, quartz, little sodic plagioclase and biotite. Secondary uranium minerals (uranophane and curite), thorium minerals (thorite) and U- and Th-bearing minerals (Zircon, allanite, columbite, samarskite, xenotime, monazite, kasolite and titanite) are identified. Other nonradioactive minerals such as magnetite, goethite, hematite, cronstedtite, pyrite, fluorite and garnet are also identified. Geochemical investigations revealed the presence of high concentration of U, Zr, Y, Nb, Ba, Zn, Rb and Sr in addition to presence of V, Pb, Ni and Cr. Au and Pt are also present. The granitic rocks of Abu Hadeida area are associated with different types of pegmatite according to their shapes, geological structure, composition, its mineral contents, and radioactivity.

Many genetic models and scenarios have been proposed to interpret the tetrad-effects including mineral phase in igneous environments [4], complexation [5], fluid-melt and/or fluid-rock interaction [6-7], and surface weathering and alteration[8]. Studies carried out by different researchers revealed that the granites and igneous systems mostly display the convex (M-shape) tetrad-effects which are associated with mineral phases, crystallization, and fluid-rock and/or solution-rock interactions [9- 10, 7,11]. Based on these investigations, fluid rock or solution-rock can play a pronounced role in generation of tetrad-effects. Occurrences of the lanthanide tetrad-effect in geochemical systems are attributed to REE3+-complexing ligands in geological environments. Mean while, thermodynamic modelling of Cl and F complexation demonstrated that convex-type tetrad effects are mostly due to REE-Cl complexing, and concave-types to REE-F complexing [12]. The behaviors of Zr, Hf, Y, and Ho are generally controlled by CHARAC behavior and the chondritic ratios for Y/Ho and Zr/Hf have ranges of 24–34 and 26–46, respectively [13]. Particle reactivity of Ho relative to Y in various geochemical processes such as aqueous and other environments causes Ho to be scavenged preferentially by Fe- and/or Mn-oxides (hydroxides) [13-15]. Moreover, during weathering conditions the Y/Ho ratios increase (44–74), due to surface complexation and/or increasing the solubility of Y relative to Ho [16]. Studies of F-rich hydrothermal fluids indicate that fractionation of Y from Ho is not related to fluid sources but mostly depends on fluid composition [17].

This work aims to study the geochemistry, mineralogy, radioactivity and genesis of Abu Hadeida pegmatites.

2. Methodology

All chemical and mineralogical studies were carried out in the labs of Nuclear Materials Authority. Trace elements were analyzed by XRF technique while the REEs analyzed by inductive coupled plasma mass spectrometer (ICP-MS). The heavy minerals were separated by heavy liquids (bromoform) and studied by stereo-microscope and Environmental Scanning Electron Microscope (ESEM).The composition of these heavy minerals were confirmed by EDX analysis.

3. Geological setting

The exposed rock units in Abu Hadeida area are arranged from the oldest to the youngest as follow; older granites, younger gabbros, younger granites, microgranitic offshoots in addition to basic and acidic dikes (Fig.2).

The younger granites represent the highest mountainous outcrops. they are hard and resistant to weathering and erosion. This granite is more homogeneous in the mineralogical composition which comprised of alkali feldspar granites and characterized by equigranular, medium to coarse grained. The younger granites are found at the South part of the studied area intruding the older granitoids and younger gabbro in different directions. The contact area is relatively represented by finer size forming chilled margins, and highly crammed with numerous xenoliths of older granitoids and younger gabbro with different shapes and sizes.

From the field observations, younger granite divided into two phases the first is the normal granite of Abu Hadeida area with regular radioactivity and the second one is the mineralized granite which called microgranite offshoots with highly radioactivity.

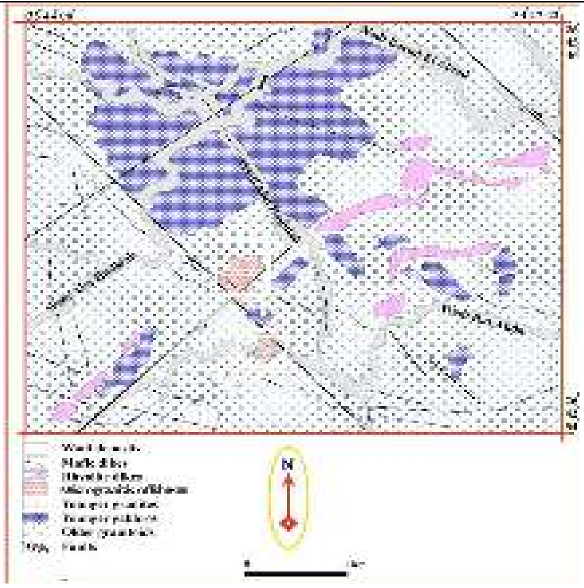
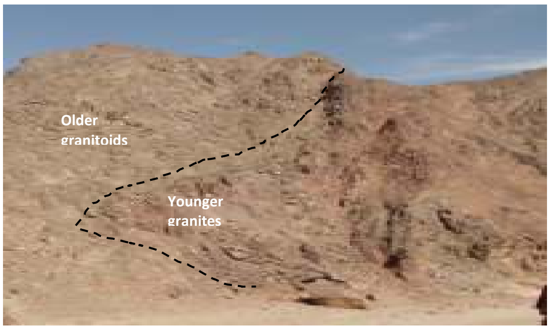


Fig (2): Geological map of Abu Hadeida area [Modified after 3].

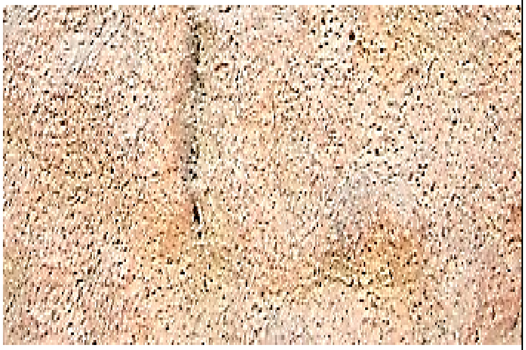
The microgranite offshoots (mineralized granite) occur as vertical walls and/or elongated elliptical-shaped bodies, with outcrop dimensions range from few meters to hundred meters in length and from less than a meter up to tens of meters in width. These offshoots have different size, shapes and intruding older granitoids (Fig.3a) and the younger gabbros.

Many hydrothermal alteration processes such as hematitization,silicification,kaolinization,episyenitization(Fig.3b), chloritization and manganese dendrites are affecting the mineralized granitic rocks with different degrees of intensity. The hematitization and silicification are the most common and the most influential. Hematitization always exists in the fractured zones accompanied with visible uranium mineralizations (Fig.3c), due to the high ability of iron oxides for uranium adsorption from its bearing solutions [18].

Pegmatite pockets and bodies are found associating the granitoid rocks and may be related to the fractures and joints in the younger granite with maximum diameter one meter (Fig.3d) or may occur along the contact with the mineralized zone in the granite (Fig.3e). Generally, this pegmatite in the studied area is categorized as unzoned type and divided into two types, the first one related to the normal granite with low radioactivity in uranium and thorium and called normal pegmatite (non-mineralized) while the second one is related to the mineralized granite (microgranite offshoots) with high radioactivity and called the mineralized pegmatite.



(fig 3a) Younger granites intruding the older granitoids



(fig 3b) Episyenitization in younger granite

(fig 3c) uranium- mineralization with iron oxides

(fig 3d) Pegmatite at the joint plane of younger granites

(fig3e) Pegmatite pocket at the mineralized zone of younger granites

On the other hand, the normal granite and the mineralized granite (micrograniti offshoots) are alkali feldspar granite [19] consist essentially of potash feldspar (perthite, microcline perthite and microcline), quartz and rarely mica. Zircon, allanite, kasolite and uranophane as accessory minerals with thorite minerals [19].The two types of pegmatite which recognized in Abu Hadeida area are consists essentially of very coarse crystals of orthoclase and quartz. The accessory minerals are different in the two types of pegmatite. The normal pegmatite has only zircon crystals, but the mineralized pegmatite has zircon, fluorite, allanite and some radioactive minerals as will shown later.

4. Geochemistry of trace and rare earth elements

4.1. Geochemistry of the trace elements:

To understand the geochemical behavior of trace elements(Table 1) in the mineralized and normal pegmatites, it is recommended to normalize the pattern of such rocks to its corresponding fresh granite. After that, the reference granite pattern becomes flat at unity and the relative depletion or enrichment are given by the deviations on both sides of the reference line.

Table (1): Chemical analyses of trace elements for Abu Hadeida and the average world pegmatites.

	Mineralized pegmatite ◆						Normal pegmatite ◆						World (20)
S.No.	1	2	3	4	5	Av.	6	7	8	9	10	Av.	
Cr	47	62	55	47	42	50.6	22	27	36	31	28	28.8	
Cu	34	11	12	12	13	16.4	19	21	22	17	20	19.8	
Ni	23	18	16	17	20	18.8	6	7	8	5	9	7	
Zn	147	199	203	56	109	142.8	57	60	47	44	39	49.3	44-148
Zr	2020	2173	2540	1998	2227	2191.6	302	325	527	445	332	386.2	117.7-218.6
Ga	27	25	39	33	35	31.8	14	18	19	11	16	15.6	21.2-29.3
Sr	37	41	41	39	40	39.6	12	11	17	15	13	13.6	32.4-80.7
Y	498	517	419	461	453	469.6	55	49	37	49	45	47	19.6-33
Rb	155	169	135	144	156	151.8	14	16	9	13	10	12.4	182.5-883.8
V	1	2	1	3	5	2.4	1	1	1	2	1	1.2	
Nb	285	378	355	311	325	33.8	53	56	92	77	66	68.8	13.9-18
Pb	31	23	14	12	15	19	17	19	12	14	15	15.4	
Ba	35	39	38	36	38	37.2	89	83	88	91	78	85.8	512-834
U	448	520	485	414	560	485.4	0.11	0.14	0.12	0.15	0.13	0.13	2.7-4.6
Th	512	612	581	483	710	579.6	2	5	3	2	1	2.6	
Rb/Sr	14.19	4.12	3.14	3.69	3.9	5.808	1.17	1.45	0.53	0.87	0.77	0.958	
Ba/Rb	0.29	0.25	0.28	0.25	0.27	0.268	6.36	5.19	9.78	7	7.8	7.226	

4.1.1. Mineralized pegmatite:

The enrichment of mineralized pegmatites in some elements (e.g., U, Th, Zr and Nb) may be resulted from the presence of Nb-Ta and U-Th mineralization and/or mineral deposits. Rb decreases may be resulted from the destruction of K-feldspar during alteration processes. Several incompatible trace elements (e.g., Ba, Nb, Zr, U, Th and Y) tend to be concentrated in the liquid and late-stage phases during melting and crystallization of magma. Consequently, they are usually enriched in the granitic liquids [21]. These elements, like other types of trace elements are mostly found either in the form of suspended and/or dispersed impurities in the late stages of magmatic differentiation. Ba and Sr increase with the presence of muscovite and illite. Ga, pb, V and Cr decrease could be related to the decomposition of biotite and ferromagnesian minerals. Zn increases with increasing sulphides such as pyrite, arsenopyrite and sphalerite. The enrichment-depletion trends for some trace elements (Fig.4a) is due to the variations in physico-chemical conditions of the fluids such as pH, Eh, temperature, and ionic complexes during the development of this deposit [22-23].

4.1.2. Non mineralized (Normal) pegmatite:

The increment of Ni may be related to its association with clay minerals during alteration processes. Sr enrichment occurs during Na-metasomatism. [24] revealed that high-temperature altering fluids cause mobility of HFSE and cause the exit of these elements from the alteration system while the low-temperature fluids induced enrichment of these elements, which could be related to Zr increasing and Y depletion (Fig.4b).

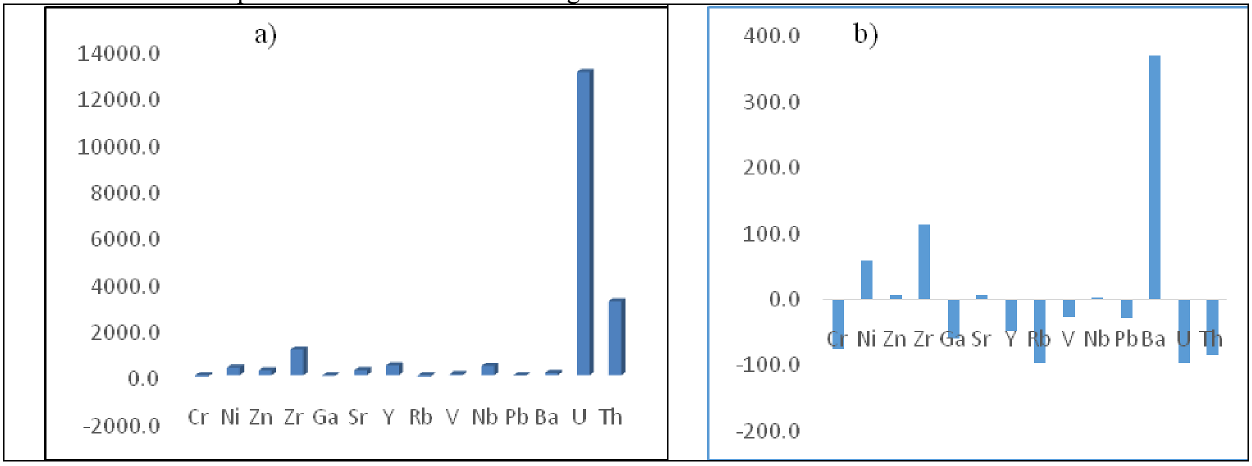


Fig (4): a): Enrichment –Depletion diagram of Mineralized pegmatite in Abu Hadeida area.
b):Enrichment –Depletion diagram of normal pegmatite in Abu Hadeida area.

4.2. Geochemistry of Isovalents:

4.2.1.La/Y ratio and Ce anomaly:

La/Y ratio values >1 are connected to alkalic environment and <1 to acidic environment [25-26 , 23]. Results of La/Y ratio in the studied mineralized and normal pegmatites are more and less than unity (Table 2) indicating the changes in the physic-chemical conditions of the mineralizing fluids in the studied rocks.

Ce anomaly is highly related fO_2 [27]. Ce^{3+} converted into Ce^{4+} in Oxidizing environments which has smaller ionic radii and higher charge [28]. Tetravalent oxidation state of Ce is less mobilized in comparison with other REE3+ [29]. Ce anomalies are <1 in the studied rocks(Table 2) suggesting the prevailing of reducing conditions.

4.2.2.Eu anomaly:

Eu has two oxidation states, Eu^{2+} and Eu^{3+}, during geochemical processes. In low oxygen fugacity (almost reducing) environments, Eu2+, along with soft bases such as HS^{-}, S^{2-} and CH_4 are commonly formed [30-31]. Thus, Eu2+ can form more stable complexes and precipitate from solutions or fluids after being oxidized to Eu^{3+} [32]. All the samples in the mineralized and normal pegmatite samples have Eu anomaly values less than unity confirming the prevailing reducing conditions especially in the normal pegmatite samples (Table 2).

4.2.3.Y/Ho ratios:

Y/Ho ratios for the crust, mantle and high-temperature hydrothermal fluids are within the range of ~26–28, where as this ratio for sea water and marine sediments increases to ~47 [33]. Studies of F-rich hydrothermal fluids indicate that fractionation of Y from Ho is not related to fluid sources but mostly depends on fluid composition [17].

Y/Ho ratios in the studied rocks vary between (16.5 and 71.4, 10 and 343.75, respectively) in the mineralized and normal pegmatites (Table 2) confirming the non-CHARAC behavior, which are quite consistent with tetrad-effects of the corresponding samples. Also, the severe shift of Y/Ho ratios from the chonderitic values may be connected to the effect high and low temperature mineralizing fluids.

. Table (2): Chemical analyses of rare earth elements for Abu Hadeida and the average world pegmatites.

	Mineralized pegmatite ◆						Normal pegmatite ◆						World (34)
S.No.	1	2	3	4	5	Av.	6	7	8	9	10	Av.	
La	298.2	408.8	310.97	312.5	620.3	390.15	81.12	10.11	64.13	10.13	18.11	36.7	270
Ce	471.75	497	436.72	507.6	889.19	560.45	74.56	9.35	61.58	9.78	17.48	34.6	470
Pr	59.65	42.62	43.89	48.25	95.93	58.07	67.77	8.03	56.8	7.35	12.4	30.5	57
Nd	283.4	163.2	141.31	167.6	444.3	239.96	55.5	4.49	45.6	6.21	9.93	24.3	221
Sm	73.21	41.6	25.39	41.73	130.61	62.51	11.72	2.38	36.41	4.2	7.45	12.4	-
Eu	3.34	2.66	1.55	2.67	3.54	2.75	0.13	0.11	0.02	0.1	0.19	0.11	2.1
Gd	36.22	43.32	46.96	31.11	73.85	46.29	5.92	0.97	5.8	0.93	3.12	3.35	49
Tb	7.31	8.77	8.29	4.3	21.42	10.02	6.34	1.51	5.03	1	4.78	3.73	1.6
Dy	28.35	56.84	37.7	27.62	98.93	49.89	1.46	1.2	3.98	1.3	6.28	2.84	-
Ho	7.55	11.5	9.34	6.48	27.45	12.46	0.16	0.63	3.63	1.2	4.5	2.02	0.8
Er	19	29.62	23.6	18.95	68.92	32.02	0.08	0.45	2.45	2.41	4.52	1.98	29
Tm	3.38	3.68	4.41	3.57	6.68	4.34	2.1	1.99	2.3	2	1.98	2.07	9
Yb	40.49	22.2	23.76	23.5	19.46	25.88	1.32	0.37	1.55	0.56	5.19	1.8	100
Lu	10.76	2.01	3.78	3.21	2.02	4.36	0.42	0.03	0.57	0.15	6.17	1.47	22
TREE	1342.61	1333.82	1117.67	1199.09	2502.6	1499.2	308.6	41.62	289.85	47.32	102.1	158	
∑LREE	1113	1111.6	932.9	1035.9	2049.7	1248.6	278.9	31.98	288.1	33.5	57.9	138	
∑HREE	73.63	57.51	55.55	49.23	97.08	66.6	3.92	2.84	6.87	5.12	17.86	7.32	
LREE/HREE	15.12	19.33	16.79	21.04	21.11	18.68	71.15	11.26	41.94	6.54	3.24	26.8	
La/Y	0.6	0.79	0.74	0.68	1.37	0.836	1.47	0.21	1.73	0.21	0.40	0.8	
Y/Ho	65.96	44.96	44.86	71.14	16.5	48.68	343.75	77.78	10.19	40.83	10	96.5	
U/Th	0.88	0.85	0.83	0.86	0.79	0.842	0.06	0.03	0.04	0.08	0.13	0.07	
Ce/Ce′	0.77	0.79	0.87	0.96	0.77	0.832	0.50	0.58	0.51	0.54	0.56	0.54	
EU/Eu*	0.2	0.2	0.1	0.2	0.1	0.16	0.043	0.188	0.003	0.108	0.103	0.09	
(La/Yb)cn	5	12.4	8.8	1.9	1.2	5.86	41.53	18.46	27.96	0.33	0.24	17.7	
(Tb/Yb)cn	0.8	1.7	1.5	0.9	1.5	1.28	20.54	17.45	13.88	5.35	6.19	12.7	
(Gd/Yb)cn	0.7	1.6	1.6	1	0.8	1.14	3.62	2.12	3.02	0.22	0.24	1.84	

(La/Sm)cn	2.6	6.2	7.7	1	1.2	3.74	4.36	2.67	1.11	2.15	3.05	2.67
t1	0.81	0.79	0.93	0.96	0.78	0.854	1.495	1.814	1.54	1.51	1.55	1.58
t3	0.95	1.09	0.92	0.83	1.11	0.98	3.4	1.87	1.06	1.17	1.59	1.82
t4	0.85	1.21	1.12	1.22	1	1.08	9.42	7.66	1.66	1.82	0.63	4.24
t1*t3	0.88	0.93	0.92	0.9	0.93	0.912	2.25	1.84	1.28	1.33	1.57	1.65
t1*t4	0.83	0.98	1.02	1.08	0.89	0.96	3.75	3.73	1.6	1.66	0.99	2.35

4.2.4.Rb-SrDiagram: The strontium distribution in igneous rocks is controlled by the extent to which Sr^{2+} (l.13 Å) can substitute for Ca^{2+} (0.99 Å) in calcium-bearing minerals and the degree to which potassium feldspar can capture Sr^{2+} in the K^+ sites. So, the principal carriers of Sr in igneous rocks are plagioclase feldspar and apatite. The Rb increases and the Sr decreases during the magmatic differentiation.(Fig.5a) show that Rb and Sr in mineralized pegmatite are greater than the normal pegmatite which mean that the mineralized pegmatite is more differentiated than the normal one. On the other hand, the concentration of Sr is high in mineralized pegmatite due to the effect of hydrothermal solution on the mineralized one comparing to the other one.

4.2.5.Ba-Sr Diagram: The Ba and Sr elements decrease continuously from less evolved samples to the most evolved samples. (Fig.5b) show that all samples of mineralized pegmatite lie below Ba/Sr=1 which are the most evolved samples but the normal pegmatite samples lie over Ba/Sr=1 which are less evolved samples.

4.2.6.Ba/Rb vs Rb/Sr Diagram: These geochemical ratios are used to evaluate the degree of evolution of the granitic pegmatite [35]. (Fig.5c) show that the mineralized pegmatite follows the more evolved trend, while those of normal pegmatite follow the trend of less evolved one, this mean that the mineralized pegmatite is highly differentiated and affected by hydrothermal solution than the normal one.

4.2.7.Th-U Diagram: Th and U increase with differentiation, also, there is a direct relation between Th and U where U increase with the increasing in Th. Thus, in (Fig.5d) there is a clear direct relation between Th and U in the mineralized pegmatite but in normal pegmatite there in no clear relation due to very low values of U, Th in these samples comparing with the other one. Although, the two types of pegmatite are found in the same area but the concentrations of Th and U are different. This difference may caused by a lot of factors, the first is the difference in magma where mineralized pegmatite derived from high Thorium and may high Uranium magma but the second one is derived from low Thorium, Uranium magma. the second factor is the effect of hydrothermal solution on mineralized pegmatite which enriched it with Uranium Quite the opposite with the other type which not affected by hydrothermal solution.

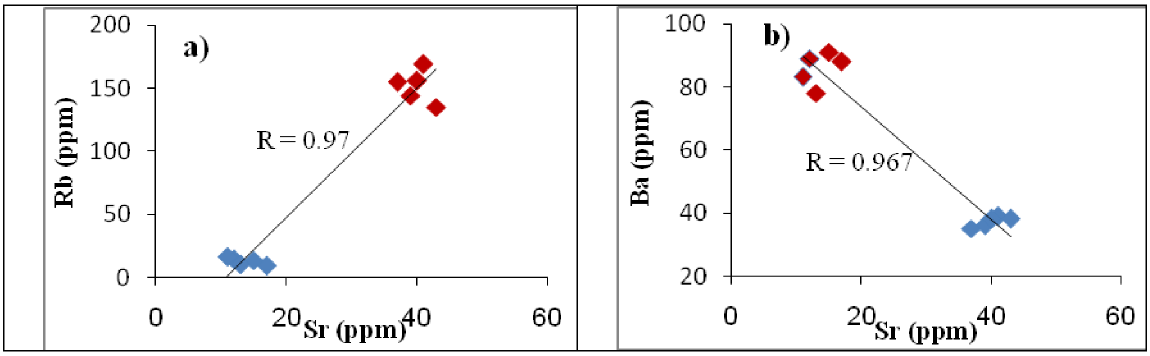
4.2.8.U-Zr Diagram: There is a direct relation between U and Zr with differentiation. (Fig.5e)show that, both U and Zr are found with high values in mineralized pegmatite due to the magma rich or effect the hydrothermal solutions but the normal one is not. This mean there are two generations or magma for the two types.

4.2.9.U-Nb Diagram: according to the differentiation of magma U has a direct relation with Nb. In (Fig,5f) the mineralized pegmatite has higher values of U and Nb than the normal pegmatite as a result of enrichment in magma or the effect of hydrothermal solution which reflect the idea of two generation or magma.

4.2.10.U-Rb Diagram: due to U and Rb increase with differentiation so, there is a direct relation between U and Rb with clear state in mineralized pegmatite. this increasing reflect the enrichment during magmatism and by the effect of hydrothermal solution, but in normal pegmatite there is no clear relation due to low values of U and Rb (Fig. 6a).

4.2.11.Th-Zr Diagram: Thorium also increase with differentiation so, there is a direct relation between Th and Zr in mineralized pegmatite due to the increasing of Th and Zr in magma melt (Fig.6b) also, there is no relation in normal pegmatite reflecting the poor of magma melt.

4.2.12.Th-Nb Diagram: Th and Nb have high values in mineralized pegmatite with direct relation with differentiation (Fig.6c) comparing with low values of normal pegmatite which reflecting the difference in magma.



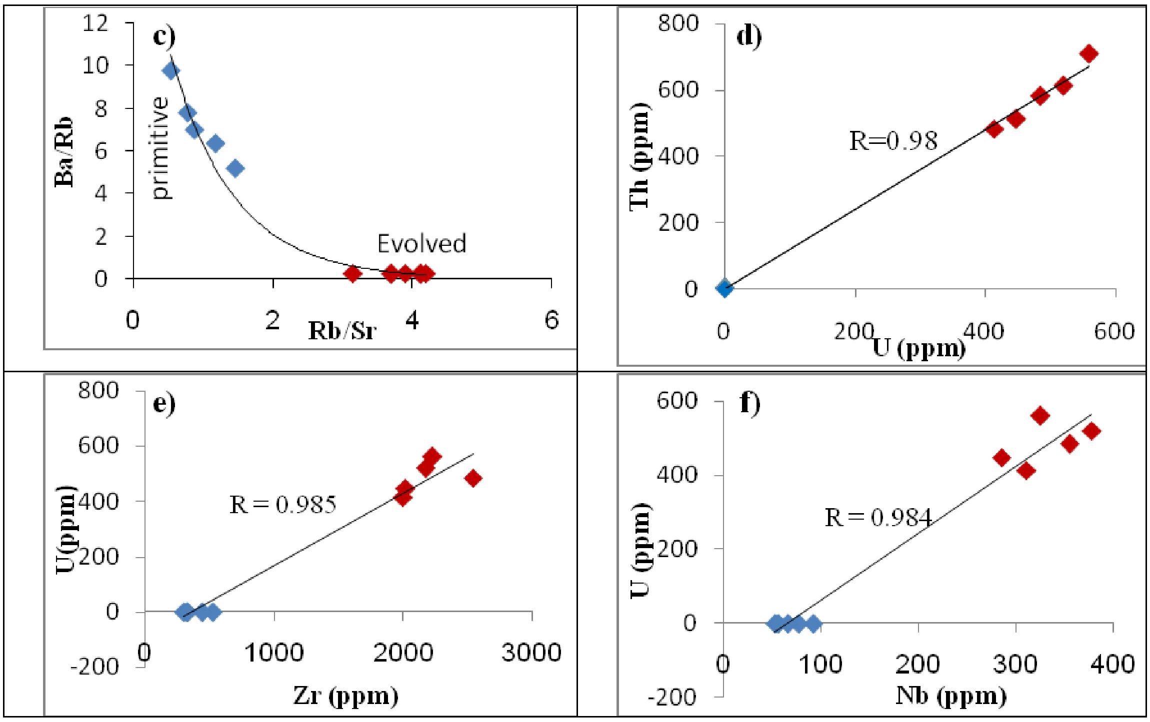
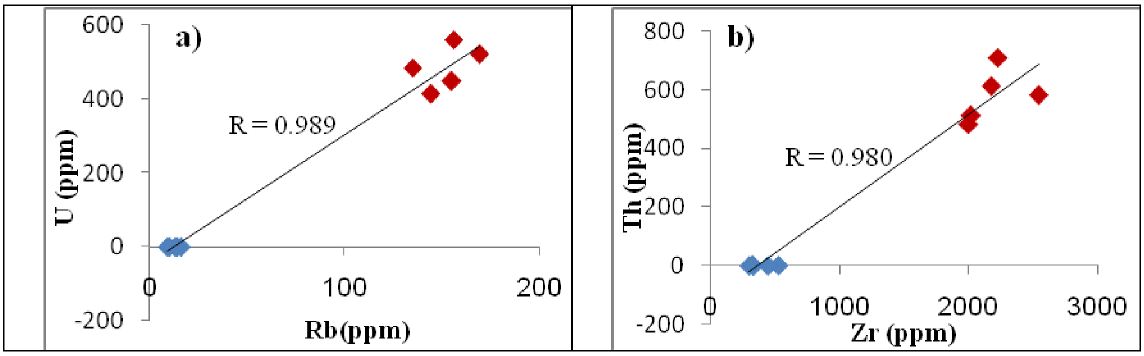


Fig (5): a)Rb-Sr. **b)**Ba-Sr. **c)**Ba/Rb V Rb/Sr. **d)**Th- U. **e)**U-Zr and **f)**U-Nb diagrams for Abu Hadeida pegmatites.
◆ Mineralized pegmatite. ◆ Normal pegmatite.

4.2.13.Th-Rb Diagram: due to the enriched magma with Th and Rb the relation between the two elements appeared clear with no identification relation in normal pegmatite (Fig.6d).

Experimentally, it was confirmed that uranium and thorium have a good geochemical coherence during crystallization of a granitic magma [36-37]. As a result, for a given magma the Th/U ratio is fairly constant, and thorium and uranium are highly correlated [38-39]. Thorium and uranium contents of the host younger granites [19] and the studied pegmatites binary diagram is manifested in (Fig.6e). It is indicated that there is a strong positive correlation between uranium and thorium which could be related to the differentiation trends [40-42]. (Fig.6e) also clarifies that the normal pegmatite and the normal granite intimate to the magmatic trend (MT) while the mineralized pegmatite is mainly related to the pegmatitic trend (PT) suggesting that all these granitic rocks couldn't be originated from the same magma and the mineralized pegmatite doesn't intimate to the normal granites or normal pegmatite.



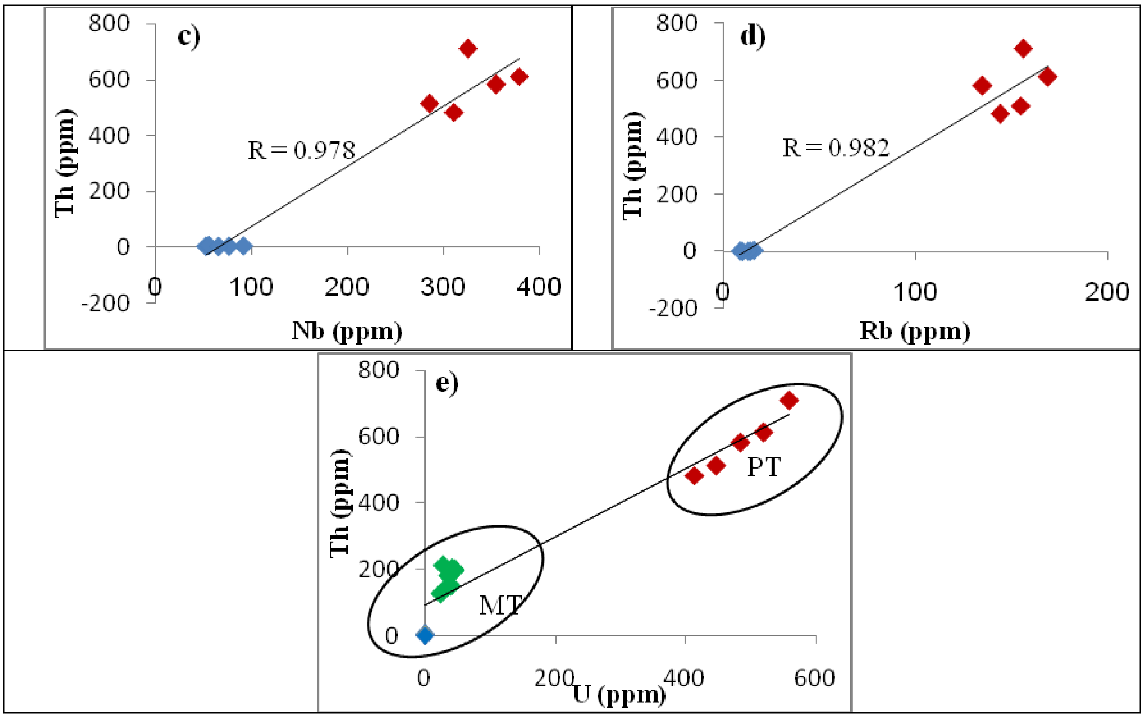


Fig (6): **a)**U-Rb. **b)**Th-Zr. **c)**Th-Nb. and **d)**Th- Rb diagrams for Abu Hadeida pegmatites.
e) eTh vs .eU binary diagram, MT(magmatic trend) and PT(pegmatite trend), after [40].
◆ Mineralized pegmatite. ◆ Normal pegmatite. ◆Normal granite

The REEs are divided into light and heavy groups based on their atomic weights. The light elements group from lanthanum to gadolinium and the heavy elements group from terbium to lutetium [43].

From (Table 2) we note that, there are two types of pegmatite according to values of REEs. The first one is the mineralized pegmatite and characterized by high values of rare earth elements and related to the mineralized granite(S.No.1 to5).But the second type is the normal pegmatite with low values of rare earth elements and related to the normal granite in the studied area(S.No.6 to10). On the other hand, ∑LREE is greater than ∑HREE in mineralized pegmatite which related to a high content of volatiles and vice versa but ∑LREE is smaller than ∑HREE in the normal pegmatite referring to low content of volatiles and vice versa. This difference between the two types in the rare earth elements values is due to the difference in magma source or the effect of hydrothermal solution rich with these elements on the mineralized pegmatite comparing the normal one.

4.3. Rare earth tetrad effect:

The average of the total REEs content of the studied mineralized pegmatite (av. ΣREE=1449.16 ppm) is higher than the world-wide granitic rocks (ΣREE=250−270 ppm) as given by [44] and the crustal abundance of REEs [45-46], (176.2, 144.3, respectively). Whereas the normal pegmatite shows lower contents (157.9), which is nearly in the range of crustal abundance. The depletion of REEs could be revised to various processes including magmatic differentiation [47], hydrothermal leaching [48] and or a combination of both [49].Pegmatites at G. El Fereyid, South Eastern Desert, Egypt have lower contents than the studied mineralized pegmatites but higher than the studied normal pegmatites, suggesting the mineralized nature of Abu Hadeida mineralized pegmatite [50].

The zigzag REE patterns of the studied pegmatites are characterized by the prominent convex and concave tetrads and pronounced negative Eu anomalies. Detailed studies indicate that the first and fourth tetrads in most samples are more pronounced than the third one in the mineralized granite whereas the first and third tetrads are clearer than the fourth one in the normal granite.

Composite types tetrad effect (M- and W- shape) have been recorded in different environments such as Terra Rossa in China, the Tono uranium deposit of Japan and other deposits worldwide [8, 51-56]. Based on the Gibbs Free Energy of REE theory, [57] reported that the existence of both W- and M-type tetrad effects in the same deposit can be related to weathering, leaching by groundwater and/or mixing of fluids and/or waters or combinations of these.

Rare earth patterns of the mineralized pegmatites have strong W-type tetrad effect in the first and strong M-type tetrad effect in the fourth one(Fig.7a), though the presence of t3 M-type tetrad in one sample and t4 W-type tetrad in other sample. It is worthy to mention that the W-type tetrad is more recognized in the mineralized pegmatite than the normal pegmatite. On the other hand, very strong M-type was detected in most samples of the normal pegmatite and W-type tetrad in only one sample(Fig.7b). The index of tetrad effect intensity, TE1,4, is higher than 1.10 ranging from 0.99 to 3.75 with 2.35 as an average whereas, TE1,3 range from 1.28 to 2.25 with average of 1.69 which suggest that there was an interaction between melt and water-haloid-rich fluid when these pegmatites are crystallized from magma [55-56]. The coexistence of W-and M-shape tetrad-effects in the mineralized pegmatite indicates the role of low-pH surface waters as illustrated from W-type tetrad and lead to the destruction, leaching and transportation of REE-bearing minerals, in contrast to the accumulation role of M-type tetrad effect.

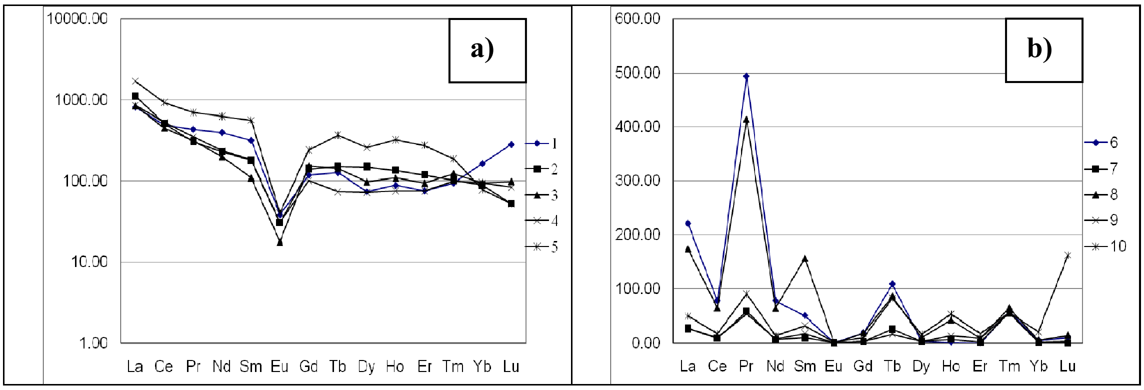


Fig (7): a) Rare earth patterns of the mineralized pegmatite.
b) Rare earth patterns of the normal pegmatite.

MW-type of tetrad effect is likely to be caused mainly by the interaction of aqueous liquids with alkaline rocks [58]. [59] in Kab Amiri granite, CED, Egypt revised the convex (M-type) T_1 associating with concave (W-type) T_4 to the physico-chemical conditions that prevailed during the alkali-metasomatism of the Kab Amiri granitoids have always been changing and the alteration products vary from one place to another. The composite MW-type tetrad effect could be an evidence for Au mineralization of reworked plutons and this vision could be applied in the study area where, there is high Au contents in the mineralized pegmatites [60].

5. Mineralogical Studies

The collected samples were subjected to heavy liquid separation to liberate the considered radioactive minerals from the other gangue minerals using bromoform solution (sp.g.2.81g/cm^3) and methylene iodide solution (sp.g.3.32g/cm^3). The heavy fractions resulted from the heavy liquid separation were magnetically classified using the High Intensity Frantz Isodynamic Magnetic Separator (model L1).The different magnetic fractions were carefully examined by the Binocular Stereomicroscope. The most important radioactive minerals in the studied mineralized samples are represented by the secondary uranium minerals; uranophane and autonite and the thorium minerals such as Thorite. On the other hand, Zircon, Fluorite, titanite and gold were also studied. The mineralogical study of the radioactive minerals and the other minerals were achieved using Environmental Scanning Electron Microscope (ESEM)at the laboratories of the Nuclear Material Authority (NMA) Egypt.

5.1. Uranium and thorium Minerals:

[61] suggested that most of the secondary uranium minerals in the shear zones are formed by replacing of primary uranium-thorium minerals (uraninite, pitchblend and/or thorite) as a result of pH and/or Eh changes through the effect of hydrothermal fluids.

The mineralized pegmatite samples are stained with noticeable concentrations of secondary uranium minerals. These minerals appear as yellow spots on the surface of the samples. Pure handpicked grains of the uranium and thorium minerals were collected from the mineralized samples. uranophane and autonite as principal secondary uranium minerals and thorite as thorium minerals were identified by the scanning electronic microscope.

5.1.1. Uranophane [$Ca (UO_2)_2SiO_3 (OH)_2 . 5(H_2O)$]

[62] stated that uranophane is a monoclinic uranyl silicate mineral fairly common in the oxidized zone of most deposits. The conditions of formation of this mineral include both the late stages reactions of uraninite with hydrothermal solutions and also alteration by groundwater [63].

[64] stated that uranophane occurs as idiomorphic prismatic, acicular or reticulate. More commonly, the mineral is compact, massive or powdery and often it is seen as scaly incrustation or films on primary minerals. The color is generally yellow (very pale yellow, canary yellow, lemon yellow, brownish yellow and orange).The massive varieties exhibit the greatest variation in color. The luster of the crystals is usually pearly or greasy while the acicular form appears silky and the massive varieties are earthy to resinous, or waxy for the more compact type. The hardness is 2-3 in the Moho′s scale.

In the studied mineralized pegmatite, uranophane occurs as massive, granular and sometimes radiated fibrous aggregates. Uranophane mineral grains exhibit canary yellow to reddish yellow color with dull to greasy luster (Fig.8a). The reddish tint of some uranophane grains may be due to the incrustation by iron oxide. ESEM analyses of the some uranophane grains are shown in (Fig.8b).

5.1.2. Autunite [$Ca(UO_2)_2 (PO_4)_2 . 10\text{-}12H_2O$]

It occurs as an oxidation product of uranium minerals in granite, pegmatite and hydrothermal deposits. Autunite crystals are generally characterized by their dull luster and present as soft aggregates or tabular grains of bright yellow colors (Fig.8c). The SEM data (Fig.8d)confirms the chemical composition of autunite.

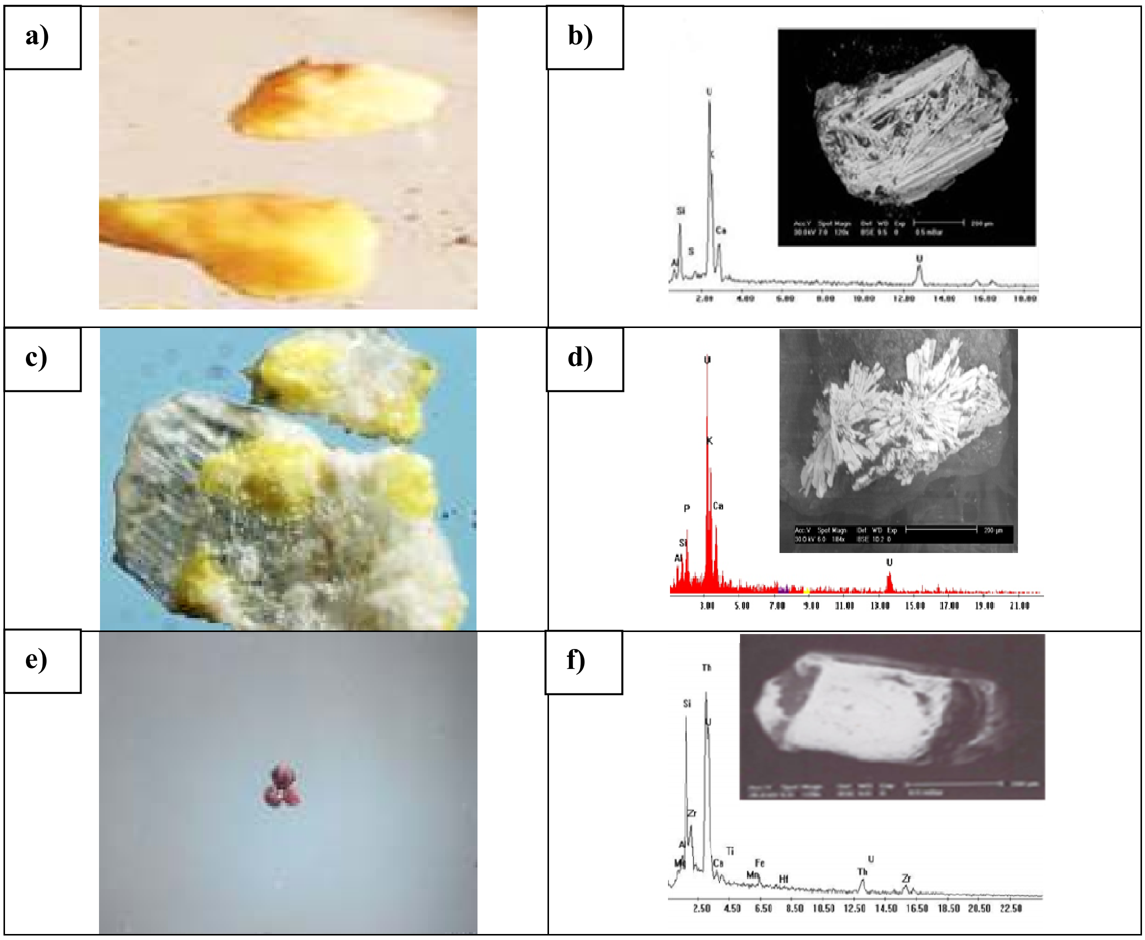


Fig (8): a) grains of Uranophane. b) ESEM photomicrograph of uranophane.
c) grains of Autonite. d) ESEM photomicrograph of autonite.
e) grains of Thorite. f) ESEM photomicrograph of thorite.

5.1.3. Thorite [$ThSiO_4$]

Thorium is estimated to be three times as common as uranium in granitic rocks [36] and all the thorium in the Earth's crust could have more potential energy than both uranium and the fossil fuel reserves combined [65]. Thorite occurs in natural as a primary mineral chiefly in pegmatites. It can vary in composition through the substitution of U, rare earths, Pb, Zr, Fe, and Ca chiefly, in variable and sometimes large amounts. Thorite almost has undergone extensive secondary alteration of both a structural and chemical nature. Structurally, the mineral may lose its crystallinity and assume a glasslike state in metamict state.

In the studied mineralized pegmatite, It occurs as brownish black to black opaque grains of greasy luster (Fig.8e). Most of thorite mineral grains are subhedral to anhedral crystals. Rarely, euhedral prismatic thorite grains are present. ESEM analyses of the some thorite grains are shown in (Fig.8f).

5.2. Uranium and Thorium bearing minerals

5.2.1. Zircon [$ZrSiO_4$]

Zircon is generally present as small early formed crystals often enclosed in later minerals, but it may form large well-developed crystals (consisting of prism and bipyramid) in granites and pegmatites [66-67]. Zircon is fairly resistant to normal chemical attack. Altered varieties are, therefore, not common. The metamict state (breakdown of the structure) in zircon may be due, at least in part, to the presence of radioactive atoms [66].

Zircon crystals are generally colorless and transparent (Fig.9.a). They are generally prismatic shape with bipyramidal termination or extremely short broken prisms, characterized by adamantine luster. (Fig.9.b) shows the analyses of the studied zircon using the (ESEM).

5.2.2. Fluorite [CaF]

[68] concluded that the granites rich in secondary uranium minerals (the highly sheared granites) are usually rich in fluorite of deep blue to violet colors. [69] classified Egyptian fluorite into two main groups according to their total REEs contents. Group A contains REEs > 100 ppm and is associated with albitized granites (mostly GIII) and rare metal mineralization whereas Group B contains REEs < 100 ppm and is associated with U and Th mineralization or devoid of any mineralization (mostly GII). He also revealed that Sr might be responsible for the appearance of colorless to rather white color while Y is responsible for the green color while the blue and mauve colors are attributed to the radiation damage and the presence of colloidal Ca.

In the studied area, fluorite is common in the mineralized pegmatite and absent in the normal pegmatite. it is found as colourless or violet fluorite (Fig.9.c) and may found associating iron oxides. ESEM analyses of some fluorite grains are shown in (Fig.9d).

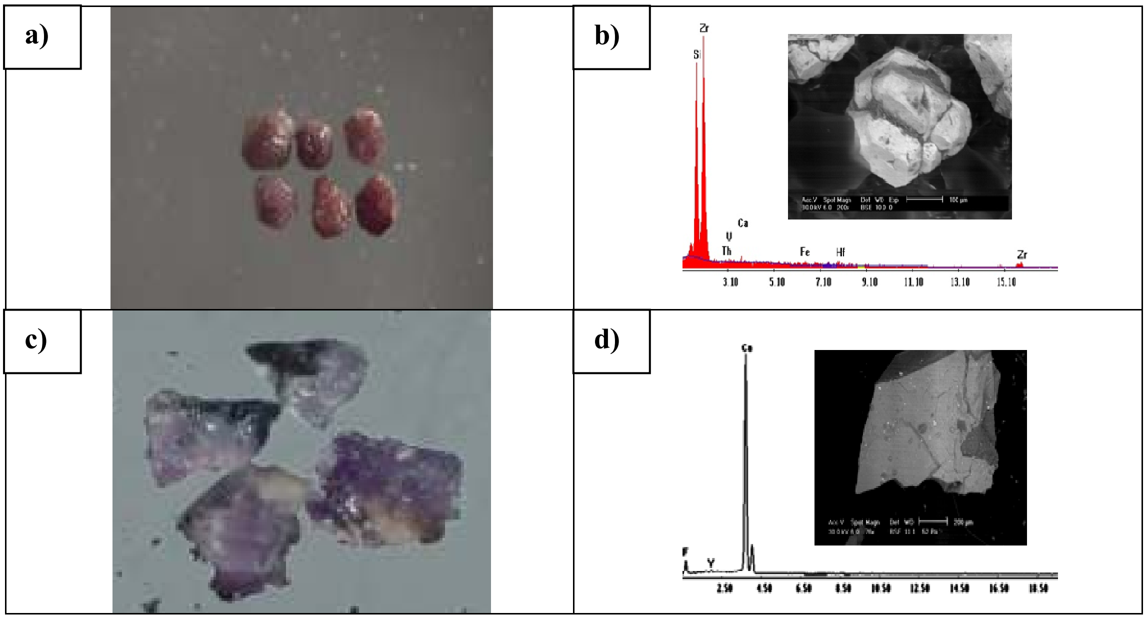


Fig (9): a) grains of Zircon. b) ESEM photomicrograph of Zircon.
c) grains of Fluorite. d) ESEM photomicrograph of Fluorite.

5.3. Other minerals

5.3.1. Titanite [$CaTi\ SiO_5$]

Titanite occurs as a common accessory mineral in intermediate and felsic igneous rocks and associated pegmatites. Titanite appears as euhedral, prismatic crystal with color rang from yellow, green, brown and black or gray(Fig.10a). The brown or black varieties of titanite may carry 1% or more Fe_2O_3 [70].ESEM analyses of the some titanite grains are shown in (Fig.10b).

5.3.2. Gold [Au]

Gold found in nature in the form of the native metal. it is a bright, slightly reddish yellow, soft and ductile metal. It occurs in hydrothermal veins deposited by ascending solutions, as disseminated particles through some sulfide deposits and in placer deposits. In the studied mineralized pegmatite gold is flaky exhibiting shinny metallic luster and ductile(Fig.10c). ESEM analyses of some gold grains are shown in (Fig.10d).

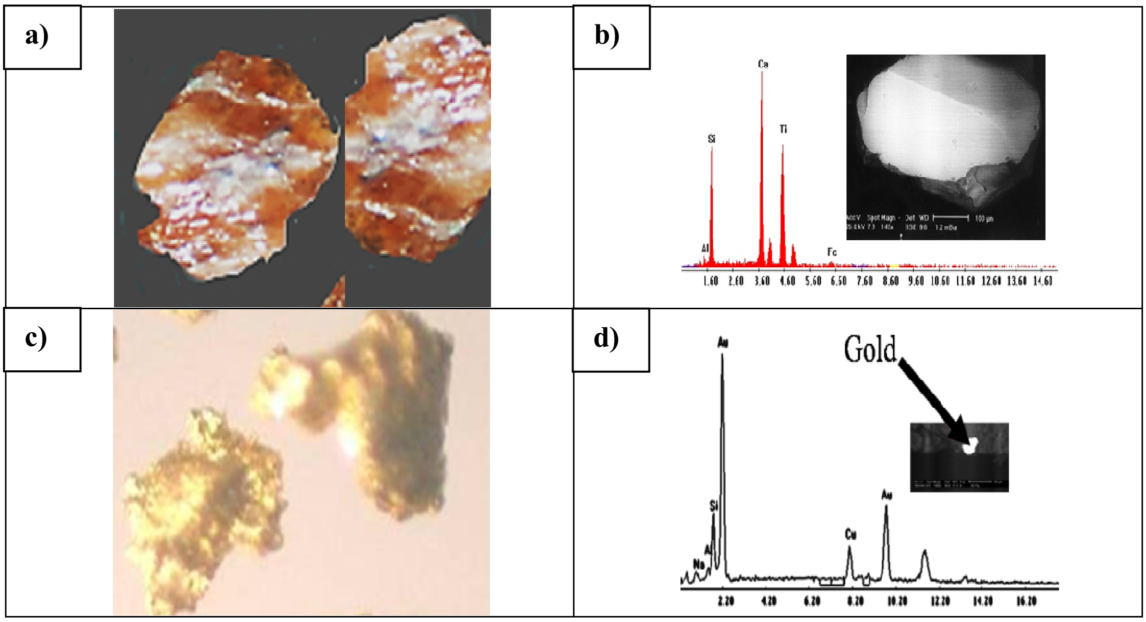


Fig (10): a) grains of Titanite. b) ESEM photomicrograph of Titanite.
c) grains of gold. d) ESEM photomicrograph of gold.

6. Conclusion

Abu Hadeida pegmatite is unzoned mineralized and non mineralized pegmatites. Geochemically, the enrichment-depletion trends for some trace elements in mineralized pegmatite is due to the variations in physico-chemical conditions of the fluids such as pH, Eh, temperature, and ionic complexes during the development of this deposit. The mineralized pegmatite has uranium and thorium contents, in contrast the normal pegmatite. U-Th binary diagram for normal granite, normal pegmatite and mineralized pegmatite show that normal pegmatite and the normal granite intimate to the magmatic trend (MT) while the mineralized pegmatite is mainly related to the pegmatitic trend (PT) and doesn't intimate to the normal granites or normal pegmatite. Rare earth element patterns of the two pegmatites show the presence of the complex M-W type tetrad effects suggesting the dual effect of late stage hydrothermal solutions and surficial or underground water. The convex-concave tetrad phenomena were also confirmed by the presence of gold mineralization. The most important minerals associating mineralized pegmatite are uranophan, autunite, thorite in addition to zircon, fluorite, titanite and gold.

Reference

[1] A. A., Omran: Geological, petrochemical studies and potentiality of uranium-thorium occurrences in Gabal Um Taghir El-Tahtani area with emphasis on the granitic rocks, Central Eastern Desert, Egypt. Ph.D. thesis, Ain Shams Univ., Cairo, Egypt (2005).189 p.

[2]A., El Hadary, A., El Azab and A.A., Omran: Contributions to the geology and mineralogy of Wadi Ras Abda area, North Eastern Desert, Egypt. Nuclear Sciences Scientific Journal.Vol.2.(2013)

[3]A.A.,Omran: Geology, mineralogy and radioelements potentiality of microgranite dikes to the South of wadi Abu Hadeida area, Northern Eastern Desert, Egypt. Al Azhar Bulletine of Science Vol.(25) No.1,June,(2014). pp.47-62.

[4] Y., Pan: Controls on the fractionation of isovalent trace elements in magmatic and aqueous system: evidence from Y/Ho, Zr/Hf and lanthanide tetrad effect A discussion of the article by (M. Bau 1996) Contrib. Min. Petro. Vol. 128,(1997) pp.405-408.

[5] E.V., Badanina, L.F., Syritso, E.V., Volkova, R., Thomas and R.B., Trumbull: Composition of Li-F granite melt and its evolution during the formation of the ore bearing Orlovka massif in Eastern Transbaikalia. Petrology 18,(2010). pp.131–157.

[6] Z.H., Zhao, X.L., Xiong, X.D., Han, Y.X., Wang, Q., Wang, Z.W., Bao, and B.M., Jahn: Controls on the REE tetrad effect in granites: evidence from the Qianlishan and Baerzhe Granites, China. Geochemical Journal, 36.(2002) pp.527–543.

[7] T., Monecke, P., Dulski and U., Kempe: Origin of convex tetrads in rare earth element patterns of hydrothermally altered siliceous igneous rocks from the Zinnwald Sn–W deposit, Germany. Geochimicaet Cosmochimica Acta, 71. (2007) pp.335-353.

[8] Y., Takahashi, H., Yoshida, N., Sato, K., Hama, Y., Yusa, and H., Shimizu: W- and M type tetrad effects in REE patterns for water–rock systems in the Tono uranium deposit, central Japan. Chem. Geol.184.(2002). pp.311–335.

[9] S.M., McLennan: Rare earth element geochemistry and the "tetrad" effect.Geochim. Cosmochim. Acta vol.58.(1994). pp.2025–2033.

[10] W., Irber: The lanthanide tetrad effect and its correlation with K/Rb, Eu/Eu*,Sr/Eu, Y/Ho, and Zr/Hf of evolving peraluminous granite suites. Geochimicaet Cosmochimica Acta, V. 63.(1999). pp.489–508.

[11] L. V. S., Nardi, M. L .L., Formoso, K., Jarvis, l.,V A. C. Bastos Neto and E., Fontana: REE, Y, Nb, U, and Th contents and tetrad effect in zircon from a magmatic-hydrothermal F-rich system of Sn-rare metale cryolite mineralized granites from the Pitinga Mine, Amazonia, Brazil. Journal of South American Earth Sciences, vol.33. (2012). pp.34-42.

[12] T., Monecke, U., Kempe, M., Trinkler, R., Thomas, P., Dulski and T., Wagner: Unusual, rare earth element fractionation in a tin-bearing magmatic hydrothermal system.–Geology, 39.(2011). pp.295-298.

[13] M., Bau: Controls on the fractionation of isovalent trace elements in magmatic and aqueous systems; evidence from Y/Ho, Zr/Hf and lanthanide tetrad effect. Contrib. Mineral. Petrol., Vol.123.(1996). pp.323-333.

[14] M., Bau, A., Koschinsky, P., Dulski and J.R., Hein: Comparison of the partitioning behaviors of yttrium, rare earth elements, and titanium between hydrogenetic marine ferromanganese crusts and sea water. Geochimicaet Cosmochimica Acta,60. (1996). pp.1709–1725.

[15] A., Koschinsky, A., Stascheit, M., Bau, and P., Halbach: Effects of phosphatization on the geochemical and mineralogical composition of marine ferromanganese crusts. Geochimicaet Cosmochimica Acta, 61(19). (1997). pp.4079-4094.

[16] Y., Nozaki, Y.S., Zhang and H., Amakawa: The fractionation between Y and Ho in the marine environment. Earth and Planetary Science Letters, 148. (1997). pp.329–340.

[17] M., Bau and P., Dulski: Comparative study of yttrium and rare earth element behaviors in fluorine-rich hydrothermal fluids. Contrib. Mineral. Petr. 119.(1996). pp.213-223.

[18] H. A., Hussein, M. I. Faris and W., Makram: Radioactivity of some accessory minerals especially zircon in some Egyptian granites and pegmatites. J. Geol., U. A. R., 9, no. 2. (1965). pp.13-16.

[19] A. A., Omran, S. M., Abdallah, M., Abdel Monsif and O., Khairy: Development of a new uranium and thorium occurrence to the South of wadi Abu Hadeida, North Eastern Desert, Egypt. Internal report.(2015).

[20] A.R., Liera , M. F., Fuente , A., Cepedal and A. M., Lzard: Barren and Li–Sn–Ta Mineralized Pegmatites from NW Spain (Central Galicia): A Comparative Study of Their Mineralogy, Geochemistry, and Wall rock Metasomatism. Minerals. 9 (12). (2019) 39; https: // doi. org/10.3390/min9120739.

[21] K.G., Cox, J.D., Bell and R.J., Pankhurst: The Interpretation of Igneous Rocks. George Allen and Unwin,(1979). p.450.

[22] M.M., Karadag, S., Kupeli, F., Aryk, A., Ayhan, V., Zedef and A., Doyen: Rare Earth Element (REE) geochemistry and genetic implications of the Mortasbauxite deposit (Seydis-ehir/Konya-Southern Turkey). Chem. Erde 69. (2009). pp.143–159.

[23] A., Abedini, M. R., Azizi and A. A., Calagar: The Lanthanide Tetrad Effect in Argillic Alteration: An Example from the Jizvan District, Northern Iran. Acta Geologica Sinica,, 92, 4 .(2018). pp.1468–1485.

[24]S., Salvi and A.E., Williams-Jones: The role of hydrothermal processes in concentrating high-field strength elements in the Strange Lake peralkaline complex, northeastern Canada. Geochim Cosmochim Ac. 60.(1996). pp.1917–1932

[25] J., Crinci, and I., Jurkowic: Rare earth elements in Triassic bauxites of Croatia Yugoslavia In: Travaux.19.(1990). pp.239–248.

[26] Z., Maksimovic and G.Y., Pantó: Contribution to the geochemistry of the rare earth elements in the karst-bauxite deposits of Yugoslavia and Greece. Geo derma 51. (1991). pp.93–109.

[27] H.G., Dill, L.I., Luna, N., Nolte and B.T., Hansen: Chemical, isotopic and mineralogical characteristics of volcanogenic epithermal fluorite deposits on the Permo-Mesozoic foreland of the Andean volcanic arc in Patagonia (Argentina).Chem. Erde-Geochem.76. (2016). pp.275–297.

[28] D., Kraemer, N., Tepe, O., Pourret and M., Bau: Negative cerium anomalies in manganese (hydr)oxide precipitates due to cerium oxidation in the presence of dissolved siderophores, Geochimica et Cosmochimica Acta, accepted manuscript. (2017).

[29] J., Constantopoulos: Fluid inclusions and rare earth element geochemistry of fluorite from south-central Idaho. Econ. Geol. 83. (1988). pp. 626–636.

[30] A.B., Dai: Coordination Chemistry. Science Press Beijing.(1987). pp.1–870 (in Chinese).

[31]L., Qicong and L., Congqiang: Geochemical Behaviors of REE and Other Trace Elements during the Formation of Strata bound Skarns and Related Deposits: A Case Study of the Dongguashan Cu (Au) Deposit, Anhui Province, China. Acta Geologica Sinica, vol.77 (2). (2010). pp.246 – 257.

[32] H.S, Tang, Y.J, Chen, M, Santosh, H, Zhong and T., Yange: REE geochemistry of carbonates from the Guanmenshan formation, Liaohe group, NE Sino-Korean craton: implications for seawater compositional change during the great oxidation event. Precambrian Res vol.227. (2013). pp.316–336.

[33] M.G., Gadd, D., Layton-Matthews and J.M., Peter: Non-hydrothermal origin of apatite in SEDEX mineralization and host rocks of the Howard's Pass district, Yukon, Canada. Am. Mineral. vol.101.(2016). pp.1061–1071.

[34] A., Kerr and H., Rafuse: Rare Earth Element (REE) Geochemistry of the Strange Lake Deposits: Implications for Resource Estimation and Metallogenic Models. New found land and Labrador Department of Natural Resources Geological Survey, Report 12-1. (2012). pp. 39-60

[35]R. B., Larsen: The distribution of rare-earth elements in K-feldspar as an indicator of petrogenetic processes in granitic pegmatites: examples from two pegmatite fields in southern Norway. The Canadian Mineralogist. Vol. 40. (2002). pp.137-1512.

[36] J. J. W., Rogers and J. A. S., Adams: Uranium and thorium In: Wedepohl. K.H. (ed), Handbook of geochemistry, New York, Springer Venlege, Vol. 4. (1969). p.92-B-1 to92-C-10.

[37] G. W., Mathews: Uranium occurrences in and related to igneous rocks .U.S. Dept. Energy Open- File GJBX-67(78). (1978). pp.121-180.

[38] J.T., Nash: Uranium and thorium in granitic rocks of north-eastern Washington and northern Idaho, with comments on uranium resource potential. U.S. Geol. Surv., Open-File Rept.79-233. (1979). p.39.

[39]J.S., Stuckless: Uranium and thorium concentrations in Precambrian granites as indicators of a uranium province in central Wyoming. Contrib. Geol. (Wyo. Univ.) 17. (1979). pp.173 -178.

[40] D. M., Shaw: A review of K-Rb fractionation trends by covariance analyses. Geochim. Cosmochim. Acta, V.32.(1968). pp.573-601.

[41] M.A., Ali, M.F., Raslan and M.G., El-Feky: Radioactivity and Mineralogy of Some Pegmatite Bodies from Gabal Al-Farayid Granites,South Eastern Desert, Egypt [C].The 9th International Mining, Petroleum and Metallurgical Engineering Conference. February21–24. Faculty of Engineering, Cairo University.(2005).

[42] M.F., Raslan, M.A., Ali and M.G., El-Feky: Mineralogy and radioactivity of pegmatites from South Wadi Khuda area, Eastern Desert, Egypt. Chin. J. Geochem. 29.(2010). pp.343–354.

[43] J.V., Walther: Essentials of Geochemistry. Jones and Bartlett Publishers Inc. USA. (2005). pp.286-296.

[44] A. G., Hermaan: Yttrium and Lanthanides. In: K. H., Wedepohl(ed),Handbook of geochemistry, Springer-Verlage, Berline II/2. (1970). P.39.

[45] W.D., Jackson and G., Christiansen: International strategic minerals inventory summary report Rare - earth oxides: U.S. Geological Survey Circular, 930N.(1993). p.68.[Also available at http:// pubs. usgs. gov/ circ/ 1993 /0930n/ report.pdf.]

[46]K.H., Wedepohl: The composition of the continental crust Geochimicaet Cosmochimica Acta, 59. (1995). pp.1217-1232.

[47] M., Cuney and M., Friedrich: Physicochemical and crystal-chemical controls on accessory mineral paragenesis in granitoids. Implications on uranium metallogenesis: Bulletin de Minéralogie, V. 110. (1987). pp.235–247.

[48] M., Cathelineau and P. Holliger: Poly phase metallogenesis of hydrothermal uranium veins from the southern amoricon massif, France. Proc. Int. Mtg Nancy.(1987). pp.212-217.

[49] H. I., Ibrahim and M. E., Darwish: Geology and geochemistry of the granitic rocks and associated dykes, East Gabal Nuqra, South Eastern Desert, Egypt. Chin. J. Geochem., vol.31. (2012). pp376–389.

[50] G. M., Saleh, A. M., Afify, B. M., Emad, M. I., Dawoud, H.A., Shahin and F.M., Khaleal: Mineralogical and geochemical characterization of radioactive minerals and rare earth elements in granitic pegmatites at G. El Fereyid, South Eastern Desert, Egypt. Journal of African Earth Sciences, 160, (2019). 103651.

[51] O.R.R., Minuzzi, A.C.B., Neto, M.L.L., Formoso, S., Andrade, V.A., Janasi, J.A., Flores: Rare Earth Element and yttrium geochemistry applied to the genetic study of cryolite ore at the Pitinga Mine (Amazon, Brazil). An. Acad. Bras. Cienc. 80.(2008). pp.719–733.

[52] I.S., Peretyazhko and E.A., Savina: Tetrad effects in the rare earth element patterns of granitoid rocks as an indicator of fluoride silicate liquid immiscibility in magmatic systems. – Petrology, 18. (2010). pp.514-543.

[53]J., Feng: Trace elements in ferromanganese concretions, gibbsite spots, and the surrounding terra rossa overlying dolomite: their mobilization, redistribution and fractionation. J Geochem Explore 108. (2011). pp.99-111

[54] M., Rezaei azizi, A., Abedini, S., Alipour, S., Niroomand, A. Sasmaz and B., Talaei: Rare earth element geochemistry and tetrad effects in fluorites: A case study from the Qahr-Abad deposit,Iran. Neues Jahrbuchfür Geologie and Paläontologie, Abhandlungen, 383 (3). (2017). pp.255-273.

[55] A.M, El-Mezayen, M.G, El-Feky, M.O, Sayed and S.A., Ibrahim: Geochemistry and a composite M-type with W-type of REE tetrad effect in altered granites of Abu Furad area, Central Eastern Desert, Egypt. Greener J Geol Earth Sci 3(2). (2015). pp.013–029

[56] A.M., El Mezayen, M. A., Heikal, M. G., El-Feky, H. A., Shahin, I. K., Abu Zeid and S.R., Lasheen: Petrology, geochemistry, radioactivity, and M–W type rare earth element tetrads of El Sela altered granites, south eastern desert, Egypt. Acta Geochim., 38 (1).(2019). pp.95–119.

[57] I., Kawabe, A., Ohta, S., Ishii, M., Tokumura and K., Miyauchi: REE partitioning between Fe-Mn oxyhydroxide precipitates and weakly acid NaCl solutions: convex tetrad effect and fractionation of Y and Sc from heavy lanthanides. Geochem. J. V.33. (1999). pp.167–180.

[58] Z.H, Zhao, Z.W, Bao and G.U., Lee Seung: A composite M- with W-type of REE tetrad effect in a north China alkaline complex. Geochim Cosmochim Acta 72 Supp:11095. (2008).

[59] A.I., Mahdy and A.M., El-Kammar: Geochemical Partitioning of Isovalent and Tetrad Effect of REE Associating Episyenitization of Kab Amiri Granites, Central Eastern Desert of Egypt C.5th In. Conf. of Geology of Middle East Cairo Egypt. (2003). pp.111–125.

[60] Z. H., Zhao, Z. W., Bao and Y. L. Qiao: A peculiar composite M- and W-type REE tetrad effect: evidence from the Shuiquangou alkaline syenite complex, Hebei Province, China. Chin. Sci. Bull. 55. ((2010)). pp.2684–2696.

[61]S.L., Korzeb: The chemical evolution and paragenssis of uranium minerals from the Ruggles and Palermogran pegmatites. New Hampshire. The Canadian Mineralogist. Vol.35. (1977). pp.227-300.

[62] F., Cebron, P. Ildefonse and M. C., Sichere: New mineralogical data on uranophane and beta-uranophane, synthesis of uranophane. Mineralogical Mag.,57. (19930. pp.301-3308.

[63] R.J. Finch and R.C., Ewing: The corrosion of uraninite under oxidizing conditions. J. Nucl. Mater. Vol.190. (1992). pp.1333-156.

[64] D.H., Gorman and E.W., Nuffield: Studies of radioactive compounds: Uranophane and beta-uranophane. Am. Miner. Vol.40. (1955). pp.634-645.

[65] E.W., Heinrich: Mineralogy and geology of radioactive raw materials. Mc Graw-Hill Book Company, New York.(1962).

[66] W. A., Deer, R. A. Howie and J., Zussman: An introduction to rock forming minerals. Longmans, London.(1966). p.517.

[67] H. H., Read: Rutley·s elements of mineralogy. Published by S. K. Jain for CBS Publishers and distributors, Delhi, India, (1984). p.560.

[68] M.F., Raslan: Mineralogical and minerallurgical characteristics of samarskite-Y, columbite and zircon from stream sediments of Ras Baroud area, Central Eastern Desert. the scientific papers of institute of mining of the Wroclaw University of Technology, Wroclaw, Polanda, No.128,Mining and Geology XII, (2009). pp.179-195.

[69] M., El-Mansi: Coloration of fluorite and its relation to radioactivity. Egypt. Min., 12.(2000). pp.93-106.

[70] W. A., Deer, R. A., Howie and J., Zussman: An Introduction to the Rock–Forming minerals. 2nd Edition, Longman Sci, London.(1992). p.696.