Nuclear Materials Authority
P.O.Box 530 Maadi, Cairo, Egypt

DOAJ DIRECTORY OF OPEN ACCESS JOURNALS

ISSN 2314-5609
Nuclear Sciences Scientific Journal
9, 119- 140
2020
http://www.ssnma.com

MINERALOGICAL AND RADIOACTIVITY CHARACTERISTICS OF ABU-DOB GRANITE AND ASSOCIATED PEGMATITE, CENTRAL EASTERN DESERT, EGYPT

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ABSTRACT

Abu Dob monzogranitic pluton occupies the northeastern part of Kadapora batholith which locates in the Central Eastern Desert. Several pegmatitic bodies of different shapes and sizes cut into this pluton. The mineralogical investigation of the monzogranite and pegmatite varieties revealed that the encountered radioactive and strategic minerals can be grouped into; uranium and thorium minerals (uranophane, beta-uranophane, kasolite, thorite and uranothorite), uranium- and thorium-bearing minerals (samarskite, allanite, monazite, columbite and zircon) and non-radioactive minerals (fluorite, titanite and iron-minerals).

On the other hand, the radiometric and chemical investigation of the rocks indicated that the uranium content was affected by addition and removal processes caused the radioactivity disequilibrium and mostly led to the uranium redistribution into the investigated rocks with probable limited migration outside Abu Dob pluton. Also, the recorded uranium mineralization might be of epigenetic origin due to the hydrothermal activity. Both the uranium and thorium elements were not preferentially hosted in the accessory minerals.

INTRODUCTION

The radioactivity which exhibited by some rocks back to their content of the natural radioactive isotopes and their daughters. Generally, the acidic igneous rocks are considered as an important source of uranium deposits which are formed either directly from fluids expelled during crystallization of the magma (primary minerals) or indirectly due to alteration and redistribution processes of the primary minerals by hydrothermal and/or meteoric solutions (secondary minerals).

Geochemically, uranium and thorium tend to be enriched with magma differentiation, so their averages reach the maximum in the felsic plutonic rocks (Rogers et al., 1978). The relatively heavy radioelements, due to their large ionic radii, were incompatible with the crystal lattices of the minerals which formed lower in the mantle and became selectively concentrated in the sialic crust (Bristo, 1983). The uranium content in the granitic and other acidic rocks occurs either as U^{6+} which is readily leachable and is believed to be concentrated along the grain boundaries and the microfractures (Stuckless and Ferriera, 1976) or as a tetra-valence form that may be largely present in the minute accessory minerals (Stuckless and Nkomo, 1980).

The current work aims to investigate the relation between the mineralogical content of

Abu-Dob granite and its associated pegmatite and their radioactivity contents as well as their adequacy as a potential environment for uranium deposition.

METHODS AND TECHNIQUES

For the mineralogical investigation, five granitic and five pegmatitic sampleswere selected where each sample approximately weighted one Kg. They were firstly crushed and ground to the sandy size (-60 to +120 mesh), then washed by the tape water and decanted to remove the slim particles and finally dried at 100 ^{o}C in the dryness oven. The dried samples were separated using the bromoform liquid (heavy liquid of specific gravity 2.86) into two portions; the light portion (approximately 98% of the original sample weight and mainly composed of quartz, feldspars and mica) and the heavy portion (always contains the target minerals).

Further separation for the heavy portions based on the magnetic fractionation at gradual electric ampers using the Frantz Iso-dynam Magnetic Separator (Model LB1). The obtained fractions where investigated under the binocular microscope and the intended minerals were picked to obtain mono-mineralic fractions for identification and analysis. The minerals identifications were carried out by the X-Ray Diffraction instrument (XRD, model Philips PW 3710/31 diffractometer, scintillation counter, Cu- target tube and Ni filter at 40 Kvand 30 mA) attached with a computer system using APD program and PDF-2 data base for the minerals identification. The scan program covers 2θ at the range from 5^{o} to 65^{o} with a step size of 0.02 degree and 0.5 second as count time /step. The chemical composition of the separated minerals was tested using the Environmental Scanning Electron Microscope (ESEM, model Philips XL30) which supported by energy dispersive spectrometer unit (EDX) used at 25-30 Kv (accelerating voltage), 1-2 mm beam diameter and 60-120 second as counting time.

On the other hand, the radioelements content was determined radiometrically and chemically. Eighteen samples were properly prepared for the laboratory γ-spectrometry investigation (nine samples from each rock) using the Multi-channel Gamma Spectrometer with NaI (Tl) detector which established in the Nuclear Materials Authority headquarter. The equivalent uranium,equivalent thorium and radium concentrations were measured as ppm while K-40 concentration was measured in percentage. In the chemical determination, the exactly weighted one gram of each sample was well ground to less than 0.063 mm in size and attacked by mixture of concentrated acids (HF, $HClO_4$ and HCl) with aggressive heating. After complete dissolution, cooling and the adequate dilution, the concentration of uranium was measured colorimetrically with the chemical reagent "Arsenazo III" using the UV/VIS spectrophotometer (Marczenko, 1986).

GEOLOGIC SETTING

Gabal Abu-Dob granitic pluton (465m height a.s.l.) locates between latitudes 25^{o} 33'and 25^{o} 34' N and longitudes 34^{o} 31' and 34^{o} 33' E. It represents the northeast part of Kadapora batholith and is bounded by Gabal Kadapora from its southern side, Gabal Um Lassaf from the northern side and GabalAteila from its western side (Fig. 1).

The granitic rock is of medium to coarse grained, pink to red color and massive features and composed mainly of quartz, alkali feldspars and plagioclase, together with minor amounts of biotite and opaques. It sends off-shoots and apophyses into the surrounding country rocks while it encloses numerous of xenoliths of older rocks (Fig. 2). Metamorphosed volcano-sedimentary rocks are also exposed in Abu-Dob area as a narrow strip between Gabal Abu-Dob granites and the younger gabbro of um Rus gold mine and include tremolite-actinoliteschist, actinolite-graphite schist and biotiteschist (Dawood, 1999). They are fine-grained, highly sheared, intensively folded, and dark grey in colour

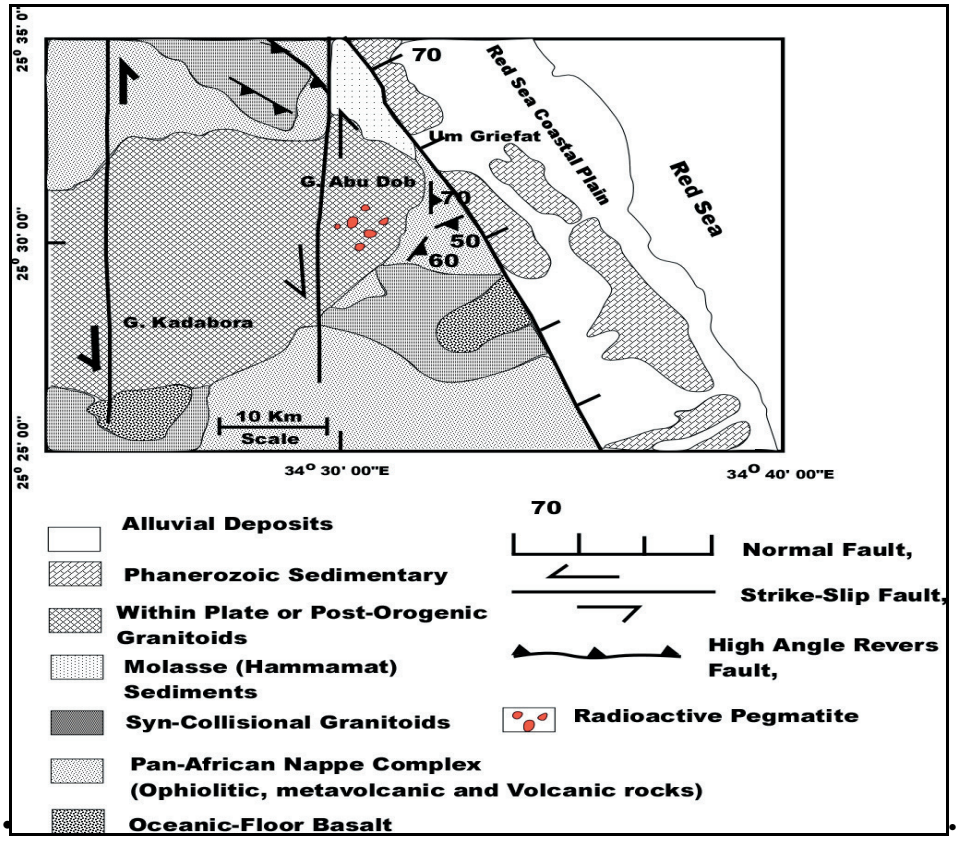

Fig. 1: Geological map of G. Abu-Dob District, Central Eastern Desert. (After Abdeen, 2003)

Fig. 2: A photograph shows xenoliths of older rocks were engulfed into Abu-Dob granite

with relics of graded-bedding. Their foliation planes dipping 28°-50° outward Gabal Abu-Dob granitic mass and strike NE-SW, NW-SE, N-S and ENE-WSW in decreasing order.

The younger granites in Gabal Abu-Dob was assigned as uraniferous granites with average uranium equal 32.5ppm but most of the radioactive anomalies are associated with pegmatites. These granites are of peraluminous and I-type magmatism (Khaleal, 2014). Its age was estimated as 595±8 m.y. (Fullager, 1980) while its source was proposed either as the upper mantle or the primitive island arc protolith suffered deficient in the lithophile

elements (Youssef et al., 2009).

Several pegmatite bodies as well as swarm of dolerites dykes and sills cut into Abu-Dob granite (Fig. 3). Some alteration features such as sericitization, hematization and silicification are locally affecting the granitic pluton (Fig. 4). The sampled pegmatite bodies are usually of the zoned type and occur as small pockets (1 x 2 m) or vein-like bodies(Fig. 5) with quartz at the core followed by alkali feldspars at the margins and sometimes suffer kaolinization**.** The feldspars vary in colour from rose to milky and in composition from K-feldspar to Na-feldspar. Sometimes intercalations of the both types are encountered. The pegmatites at some pockets show a radial fabric of stretched augen quartz (15 x 30 cm) enclosing metamict porphyritic zircon and columbite.

Fig. 3: A photograph showsdolerite dyke invades into Abu-Dob granite

Fig. 4: A photograph shows Abu-Dob granite suffered some alteration features

Fig. 5: A photograph shows slightly kaolinized pegmatite vein invades into Abu-Dob granite

Some occurrences of uranium and columbite mineralizations in Gabal Abu-Dob younger granite and its related pegmatites were recorded particularly with the rose feldspar of the uraniferous pegmatite (Ibrahim et al., 1997).

MINERALOGICAL INVESTIGATION

The identified economic and strategic minerals can be grouped into;

Uranium and Thorium Minerals

Uranophane and beta-uranophane [$Ca(UO_2)_2Si_2O.6H_2O$]

The uranophane grains were separated from Abu-Dob granite and pegmatite (found as fracture filling crystalline aggregates). They are characterized by massive habit, canary-yellow color and pearly to greasy luster(Fig. 6). The uranophane aggregates are intimately intergrowth with fine calcite crystal along the fractures surfaces and the silica veinlets in as-

sociation with Fe- and Mn-oxides. In general, the uranophane mineralization is considered the alteration product of uraninite, gummite and other uranium minerals and sometimes formed directly as a result of the hydrothermal solutions activity. The beta-uranophane mineral is of similar mineralogical and chemical characteristics as the uranophane, was also detected but only through the XRD investigation (Fig. 7). The difference between uranophane and beta-uranophane is related to the H_2O content (smith et al, 1957) or the extinction property (Heinrich 1958). The ESEM-EDX investigation of the uranophane grains (Fig. 8) revealed the U and Si as the main constituents and Al, Ti, Fe and Ca as the minor components.

Fig. 6: Stereo-photographs showing the separated uranophane

Kasolite (Pb. UO_3. SiO_2. H_2O)

The kasolite was found as compact and brownish-yellow grains (Fig. 9) separated from Abu-Dob granite and pegmatite. It is considered as rare alteration product of other uranium minerals. The ESEM-EDX pattern of the kasolite (Fig. 10) revealed that the PbO, UO_2 and SiO_2 are the dominant components and approximately formed 100% of the kasolite composition.

Thorite (Th, U) SiO_4

The thorite grains are of small prismatic habit, brownish black in color and show glassy luster that reflects their freshness (Fig. 11). Thorite usually contains ThO_2 ranges between 35 and 80% with minor uranium content. The thorite grains were separated from the Abu-Dob pegmatite and usually accompanied with

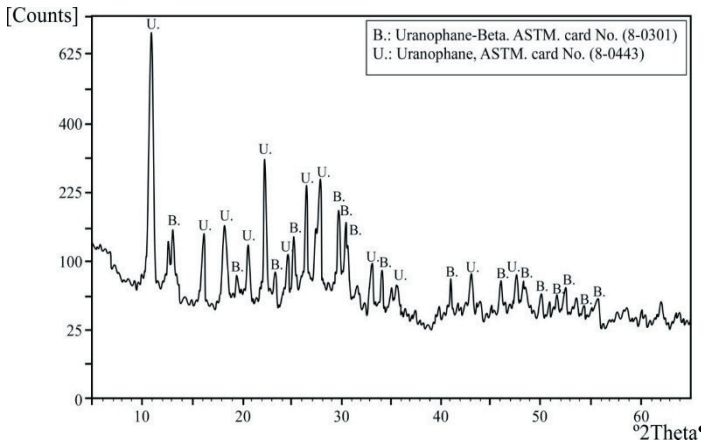

Fig. 7: X-ray diffractogram of uranophane and beta-uranophane

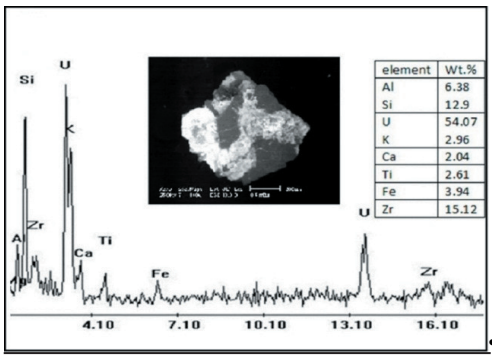

Fig. 8: Microphotograph and EDX charts for uranophane

Fig. 11: Stereo-photographs showing the separated thorite

Fig. 9: Stereo-photographs showing the separated kasolite

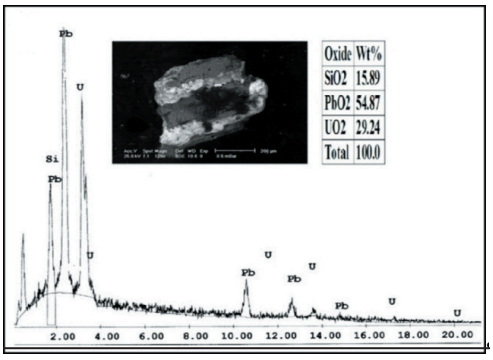

Fig. 10: Microphotograph and EDX charts for kasolite

the allanite mineral (Fig. 12).

Uranothorite (Th, U) SiO_4

The uranothorite grains were separated from Abu-Dob pegmatite. They are massive, reddish brown to brownish black in color and of glassy luster and sometimes greasy due to the alteration effect (Fig. 13). It resembles the thorite except its U_3O_8 content that exceeds 5% with other minor constituent as P, Al, Ca and Fe (Fig. 14).

Uranium and Thorium Bearing Minerals

Samarskite
(Y, La, U, Ca, Fe) $(Nb, Ta, Ti)_2O_6$

The samarskite was separated from Abu-Dob pegmatite. Its grains have massive and sometimes roughly prismatic habit, with dark brown color and occasionally show reddish cast due to the iron staining and usually have glassy luster which turned to greasy in the non-fresh grains (Fig. 15). The samarskite mineral is a columbite and tantalite of the yttrium-rare earths group with variable amounts of uranium, iron, calcium, lead and thorium. Its uranium content usually (up to 12.90 % U_3O_8) higher than thorium content (Fig. 16).

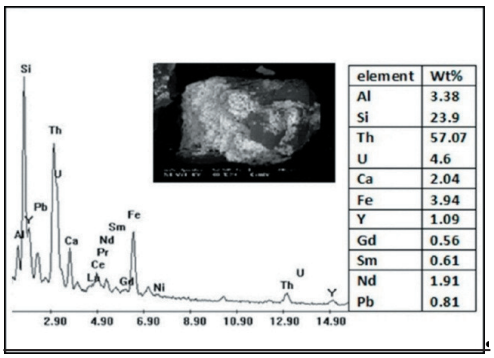

Fig. 12: Microphotograph and EDX charts for thorite

Fig. 15: Stereo-photograph showing the identified samarskite

Fig. 13: Stereo-photographs showing the separated uranothorite

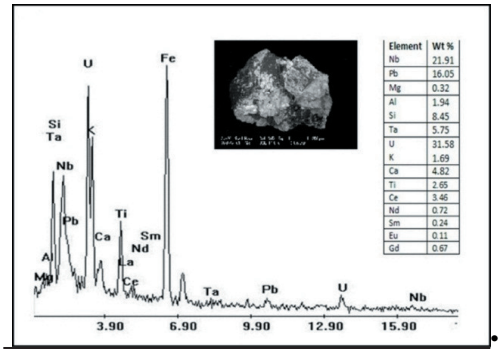

Fig. 16: Microphotograph and EDX charts of samarskite enclosed in Orthoclase

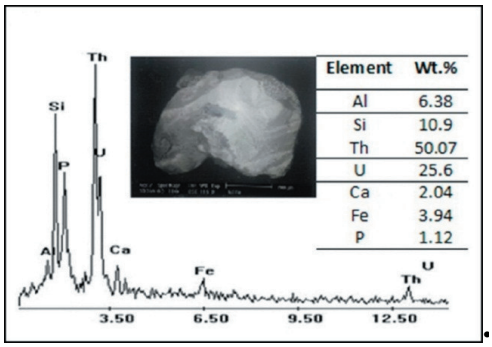

Fig. 14: Microphotograph and EDX charts for uranothorite

Allanite (Ca, Ce, La Y)$_2$ (Al, Fe)$_3$ (OH)

The allanite grains were found in the Abu-Dob pegmatite samples in a massive form with yellowish orange color and exhibits the resinous luster (Fig. 17). The EDX-pattern of the allanite (Fig. 18) revealed the considerable LREE content relative to uranium and thorium content, so it could be named as Ce-allanite. Also, the ESEM-image showed that the allanite suffered fracturing that usually ascribed to the damage effect of its content of radioactive elements which destroy the crystal lattice. Such fractures were filled, later on, by iron oxides and silica.

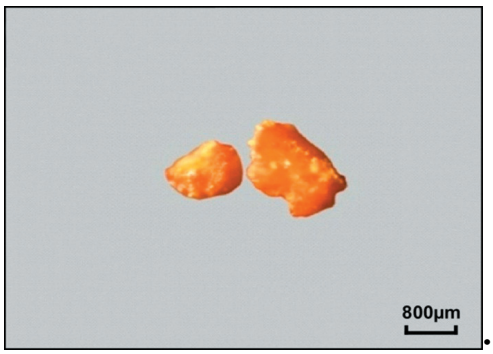

Fig. 17: Stereo-photograph showing the identified allanite

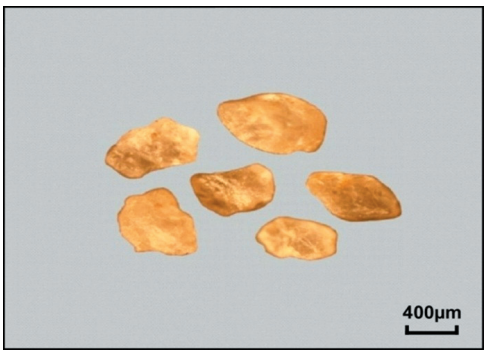

Fig. 19: Stereo-photograph showing the identified monazite

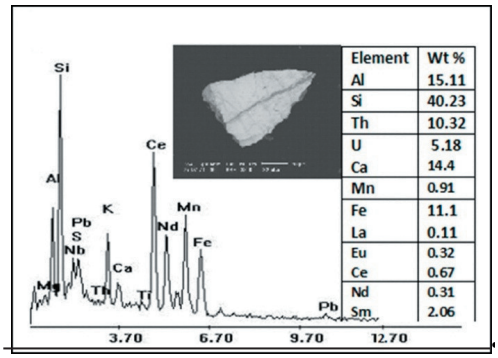

Fig. 18: Microphotograph and EDX charts of allanite

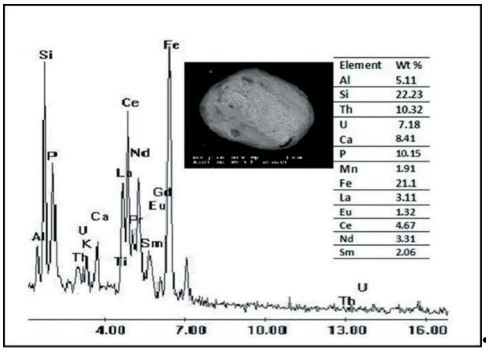

Fig. 20: Microphotograph and EDX charts of monazite

Monazite (Ce, La, Nd, Th) PO_4

The monazite was separated from and Abu-Dob monzogranite and pegmatite as flattened crystals of yellow color and resinous luster (Fig. 19). As shown from its EDX-pattern (Fig. 20), the monazite is a phosphate mineral rich in the rare earths particularly the Ce-element. Also it contains Th that can reach up to 15% (as ThO_2) and U that may be reach up to 1% (as U_3O_8). This significant content of both Th and U made the monazite as non-conventional resource for extraction of the two radioactive elements.

Columbite (Fe, Mn, Mg) $(Nb, Ta)_2O_2$

The columbite grains of brown colour and metallic luster were separated from the pegmatitic samples (Fig. 21). The columbite was in association with xenotime, muscovite and iron–oxides on the periphery of the pegmatitic body reflecting the enrichment of both Li and P in the source liquid.

Beside the essential constituents, U, Th, Ce, Ti and Y were detected in the EDX pattern of columbite (Fig. 22). The Nb/Ta ratios indicate the high enrichment of Nb rather than Ta in the residual magma from which the peg-

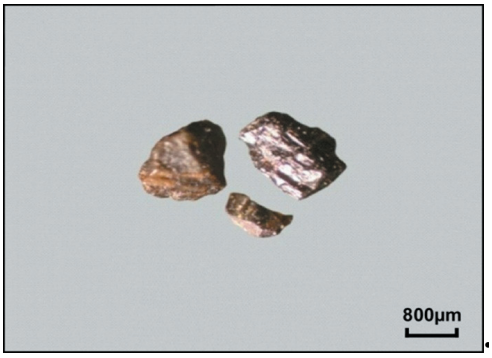

Fig. 21: Stereo-photograph showing the identified columbite

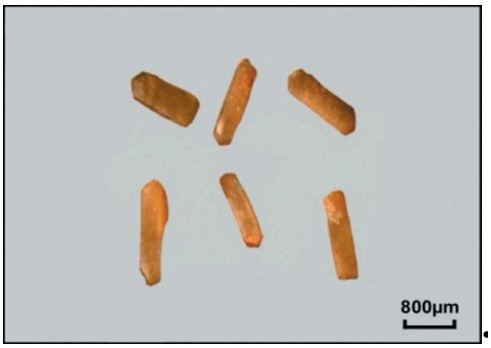

Fig. 23: Stereo-photograph showing Euhedral zircon (Abu-Dob granite)

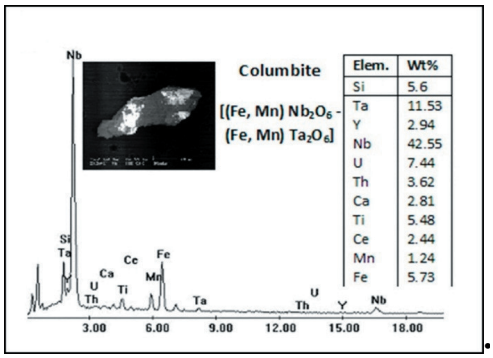

Fig. 22: Microphotograph and EDX charts of columbite.

Fig. 24: Stereo-photograph showing Partially metamictized zircon (Abu-Dob pegmatite)

matite was originated.

Zircon ($ZrSiO_4$)

Zircon grains are encountered in Abu-Dob granitic and pegmatite samples. The separated grains revealed variable morphological forms, colors and radioactive content (Figs. 23-25). Well-developed grains of elongated prisms and pyramidal terminations with the pale-yellow to yellow colors were separated from Abu-Dob granite. This variety could be assigned as fresh or non-radioactive zircon where its complete crystal forms and yellow colors as well as absences of the metamictization frac-

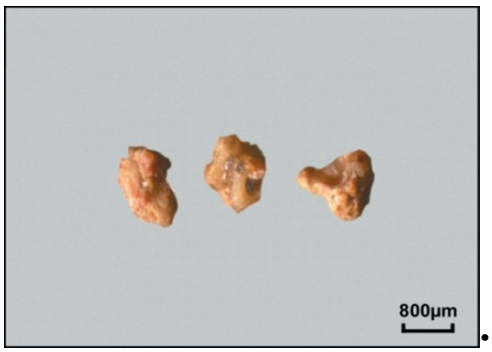

Fig. 25: Stereo-photograph showing elbow parallel zircon grains

tures are signs of its low radioactive contents or the young age of its crystallization(Figs. 23, 26 and 27). Also the euhedral elongated prismatic habit suggests the high fluid contents of its source magma and is considered a function of the temperature and the degree of zirconium super-saturation in the liquid (Poldervaart, 1956, Pupin &Turco, 1979,Dardier, 1999 and El-Mansi et al., 2004).

On the other hand, those grains which separated from Abu-Dob pegmatite are characterized by their deformed habit, brownish color and suffer fracturing (Fig. 24). These features are reasonably ascribed to their metamictization due to the high radioactive content that leads to the radiation accumulation into the crystal lattice and damages the crystal structure of zircon or even the other adjacent minerals (Woodhead et al., 1991).

The radioactivity of this variety is essentially related to its original content of the radio-elements due to substitution of Zr^{4+} by U^{4+} and Th^{4+} during the crystallization process or occasionally ascribed to inclusion of other radioactive minerals into zircon grains, such as thorite mineral which has isomorphic relation with zircon (Fig. 28). The metamictized zircon is considered a source for uranium anomalies in the hosting rock units through the available bath ways in the destroyed grains from which the uranium content can be leached out. Although most of separated zircon grains are found in individual forms but sometimes they formed as elbow twinned crystals (Fig. 25).

The XRD chart pointed to presence of xenotime mineral as inclusion into some zircon grains (Fig. 29) which caused the occasional appearance of the LREE in considerable amounts in some chemically analyzed zircon grains.

Non-Radioactive Minerals

Fluorite (CaF_2)

The fluorite was found in Abu-Dob granite and pegmatite samples as disseminated grains

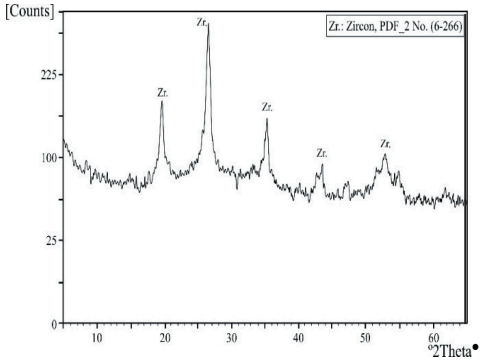

Fig. 26: X-ray diffractogram of Zircon

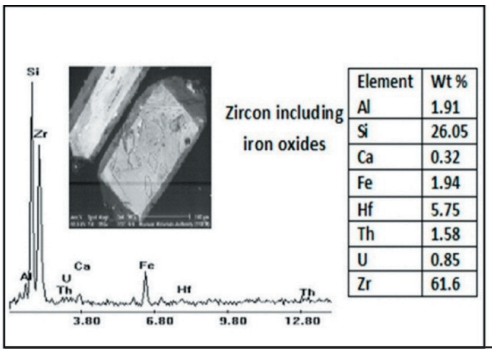

Fig. 27: Microphotograph and EDX charts of euhedral zircon

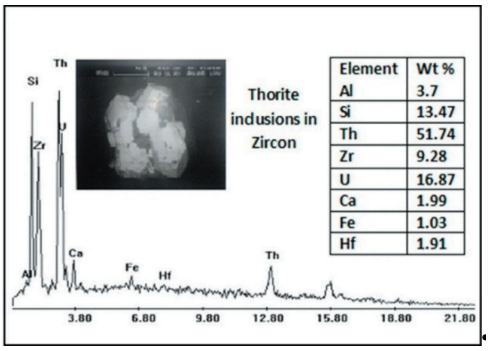

Fig. 28: Microphotograph and EDX charts of zircon has thorite inclusion

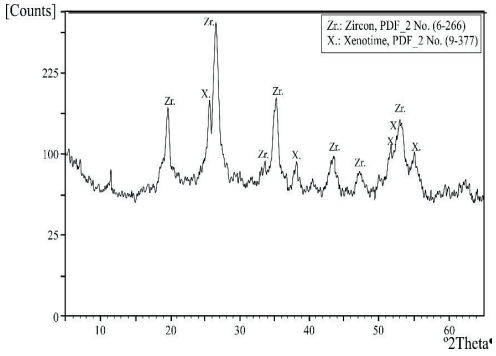

Fig. 29: X-ray diffractogram ofZircon associated with xenotime

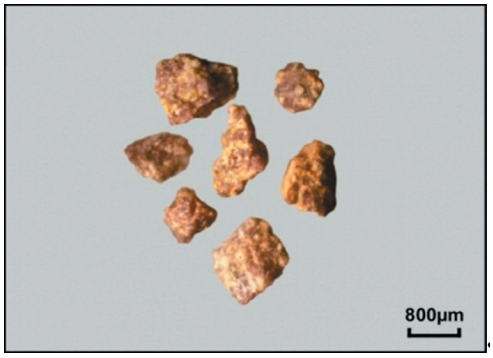

Fig. 30: Stereo-photograph showing fluorite

associated with the radioactive spots which recorded in the studied rocks (Figs. 30 and 31). The Fluorite crystals have violet to dark violet colors at Abu-dob granite and pegmatite. Presence of the fluorite in association with the radioactive minerals suggests the epigenetic hydrothermal origin of the uranium mineralizations (Sarcia, 1958).

Allen (1952) attributed the colours of fluorite to the action of their content of the rare earth elements during the magma differentiation or due to presence of the manganese.Khazback and Raslan (1995) remarked a positive relation between the fluorite color and the accompanied secondary uranium minerals. The rocks that rich in secondary uranium minerals usually enclose fluorite crystals of very deep blue to violet colour. The occasional presence of uranium in fluorite is most probably back to the ability of the fluorine ion to form an ionic complex with uranium as uranyl fluoride, which is important for the uranium transportation in the acidic fluids.

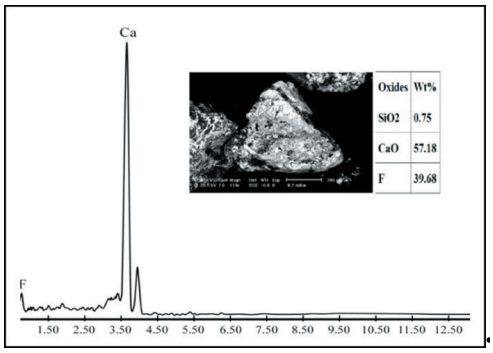

Fig. 31: Micrograph and EDX charts of fluorite

Titanite ($CaTiSiO_4$)

The titanite (sphene) was found as brown elongated broken crystals (Fig. 32). The color of sphene is usually related to the percentage of Fe_2O_3 which is responsible about the brown color (Deer et al., 1992).

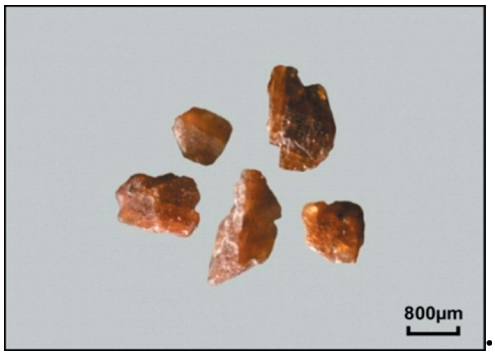

Fig. 32: Stereo-photograph showing titanite (sphene)

The ESEM-EDX analysis of the sphene mineral (Fig. 33) showed that the major composition consists of CaO, TiO_2 and SiO_2 in addition to the trace elements which represented by U, Th, Ta, S and REE.

Iron minerals

They were separated from the different studied samples as opaques of the metallic luster (Fig. 34). Hematite, magnetite, goethite $Fe^{3+}O(OH)$ and jacobsite are the most common iron minerals in the investigated samples (Figs. 35&36).

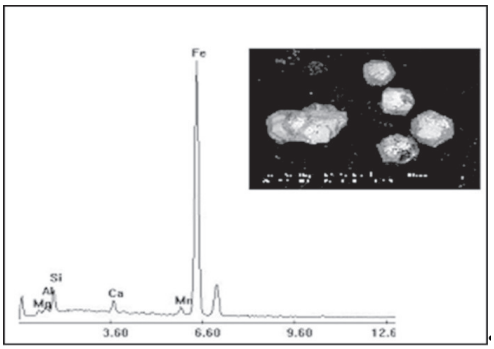

Fig. 35: Micrograph and EDX charts of iron oxides

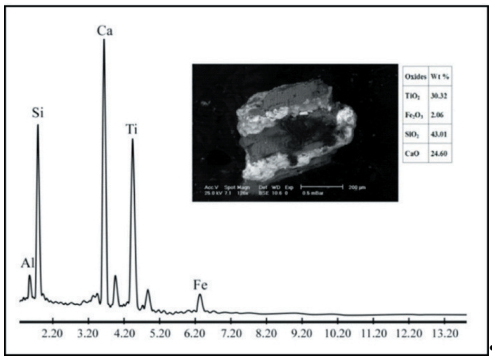

Fig. 33: Micrograph and EDX charts of titanite

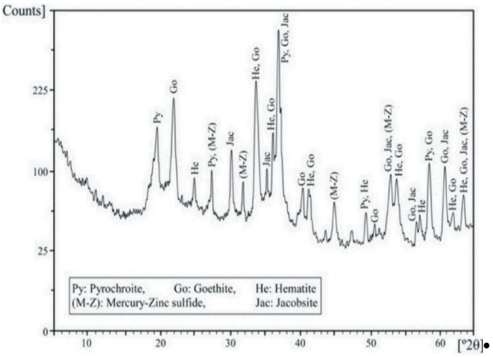

Fig. (36): X-ray diffractogram of pyrochorite, goethite, hematite and jacobsite

Fig. 34: Stereo-photograph showing magnetite

THE RADIOMETRICAL AND CHEMICAL MEASUREMENTS OF THE STUDIED ROCKS

The gamma-spectrometric and the chemical measurements of the studied samples were listed in Table (1) and hereafter the feedback from these data will be discussed in some details.

Origin of the Thorium and Uranium Mineralization

Although thorium is more abundant than uranium in the earth's crust (Th is 3-4 times as

Table 1: Gamma-spectrometry measurements and the chemical measured uranium of the studied rocks

Sample type	S. No.	eU (ppm)	eTh (ppm)	Ra (ppm)	K (%)	U-chemical (ppm)
Abu-Dob Pegmatite	33	55	98	34	2.67	98
	34	46	128	31	2.66	121
	35	97	173	43	3.15	181
	36	123	276	98	3.68	166
	37	94	121	64	3.81	65
	38	87	413	42	3.79	121
	39	1850	2850	1520	5.91	1870
	40	695	654	413	4.68	864
	41	452	312	245	3.58	163
Abu-Dob Granite	42	119	35	72	3.68	98
	43	177	32	104	3.78	112
	44	93	187	54	3.12	134
	45	176	154	136	3.69	63
	46	61	20	18	2.57	135
	47	83	22	61	2.98	114
	48	150	280	110	3.74	132
	49	210	193	123	3.96	151
	50	198	165	175	3.91	112

U) but its chemical properties restrict its easy movement or formation of secondary minerals after the original deposition, consequently the number of thorium minerals is small compared to those of uranium. Accordingly, the identified thorite and uranothorite (derivative of thorite when contains □5% U_3O_8) in the Abu-Dob pegmatite are only ascribed to the direct magmatic origin.

On the other hand, origin of the secondary uranium minerals which identified in this work can be discussed and explained through several probable mechanisms:

1-Mobilization of labile uranium.

2-U-mobilization from the oxidized pri mary uranium minerals.

3-Mobilization from accessory and refrac tory minerals.

4-Hydrothermal origin.

The first mechanism

This means the physically bounded or adsorbed uranium to surface of some minerals like Fe-oxides and biotite. This kind of uranium may be remobilized either by the effect of transporting medium such as meteoric water that acquires slight acidity through the dissolved CO_2 and forming the weak H_2CO_3 acid or by the effect of the moved hydrothermal solution along the macro-or micro-channels. Several uranium mineralizations in the sandstone and vein-type deposits were formed by the labile uranium (Stuckless and Ferreira, 1976). Referring to the provisions of this mechanism in the acidic igneous rocks (the silica content, the alkaline affinity, the anomalous Th concentration, Zr-content, Th/U ratio and U/K ratio), the labile uranium in the studied igneous varieties is reasonably to be excluded as probable source for the identified secondary uranium minerals (Stuckless& Ferreira, 1976, Watson, 1979 and Stuckless et

al., 1984).

The second mechanism

This mechanism is based on the pre-existing primary uranium minerals (e.g. uraninite) in which the uranium found as U^{4+} and keeps its stability and immobilization as the reducing environment continues. With the availability of the oxidizing conditions, the U^{+4} oxidized into the hexa-valence form (U^{6+}) and becomes easily mobile with the circulating fluids. Under the relevant conditions of the pH, Eh, temperature and concentrations of the other cations and anions in the carrier fluids, the secondary uranium minerals formed. However, this mechanism could be ignored taking in account the petrographical and the mineralogical studies in this work, or even in the previous researches, where no signs of primary uranium mineralization were recorded in the studied area. In addition, absence of important primary muscovite and albite constituents in the investigated rocks does not support this mechanism (Cambon, 1994).

The third mechanism

This assumes releasing of U^{4+} from the destroyed crystal lattice of the metamictized accessory minerals or those suffered fracturing due to certain stresses. By the interaction of the circulating meteoric water or the hydrothermal fluids with the deformed accessory minerals, the U^{+4} is oxidized to U^{+6} and leached out then subsequently redeposited in near surface, low temperature shear zones or even travels to the surroundings according to the available pathways forming the secondary uranium minerals (Simpsonetal.,1979). This model seems to be accepted in our case where the mineralogical study recorded existing of the metamictized zircon in the investigated rocks.

The forth model

This means that, in opposite to the other mechanisms, the original uranium is of epigenetic source comes with the hydrothermal solution and the secondary uranium minerals are formed in-situ without further mobilization of uranium. Confinement of the secondary uranium minerals to the shear zone and their association with the hydrothermal alteration features in this study as well as tempting of this model by many authors to explain the origin of uranium mineralization encourage the probability of this mechanism.

Radiometric Equilibrium in the Studied Rocks

Within a closed system, the process of radioactive decay of uranium and thorium reaches the equilibrium state when the production rate of any intermediate daughter in the decay chain equals its decay rate. Attaining the equilibrium status in the U^{238} decay-series requires approximately 1.5×10^{6} years while 40 years are enough to attain the equilibrium in the Th^{232} series (Faure, 1986).

On the other hand, near the surface geological conditions the closed system usually not be attained or even destroyed if it was present where the weathering and circulation fluids usually remove some of the decay-series daughters particularly Rn^{222} as well as removal or addition of the uranium element causing the disequilibrium state.

The equilibrium in the uranium decay series can be investigated as a function of some radio-isotopic ratios of both the tested and standard samples (e.g. Th^{234}-sample/Th^{234}-standard) or through the ratio of the radiometric measured uranium and radium in each tested sample (eU/Ra) what is known as P-factor (Motalin, 1991 and El Galy, 1994). Departure of these ratios from unity indicates a disequilibrium state.

In the radiometric measured samples, all the eU/Ra ratios (Table 2 and Figs. 37&38) of the studied rocks are out of the unity value indicating the disequilibrium in their uranium decay series. All the samples of Abu-Dob granite and pegmatite are greater than unity. This major trend in the eU/Ra values reflects

Table 2: Some calculated ratios of the radiometric and chemical measured elements

Sample type	S. No.	eU/Ra	eU – (eTh/3.5)	eTh/eU	U-chem./ U-rad.
Abu-Dob Pegmatite	33	1.62	27.0	1.78	1.78
	34	1.48	9.4	2.78	2.63
	35	2.26	47.6	1.78	1.87
	36	1.26	44.1	2.24	1.35
	37	1.47	59.4	1.29	0.69
	38	2.07	-31.0	4.75	1.39
	39	1.22	1035.7	1.54	1.01
	40	1.68	508.1	0.94	1.24
	41	1,84	362.9	0.69	0.36
Abu-Dob Granite	42	1.65	109.0	0.29	0.82
	43	1.70	167.9	0.18	0.63
	44	1.72	39.6	2.01	1.44
	45	1.29	132.0	0.88	0.36
	46	3.39	55.3	0.33	2.21
	47	1.36	76.7	0.27	1.37
	48	1.36	70.0	1.87	0.88
	49	1.71	154.9	0.92	0.72
	50	1.13	150.9	0.83	0.57

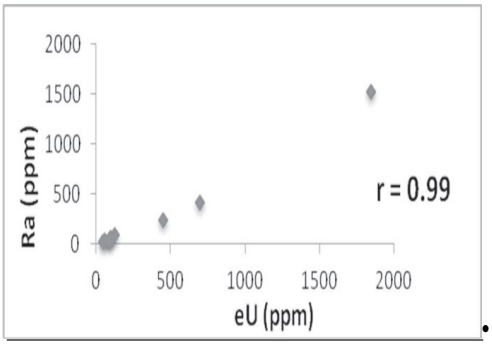

Fig. 37: The laboratory gamma-spectrometric measured uranium (eU) versus radium (Ra) for Abu Dob pegmatite

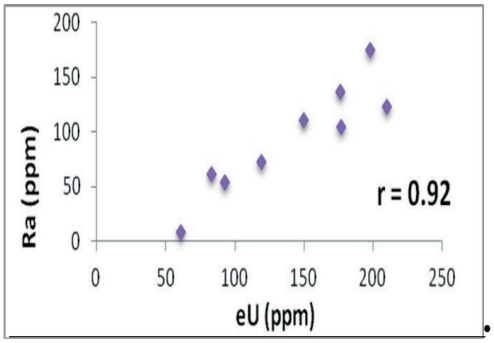

Fig. 38: The laboratory gamma-spectrometric measured uranium (eU) versus radium (Ra) for Abu Dob granite

the probability of recent uranium addition to the studied rocks and supports the hydrothermal mechanism of the formed secondary uranium minerals (Mohammaden, 1996).

Also the outputs of the eU-eTh/3.5 are function of the uranium mobilization. The zero result of this mathematical relation indicates no uranium mobilization since its first deposition and it is of magmatic origin while the results greater or lesser than zero reflect the uranium mobilization due to addition or removal processes respectively. Referring to the obtained results for the studied samples (Table 2 and Figs. 39&40) it can conclude that the uranium stabilization was not attained by any of the investigated rocks and addition of uranium clearly affected the uranium concentration expect for one pegmatite samples. Also the wide variation in the resultants could point to more than one cycle of the uranium mobilization or a complicated history of mutual addition and removal of uranium but the more effective was the addition activity. Anyhow, this conclusion supports the one that achieved from the outputs of the eU/Ra ratios of the same samples.

However, to confirm this conclusion, the D-factor of the concerned samples was calculated (Table 2). The D-factor is the ratio of the chemically measured uranium to the radiometric measured uranium in the same samples if this factor equals one it will mean no increasing or decreasing in the uranium content since its original depositions while values more or less than one point to addition or removal process of uranium respectively (Hansink, 1976andStuckless et al., 1984).

According to the calculated D-factor in this study several remarks have to be considered;

-All the D-factor values, except two, of the pegmatitic samples suggest a major process of uranium addition which compatible with presence of the recent uranium as concluded from the eU/Ra values in the pegmatite samples.

-On the other hand, the D-factors of the granitic samples tend to declare the uranium removal as the dominant process affected Abu-Dob monzogranite although the eU/Ra ratios suggest a probable recent uranium addition.

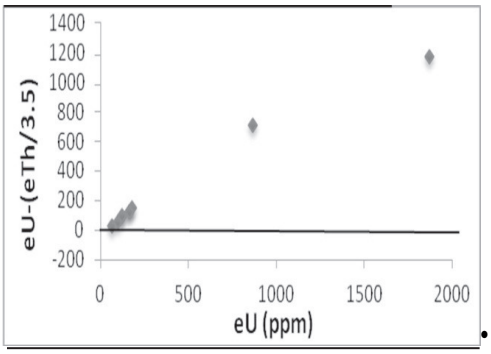

Fig. 39: The radiometric measured eU versus the rad-ratio eU-(eTh/3.5) for Abu Dob pegmatite

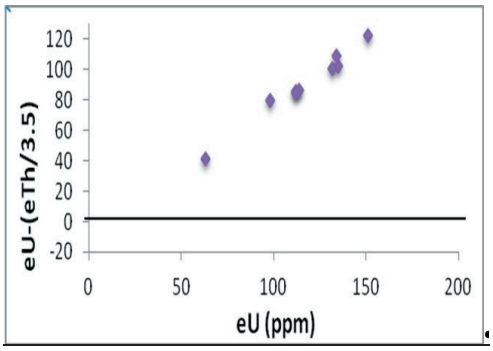

Fig. 40: The radiometric measured eU versus the rad-ratio eU-(eTh/3.5) for Abu Dob granite

This contrast could be understood if we considered the following proposed mechanism as the ordering of;

1.Uranium of magmatic origin was incorporated into the accessory and refractory minerals and kept confined to their crystals lattices.

2.To some extent, an old process of the

uranium-addition caused, in addition to the magmatic uranium, the elevation of the radiometric ratio eU/Ra and formed the secondary uranium minerals.

3.More recent leaching process for the U^{6+} ions from their bearing secondary minerals, under the effect of the hydrothermal solution and/or the slightly acidic meteoric water, led to the current low values of U-chemical/U-radiometric.

4.The uranium content in the accessory and refractory minerals (the magmatic uranium) would not leach out due to resistance of these minerals for the leaching process although the presence of some metamictized zircon grains.

However, this is just a speculation that needs more verification by further investigation. At this point; the main concern shall be the fate of the wide uranium removal from the Abu-Dob monzogranite. It could be added to the other parts in the same pluton but the limited distribution of the samples that have high D-factor does not support this assumption. So, the more accepted conclusion is the migration of the removed uranium out of the plutons through the available channels.

Origin of Uranium in Abu-Dob Monzogranite and Pegmatite

The wide range of uranium contents in the granitic and pegmatitic samples of Gabal Abu-Dob (Table 1) is likely to be ascribed to redistribution of the original content during the post magmatic processes (Dardier and El-Galy, 2000). Also the disturbance of the Th/U ratio (Table 2) away from their known normal ratio (3-4) indicates the uranium redistribution either by depletion or enrichment processes (Dardier et al., 2002).

Testifying the uranium origin is reasonably examined through its relation with Th and Zr elements which are known by their magmatic origin. From the binary relations of eU-Zr and eU-eTh for both the granitic and pegmatitic samples (Figs. 41-44) it is found that the

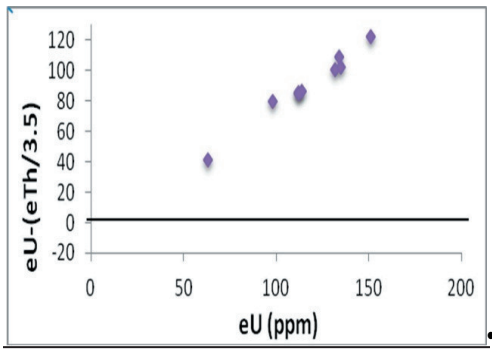

Fig. 41: The laboratory gamma-spectrometric measured uranium (eU) versus Zrfor Abu Dob granite

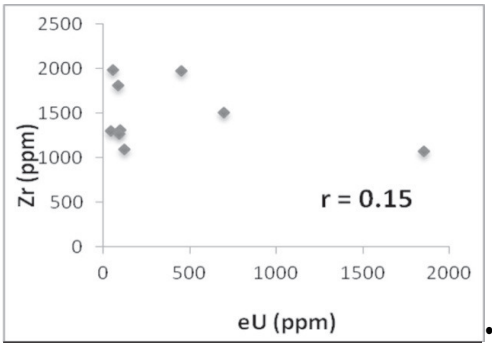

Fig. 42: The laboratory gamma-spectrometric measured uranium (eU) versus Zr for Abu Dob pegmatite

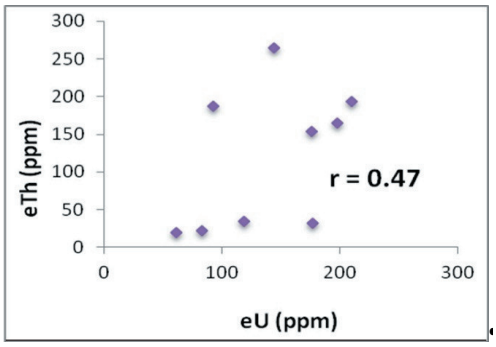

Fig. 43: The radiometric measured (eU) versus thorium (eTh) for Abu Dob granite

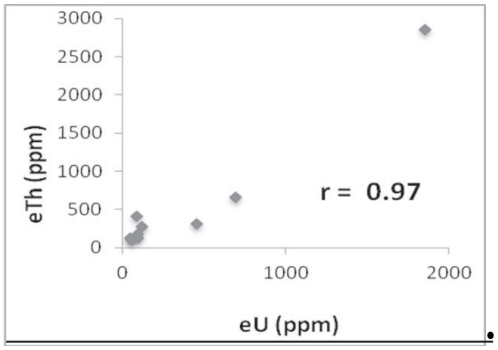

Fig. 44: The radiometric measured (eU) versus thorium (eTh) for Abu Dob pegmatite

correlation factors of eU-Zr in both the rocks are very weak (r = 0.1 and 0.15 for the granite and pegmatite respectively) that sensibly rejects the magmatic origin of the uranium and also minimizes the role of the accessory zircon mineral in the uranium distribution (Salehetal.,2007).

On the other hand, the correlation factors resulted from the eU-eTh in the two rocks revealed moderate relation in the granitic samples (r = 0.47) indicating the non-coherence of the two elements and supports the non-magmatic origin of the uranium (Mohammadenetal.,2014). To the opposite, the same relation in the pegmatite gave strong correlation (r = 0.97) that for while supports the magmatic origin of uranium but with considering the very weak eU-Zr relation in the same rock it could be ascribing the strong relation of eU and eTh to presence of the thorite and uranothorite minerals in sensible amount in the pegmatite as revealed from the mineralogic study in this work.

Hosting of Th and U in the Accessory Minerals

Traditionally, Th and U ions are incorporated into the accessory minerals e.g. zircon, monazite, allanite, apatite and fluorite by substitution with various ions of approximate similar ionic radii (e.g. Ce^{3+}, Y^{3+} and Zr^{4+}). So, the accessory minerals usually play an important role in distribution, concentration and controlling of Th and U according to the availability of these minerals in the hosting rocks.

In this work, different accessory minerals of sensible REE content were detected such as; zircon, allanite and fluorite. To testify the hospitality of these accessory minerals toward Th and U ions in the studied rocks, the binary relations of Ce-eTh, Ce-eU, Zr-eTh and Zr-eU have been examined (Figs. 45-52).

The significant negative correlation values or the weak positive correlation which revealed from these binary relations indicate

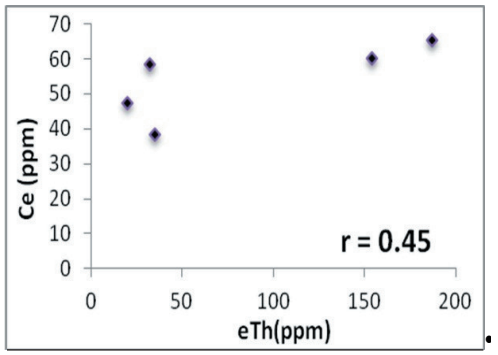

Fig. 45: The binary relations of Ce versus eTh for Abu Dob granite

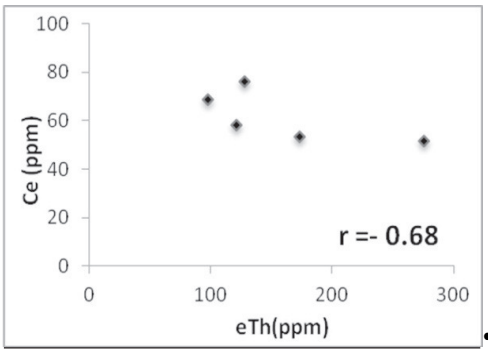

Fig. 46: The binary relations of Ce versus eTh for Abu Dob pegmatite

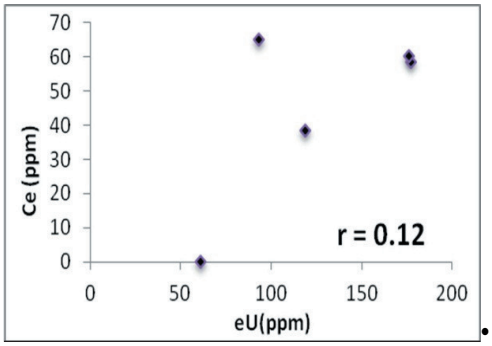

Fig. 47: The binary relations of Ce versus eU for Abu Dob granite

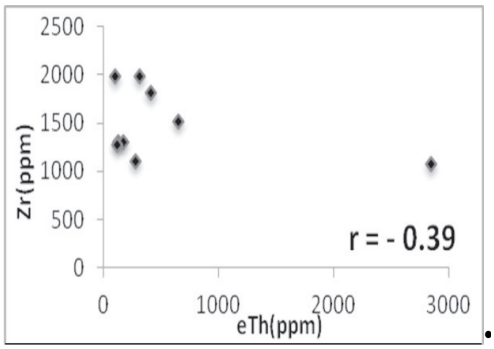

Fig. 50: The binary relations of Zr versus eTh for Abu Dob pegmatite

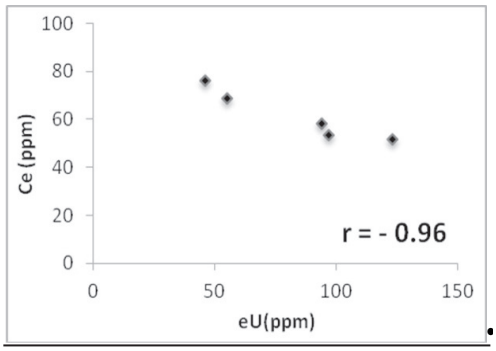

Fig. 48: The binary relations of Ce versus eU for Abu Dob pegmatite

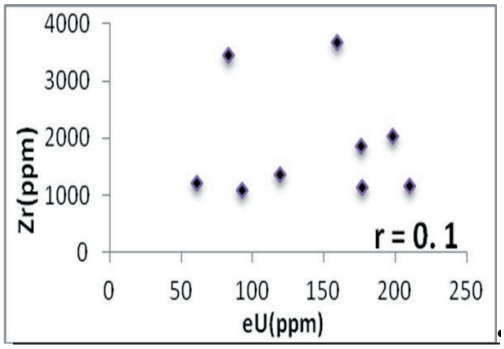

Fig. 51: The binary relations of Zr versus eU for Abu Dob granite

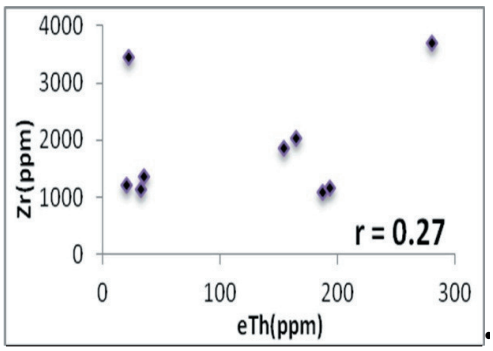

Fig. 49: The binary relations of Zr versus eTh for Abu Dob granite

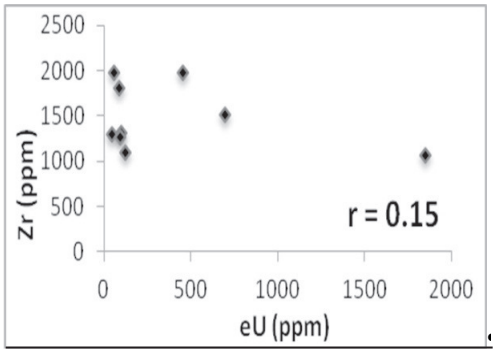

Fig. 52: The binary relations of Zr versus eU for Abu Dob pegmatite

that both uranium and thorium are not preferentially hosted in the accessory minerals of the studied samples (Saleh et.al., 2007)

CONCLUSION

The pervious discussion of the mineralogical and radioactivity characteristics of Abu-Dob granite and its associated pegmatites leads to some conclusions which can be summarized in the following points

1.The uranium mineralizations were found as syngenetic (from the magmatic uranium which incorporated in the accessory minerals) and/or epigenetic due to the hydrothermal activities

2.No evidences on a wide uranium migration from the Abu-Dob monzogranite and pegmatite although the established movement of uranium either by addition or removal processes into these basement varieties but this movement led to redistribution of most the mobile uranium into the monzogranite and pegmatite bodies themselves.

3.Based on the effective movement of uranium in the monzogranite and pegmatite rocks and the high probable confinement of the redistributed uranium to other parts within the same basement bodies, it is highly recommended to carryout intensive uranium prospection in the granitic pluton and the accompanied pegmatite bodies particularly in the sub-surface and shear zones or even in the close surrounding areas.

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الصفات المعدنيه و الإشعاعيه لجرانيت أبو دُب والبجماتيت المُصاحب، وسط الصحراء الشرقيه، مصر

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يشغل جبل أبو دُب الطرف الشمالى الشرقى من باثوليث كادابورا بوسط الصحراء الشرقيه، مصر ويقع بين خطى عرض "٣٣ ٠٢٥ ـ "٣٤ ٠٢٥ شمالاً وخطى طول "٣١ ٠٣٤ ـ "٣٣ ٠٣٤ شرقاً ويتكون من صخر المونزوجرانيت والذى يقطعه العديدمن أجسام البيجماتيت ذات الأشكال والأحجام المختلفه.

وقد أوضحت الدراسه المعدنيه لكل من صخرى المونزوجرانيت والبيجماتيت احتوائهما على العديد من المعادن المشعه ومعادن ذات أهميه إقتصاديه وقد تم تقسيم هذه المعادن إلى ثلاث مجموعات هى:

- معادن اليورانيوم والثوريوم وشملت اليورانوفين، البيتايورانوفين، الكازوليت، الثوريت واليورانوثوريت.
- معادن حامله لليورانيوم والثوريوم وتمثلت فى السمارسكيت، الألانيت، المونازيت، الكلومبيت والزيرقون.
- معادن غير مشعه و شملت الفلوريت، التيتانيت ومعادن الحديد.

بينما أظهرت الدراسه الإشعاعيه و الكيميائيه أن اليورانيوم المُتَكون فى كل من صخرى المونزوجرانيت والبيجماتيت قد تأثر بعمليات إضافه و إزاله متعاقبه أدت إلى عدم الإتزان الإشعاعى وإلى إعادة توزيع اليورانيوم داخل هذه الصخور مع وجود إحتمال لهجرة اليورانيوم بشكل محدود خارج هذين الصخرين.

أيضاً فإن الدراسه الإشعاعيه أشارت إلى أن تمعدنات اليورانيوم تكونت بعمليات لاحقه لتكون الصخر الحاوى لها كما أظهرت أن المعادن الإضافيه لم تكن بيئه مفضله لتواجد عنصرى اليورانيوم والثوريوم.