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MINERALOGY AND RADIOACTIVITY OF THE ZONED PEGMATITE BODIES, GABAL ABU ATEILA GRANITE, CENTRAL EASTERN DESERT, EGYPT.

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ABSTRACT

The studied pegmatite bodies associated with Gabal Abu Ateila granite, Central Eastern Desert of Egypt revealed their strong radioactivity. These pegmatites occur as lenticular and/or sheet-like bodies cutting the granitic pluton. Detailed microscopic investigations and Environmental Scanning Electron Microscope (ESEM) were used to identify the present heavy and radioactive minerals. The study revealed the presence of columbite, zircon, thorite and fluorite as the main radioactive-bearing minerals in these pegmatites. In addition to minor amounts of sulphides as pyrite and galena.

The radiometric studies of the anomalous pegmatite samples show that their equivalent uranium contents (eU) range from 587 to 957 ppm while their equivalent thorium contents (eTh) variy from 148 to 880 ppm. On the contrary of the Abu Ateila granites eU and eTh contents range from 5 to 11 and from 13 to 20 respectively. This indicates strong post magmatic uranium enrichment in the pegmatitic melt.

Key words: Abu Ateila, pegmatite, radioactivity

INTRODUCTION

The study area is a part of the Egyptian granitoids, which have been formed during the Pan-African orogeny; in the Eastern Desert emplaced around 430-622 Ma ago. They are contemporaneous with the Pan-African tectonic-thermal events (El Manharawey, 1977; Hashad, 1980; Rogers and Greenberg, 1981 and Abdel Wahed et. al., 2002) formed by several processes. They are considered as products of differentiation from a basic magma in a subduction-related arc-type environment or as magmas produced in an active continental margin (Stern and Hedge, 1985). Greenberg (1981) considered that anorogenic granitoids represent magmatism associated with rifting similar to the felsic intrusions in the Oslo rift. However, the role of rift-tectonics in the crustal growth of the Egyptian Eastern Desert is a matter of question and requires further re-evaluation. The post-tectonic granites in the Kadabora area are represented by Kadabora pluton that forms an oval shaped body trending ENE-WSW. Kadabora pluton comprises four masses forming G. Abu Dob, G. Kadabora El-Hamra, G. Klia El- Rakab and G. Abu Ateila. The rocks are represented by syeno to monzogranites with graditional contacts between them. These plutons are injected by widespread dyke swarms and associated with large number of pegmatitic bodies; Abde' Monem et al., (2003). The studied area is a part of the Kadabora area.

For the last 20 years, petrological, mineralogical and geochemical studies for the granites and the associated pegmatites, have been carried out by many researchers. Very coarse-grained, quartz-feldspar rocks are texturally described as pegmatites (Hibbard, 1995). Pegmatites were divided into simple and complex, the simple bodies are subdivided into zoned and unzoned, whereas the complex bodies are compositionally divided. This classification also includes metasomatic and hydrothermal deposits. Some of the Egyptian pegmatites acquired their importance from hosting many rare metals or valuable minerals. The most recent works done on the rare metal pegmatite associated with the granitoid rocks include, Ibrahim et al. (1997); Abdallah and El Afandy (2003); Sherif (2003) and Abd El Wahed, et. al., (2005).

This work is a contribution to the understanding of the geology, mineralogy and radioactivity of Gabal Abu Atiela granite and the associated pegmatite bodies. The studied area is located about 70 km southwest of Qusseir City and accessible by Red Sea and Wadi Umm Gheig desert road. It is delineated by latitudes 25^{O} 27$^{\backslash}$ to 25^{O} 34$^{\backslash}$ N and longitude 34^{O} 18$^{\backslash}$ to 34^{O} 24$^{\backslash}$E (Fig.1). The main target of this study is to clarify the importance of pegmatites as hosting accessory, rare earth and radioactive minerals in Abu Ateila area.

SAMPLING AND TECHNIQUES

More than 20 samples were collected from the studied granitic rocks and pegmatite bodies. (using The gamma-ray spectrometry measurements GS-256 spectrometer with 7.62X 7.62 cm^2 Sodium iodide Thalium [NaI(TI)] crystal detector). The pegmatitic bodies and dykes represent the highest values of anomalous sites. Ten thin sections were prepared and studied to determine the petrographic characteristics of these rocks. The collected samples were subjected to various mineral separation steps; disintegration (crushing and grinding), desliming, sizing and heavy liquid separation using bromoform (Sp.Gr. 2.85). The heavy mineral grains picked under binocular-stereo microscope. Environmental Scanning Electron Microscope (ESEM) supported by energy dispersive spectrometer (EDS) unit (model Philips XL 30 ESEM) at the laboratory of the Nuclear Materials Authority (NMA) were used. The analytical conditions were 25-30 Kv accelerating voltages, 1-2 mm beam diameter and 60-120 second counting times. Minimum detectable weight concentration from 0.1 to 1 wt%

precision is well below 1%, the relative accuracy of quantitative result 2-10% for elements Z>9 (F), and 10-20 % for the light elements B, C, N, O and F); were used to identify the present heavy minerals as well as radioactive minerals.

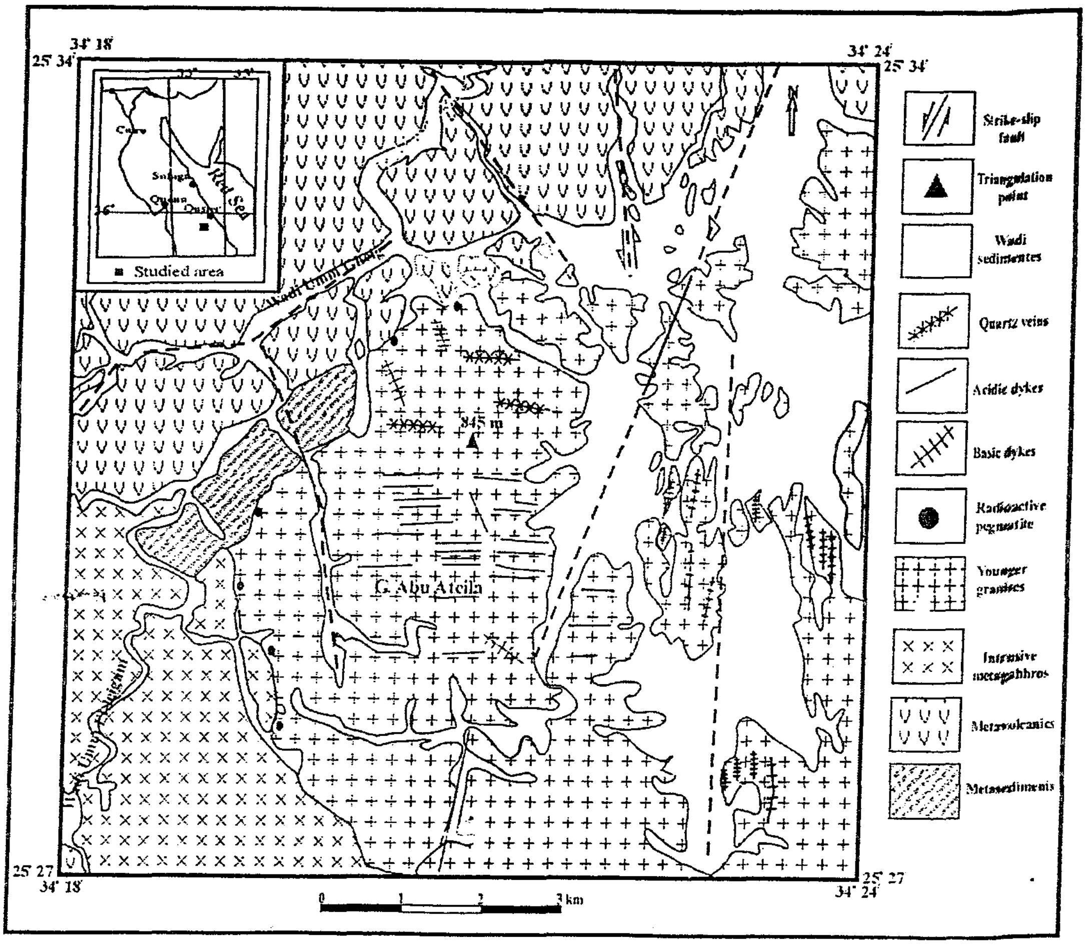


Fig.(1): Geological map of Gabal Abu Ateila granite, Central Eastern Desert, Egypt. Modified after Abdel Monem et al.,(2003).

FIELD GEOLOGY AND PETROGRAPHY

Abu Ateila granitic pluton forms a large elongated belt trending in N-S direction. Generally, they exhibit high to moderate relief, medium- to coarse-grained, exfoliation, cavernous and bouldery appearance intrude the metavolcanics and metagabbros sending several off shoots into them and containing several xenoliths with different shapes and sizes of the oldest types.

The pegmatites occurred as large elongated bodies ranging from 0.3m to 2m in the width and from 5m to 10 m in length. Also, they are found as small pockets and lenses exhibiting variation in color and display sharp contacts with the granite host (Plate 2a). In all cases, the pegmatites are characterized by obvious simple zonation, being composed of alkali feldspar at the margins followed by quartz at the core. Quartz occurs as very coarse crystals of different colors; rose, milky white or colorless, dissected by numerous fractures completely stained by iron oxides and associated with radioactive minerals.

The microscopic study revealed that Abu Atheila granite is monzogranite in composition with equigranular and hypidiomorphic textures. It is composed essentially of quartz, K-feldspar, plagioclase and flakes of biotite. Zircon, apatite, fluorite, sphene and opaques are the accessories. Secondary minerals are the least dominant mineral constituents represented by chlorite, secondary muscovite, sericite and epidote.

Quartz occurs in more than one generation. The earliest one is found as anhedral coarse to medium crystals exhibiting andulose extinction. The other secondary quartz and feldspar intergrowths are observed as graphic textures (Plate 2b). Plagioclase (albite to oligoclase, An_{10-21}) occurs as euhedral to subhedral prismatic crystals of clear lamellar, pericline and composite twinning, zoned crystals are common. Plagioclases are partially sericitized and muscovitized (Plate 2c). K-feldspars are commonly represented by microcline perthite and antiperthite exhibiting string and patchy types. In some places, small plagioclase lathes forming minor albitic phase occur mostly within perthite crystals (Plate.2d). Biotite is found as anhedral to subhedral brownish flaky crystals corroded by quartz, plagioclase and perthite exhibiting partial chloritization, muscovitization and epidotization (Plate 2e). Enrichment in many accessory mineral fractions in the granites occurs as abundant crystals of zircon, fluorite, sphene, allanite, pyrite and opaques.

Petrographically, the studied pegmatite bodies are holocrystalline, coarse to very coarse grained and composed mainly of quartz, k-feldspars, plagioclase and flakes of mica. The accessory minerals are mainly zircon, fluorite, apatite and opaques. The mica minerals are mainly muscovite and biotite. Quartz is the most predominant mineral, found as subhedral to euhedral interstitial grains between plagioclase and perthites. K-feldspars are represented by orthoclase, microcline and microcline perthite. Perthite and antiperthite form subhedral to euhedral prismatic megacrysts corroded by quartz (plate 2f). Plagioclase (An_{12-27}) albite to oligoclase in composition occurs as euhedral to subhedral crystals exhibiting slight deformation; sericitization and muscovitization in some plates (plate 2g). Mica occurs as subhedral to euhedral flakes of muscovite intercalated between feldspars and quartz intimately associated with acsseory mineral (plate 2h). Zircon occurred as colorless subhedral to euhedral prismatic crystals generally enclosed in mica and plagioclase. These crystals mainly being in the metamict state contain radioactive inclusions

MINERALOGICAL INVESTIGATION

Columbite-Tantalite series [$(Fe,Mn)(Nb,Ta)_2O_6$]. Nb and Ta occur mostly together as complex oxides or hydroxides, rarely as silicates in different rock types. Pegmatites represent the main source of Ta and Na (90% of total world production, Naeim et al., 1990). Columbite easily separated by heavy liquid separation occurred as deeply black medium to fine suhedral to euhedral grain-size, luster varying from metallic to submtallic under the binocular-stereo microscope (Plate 3a). The crystals disseminated in pegmatite, were identified by ESEM techniques. This series represents solid solution between niobite

$(Fe,Mn)(Nb,Ta)_2O_6$ and tantalite $(Fe,Mn)(Ta,Nb)_2O_6$. In fact, the close relationships between Nb and Ta elements, both being pentavalent, preferring octahedral coordination in oxide compounds with similar ionic radii=0.72Å (Whitlaker and Muntus, 1970) cause extensive mutual substitution between them. Tantalum generally accompanies Nb with an abundance of 1/10 to 1/15 that of Nb. Columbite is isomorphous with tantalite and is an ore of niobium as well as a source of tantalum. The high U contents with the relatively low Th content of the studied columbites further suggest the presence of submicroscopic uranium inclusions in these minerals. The analyzed columbites are distinctly enriched in U, Y and Ta respectively (Plate 3 b,c&d).

The columbite-tantalite series are the most abundant in the granitic pegmatites, particularly those with well- marked albite and Li silicates associated with albite, microcline, lepidolite and muscovite.

Thorite occurs as euhedral to suhedral fine to very fine blackish opaque minerals. It was separated by heavy liquid and picked up under the binocular microscope confirmed by the ESEM technique. The EDAX analyses of thorite reflect mainly Th with appreciable amount of other elements commonly present in small to minor amounts as Ca, Fe, Pb, Cu, Ni, Mn, Mo and Al (plate 3d).

a): Photo geology of pegmatite bodies in the Gabal Abu Ateila granites, along Wadi Umm Gheig.

b): andulose extinction of quartz and secondary graphic texture in granites (CN.60).

c): euhedral lamellar twinning, zoned plagioclase crystals partially serecitized in granites (CN.120).

d): microcline perthite including albite crystal, in granites (CN.120).

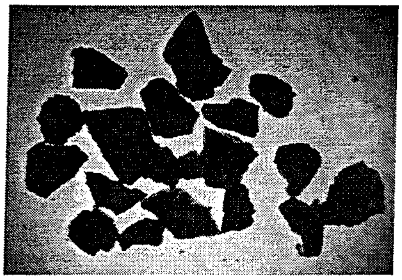
e): chloritized and muscovitized biotite corroded by quartz and perthites. in granites (CN.120).

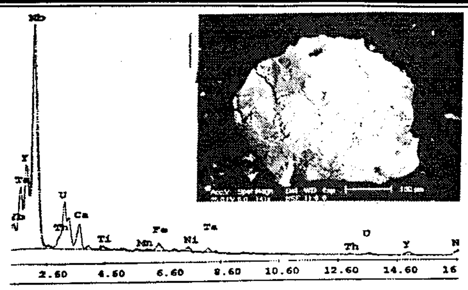
f): subhedral crystals of microcline perthite corroded by plagioclase and quartz in pegmatite, (CN.120).

g): euhedral plagioclase crystals slightly muscovitzed in pegmatite, (CN.120).

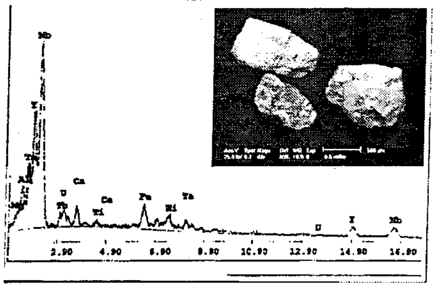
h): flakes of muscovite intercalated between feldspars and quartz associated with accessory mineral, (CN.120).

Plate 2

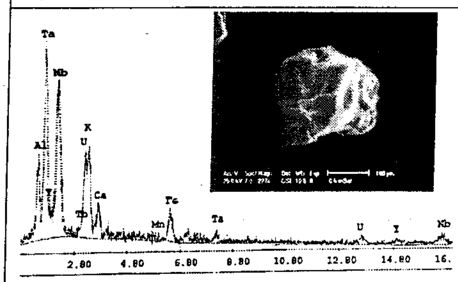




b):

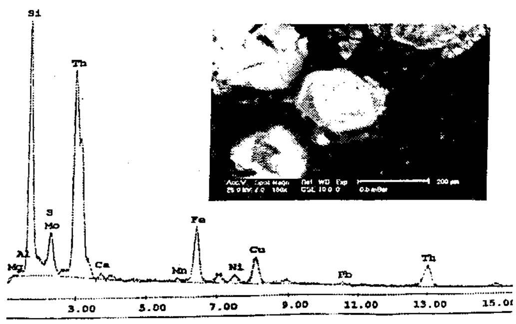


c):



d):

a) Subhedral grains of columbite. (PPL).
b) EDX and back scattered images of columbite-tantalite series. richU.
c) rich Y and
d) tantalite columbite, rich U.



e) EDX and back scattered images of thorite inclusions.

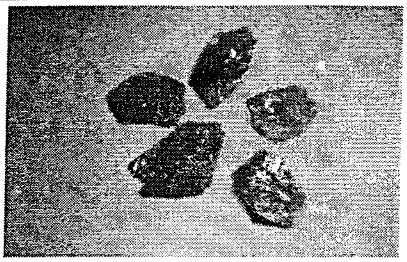
Plate 3

Zircon ($ZrSiO_4$) has been found as the most abundant accessory mineral in the studied granite and pegmatite samples. In the studied area, zircon occurs as euhedral prismatic zoned crystals with clusters of opaque inclusions (plate 4d). **Hussein (1978)** stated that the radioactive zircons are usually zoned. The radioactive zircon also was characterized by metamictization. The explanation for the origin of the "Metamict State" is that the internal order of an originally crystalline form has been destroyed by $\propto$-particles bombardment from radionuclide within the structure. Zircon may be partially or completely modified giving amorphous zircon with more isotropic character; such minerals are called metamict zircon.

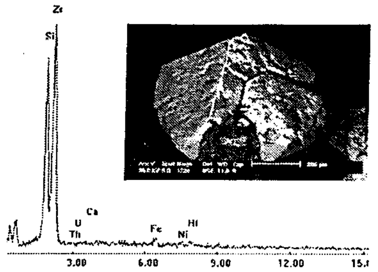
Zircon crystals in these pegmatites are mainly characterized by high metamictization. It is known that zircon can incorporate uranium in its lattice and enclose the radioactive materials as mineral inclusions. By using the environmental scanning electron microscope (ESEM), the analyses of zircon crystals show that it consists essentially of Zr and Si. All data show significant amounts of Fe, which occurs as staining Fe oxides. The ESEM revealed that this mineral incorporated uranium in its lattice (plate 4b).

Fluorite (CaF_2) has been detected wide spresd in the studied samples. It is characterized by ranges in color varying from colorless, blackish to violet euhedral to subhedral crystals (plate 4c). In both colorless and violet fluorite varieties more than 70 % of the rare earths content in fluorite is of HREE (Bulnayev and Kaperskaya, 1990). Hence the violet fluorite is obviously good accumulator of REEs and radioactive elements. The high concentration of the alkalinity in the magmatic melts and mineralizing solutions play an important role where the presence of fluorine may cause full separation of the REE and hence preferential accumulation of the heavy REE in the fluorite (Bulnayev and Kaperskaya, 1990).

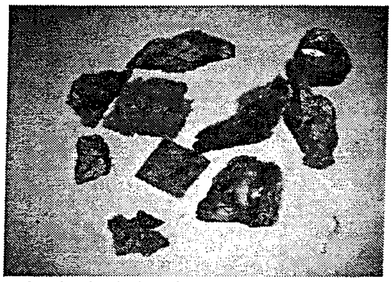
Pyrite (FeS) occurs as well developed cubic octahedron crystals with pale-brass yellow color and metallic luster (Fig. 5e). It is mainly composed of Fe and S with Ni and Mo impurities (plate 4g). This explains the reducing conditions during the late stages of columbite crystallization, which is also responsible for the formation of pyrite. Gold and other traces were not found in the pyrite crystals. In addition, some polymetalic galena is hosted in Ca carbonate. This may explain the metasomatic processes took place under alkaline medium (plate 4h).



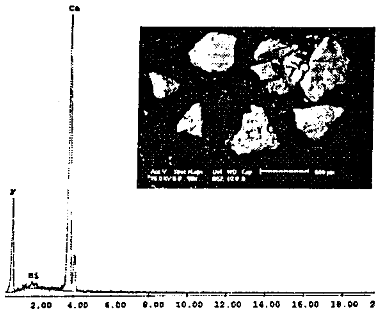
a) euhedral reddish zircon crystals (PPL).



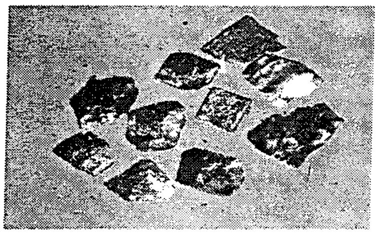
b) EDX and back scattered images of zircon.



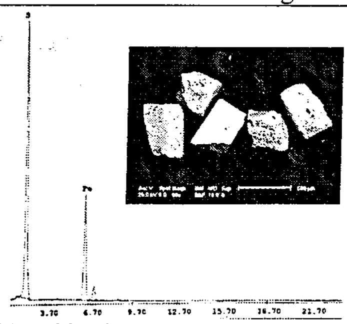
c) Euhedral violet flourite crystals (PPL).



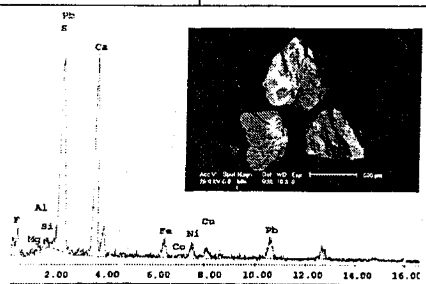
d) EDX and back scattered images of fluorite



e) Subhedral grains of pyrite(PPL).



f) EDX and back scattered images of pyrite.



g) EDX and back scattered images of polymetalic galena hosted in Ca carbonate and fluorite.

Plate 4

U AND Th SPECTROMETRY

Uranium occurs in nature in several valance states, in which tetravalent (U^{+4}) and hexavalent (U^{+6}) are the most common ones, where thorium exists only in tetravalent (Th^{+4}) state. The U^{+4} has an ionic radius similar to the ionic radii of Th, Ca, Na, Zr, Nb, Y, Ce, Pb, Fe^{+2} and the rare earth elements. Therefore, U^{+4} can substitute these elements in the structure of their minerals (Gascoyne, 1982). U^{+4} is insoluble in water and occurs mainly in primary minerals, but when oxidized to U^{+6} becomes soluble in water and forms secondary

minerals. Thorium is insoluble in water, occurs mainly in primary minerals, and is rarely leached by secondary processes.

Equivalent uranium (eU) and equivalent thorium (eTh) contents of the studied Gabal Abu Ateila granites are given in (Table.1). The eU contents of the analyzed granitic samples range from 5ppm to 11ppm and the eTh contents range from 13 to 20 ppm. The eTh/eU ratios of these granites range from 1.82 to 2.67.

Table (1): eU (ppm), eTh (ppm) and eTh/eU raitos of Gabal Abu Ateila granites and associated pegmatites.

S.No.	Abu Ateila granites						Abu Ateila pegmatites				
	G1	G2	G3	G4	G5	G6	P10	P11	P12	P13	P14
eU	8	7	5	9	11	6	737	587	672	957	732
eTh	16	18	13	18	20	16	880	242	296	315	148
eTh/eU	2.00	2.57	2.6	2.0	1.82	2.67	1.19	0.41	0.44	0.33	0.20

The correlation between eU and eTh concentrations for the studied Gabal Abu Ateila granites show that the U and Th reflect a strong positive correlation (R= 0.87) and the samples show a linear correlation (plate 5a). On the contrary, the eTh/eU ratio show a negative relation with eU (plate 5b) suggesting that the U was added preferentially to Th in these samples confirming the mobilization of U by hydrothermal solutions.

Pagel (1982) stated that in igneous rocks, U and Th occur mainly in accessory minerals as thorite, monazite and zircon. The minerals with high content of U and Th lose their crystallinity as a result of internal radiation damage becoming metamict and more readily altered and hydrated, so that U would be easily leachable by circulating hydrothermal solutions.

The eU-contents of Gabal Abu Ateila granites are shown in table (1) as well as the results of some trace elements are given in (Table.2). The eU-contents exhibit an inverse relation with Rb Y, Ba and Nb (Plate 5c, d, e, f & g) and positive relation with Zr contents (R= 0.5) (Plate 5c).

Table (2): Results of trace element analysis (ppm) of granitic and pegmatitic samples of Gabal. Abu Ateila

	Abu Ateila granite						Abu Ateila pegmatite				
S.No.	G1	G2	G3	G4	G5	G6	P10	P11	P12	P13	**P14**
Zr	88	120	162	125	576	350	3375	4209	3976	3569	**3250**
Rb	157	250	350	281	92	140	77	91	95	90	**91**
Y	37	76	117	144	45	100	272	346	343	317	**284**
Ba	84	70	68	77	68	75	219	226	234	225	**209**
Sr	54	40	24	19	4	20	1	1	6	4	**1**
Nb	16	50	80	62	54	45	141	196	190	182	**122**
Pb	2	10	7	23	1	12	714	859	862	816	**721**

U and Th distribution of Abu Ateila mineralized pegmatites

The eU and eTh contents and the eTh/eU ratios of the studied Abu Ateila mineralized pegmatite bodies are given in table (1). The eU contents of the analyzed pegmatite samples range from 587 to 957ppm and the eTh contents range from 148 to 880 ppm. The eTh/eU ratios of these samples range from 0.20 to 1.19. The very low eTh/eU in the pegmatites indicate strong addition of uranium during post-magmatic stages (Charbonneau, 1982).

The relationship of the eU and eTh concentrations for these pegmatitc bodies are directly correlated (Plate 6A), while the eTh/eU ratio is inversely correlated with U (Plate 6b) and with the eTh contents (Plate 6c). This means that the studied pegmatitic bodies may be enriched in U relative to Th by hydrothermal solutions.

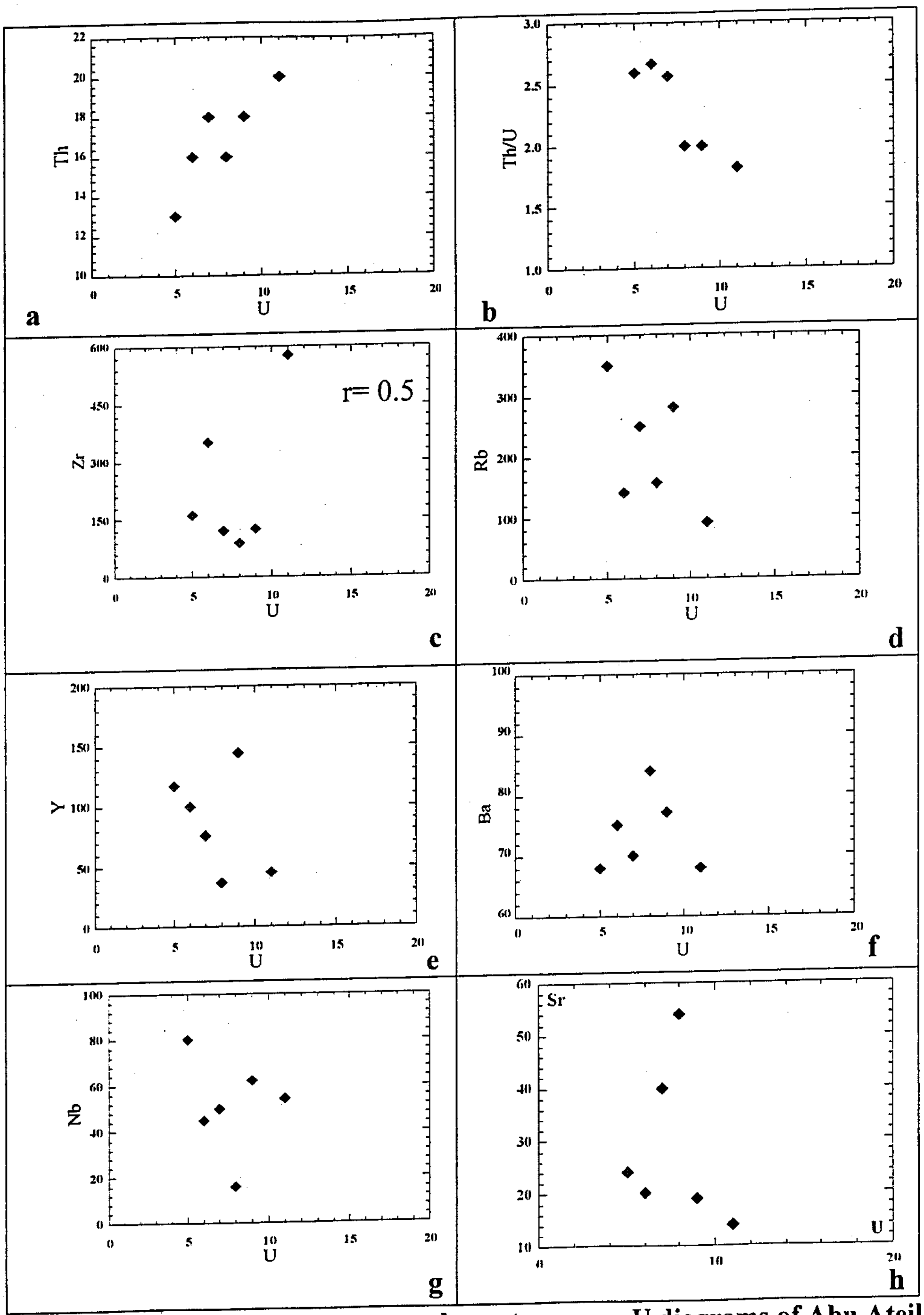


Plate 5: eTh, eTh/eU and some trace elements versus eU diagrams of Abu Ateila granites.

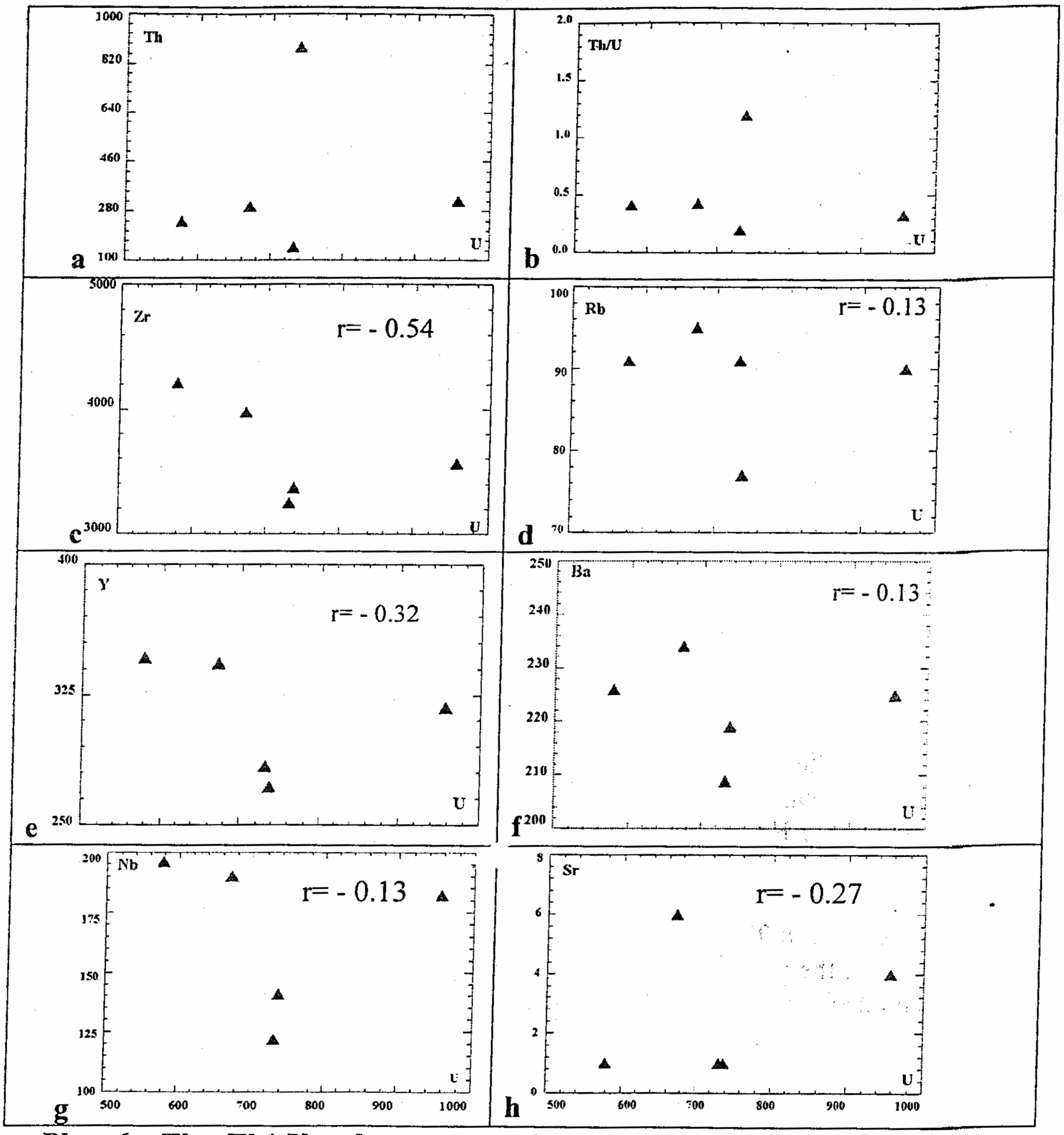


Plate 6: eTh, eTh/eU and some trace elements versus eU diagrams of Abu Ateila pegmatite.

The non-systematic relations between the U-contents of Gabal Abu Ateila pegmatites and some trace elements (Table.2) are attributed to the hydrothermal solutions effects, where the U-contents exhibit a weakly negative relation with Zr

(R= -0.54), Rb, (R= -0.13) Y (R= -0.32), Ba (R= -0.13)and Nb (R= -0.13) (Plate 6c,d,e,f&g) and a weakly positive relation with Sr (R=0.27) (Plate 6h).These relations discuss that the uranium is concerned with the presence of columbite and thorite.

CONCLUSION

The studied granites and pegmatitic bodies of Gabal Abu Ateila represent a part of the basement rocks of the Central Eastern Desert of Egypt. The pegmatites occur as elongated bodies ranging from 0.3m to 2m in width and from 5m to 10m in length. Also, they are found as small pockets and lenses exhibiting variation in color and display sharp contacts with the granite host. In all cases, the pegmatites are characterized by obvious simple zonation, Detailed microscopic investigations and Environmental Scanning Electron Microscope (ESEM) were used to identify the present heavy minerals as well as radioactive minerals.

The radiometric studies of anomalous pegmatite samples show that their equivalent uranium contents (eU) range from 587 to 957ppm while their equivalent thorium contents (eTh) vary from 148 to 880 ppm.

The very high Th contents are recorded in the studied pegmatites, due to the primary Th radioactive mineral (thorite) occurance. Whereas uranium concentration in the lattice of the accessory minerals such as zircon, fluorite, radioactive-bearing mineral as columbite and/or adsorbed by accessory minerals such iron oxides.

These studies revealed that, the presence of radioactive mineral such as thorite and U-bearing radioavtive minerals as columbite, zircon fluorite are responsible for the high radioactivity of the studied pegmatites. Minor amounts of pyrite and galena were also recorded.

The present study proved that thorite and columbite are the main minerals responsible for both Th and U contents in the studied pegmatite. The study throw some lights on the presence of some base metals (pyrite and galena) which needs more detailed exploration work in the future.

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دراسات معدنية واشعاعية للاجسام البجماتيتية فى الصخور الجرانيتية بجبل ابو عتيلة وسط الصحراء الشرقية مصر

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اثبتت عمليات المسح الراديومترية للاجسام البجماتيتية فى الصخور الجرانيتية بجبل ابو عتيلة وسط الصحراء الشرقية عن وجود شذات اشعاعية ، واكدت القياسات الراديومترية لهذة الصخور ان محتوى اليورانيوم يتراوح بين ٥٨٧ الى ٩٥٧ جزء من المليون بينما يتراوح محتوى الثوريوم بين ١٤٨ الى ٨٨٠ جزء من المليون. اما بالنسبة لصخور الجرانيت يتراوح محتوى اليورانيوم بين ٥ الى ١١ جزء من المليون بينما يتراوح محتوى الثوريوم بين ١٣ الى ٢٠ جزء من المليون.

وقد تمت الراسات المعدنية المستفيضة على المعادن الثقيلة المفصولة من هذة الاجسام البجماتيتية باستخدام الميكروسكوب الضوئى وكذلك الميكروسكوب الماسح الاليكترونى وقد اكدت هذة الدراسات تواجد معادن الثوريت والكولومبيت والزركون والفلوريت والبيريت والجالينا.

واثبتت الدراسات الحالية ان معادن الثوريت والكولومبيت هى المسؤلة عن الاشعاع فى صخور البجماتيت ويرجع ذلك الى تاثير المحاليل الحارة الحاملة لهذة المعادن والتى أثرت على الصخور البجماتيتية الموجودة فى الصخور الجرانيتية بهذة المنطقة.