GEOLOGY AND RADIOACTIVITY OF PERALUMINOUS GRANITE AND ASSOCIATED PEGMATITE HOSTING MAGNETITE MINERALIZATION AT UM REGEBA AREA, SOUTHEASTERN DESERT, EGYPT

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ABSTRACT

The study area represents the southeastern part of Wadi El-Gemal-Hafafit culmination in the south eastern Desert of Egypt. Magnetite mineralization occurs in Wadi El-Gemal area in many localities, Um Regeba area is the case study.

Petrographically, the studied peraluminous granites (PG) are medium- to coarse-grained and mainly composed of plagioclase (An$_{5-10}$), K-feldspar, quartz, biotite and muscovite. Sericite and chlorite are secondary minerals, while allanite and zircon are the common accessories. The peraluminous pegmatites (PP) are coarse-grained and composed essentially of K-feldspar, quartz, plagioclase (An$_{6-10}$), muscovite and biotite. Titanite, allanite, zircon and magnetite are common accessories.

Geochemically, the studied peraluminous granites and peraluminous pegmatites are monzogranite and syeno- to alkali feldspar granite respectively. They have peraluminous character, calc alkaline and alkaline affinities respectively, emplaced in within plate setting, crystallized under water–vapor pressure (2-3 Kb), temperature from 760° to 800° C, pertaining to the I-type granite originated by highly differentiated magma generated from upper mantle contaminated with some crustal materials.

Magnetite usually occurs as small lumps, concentrated by to accumulation in magmatic segregations that developed in response to fractional crystallization. Magnetite showed lamellar intergrowth with ilmenite. The latter can be seen with a hand lens in most magnetite samples. The magnetite of Um Regeba area represents a late stage magmatic product. From the microprobe results, magnetite is characterized by high content of SiO$_2$, Al$_2$O$_3$, CoO and Cr$_2$O$_3$, whereas ilmenite is characterized by high content of MnO and ZnO. The average eU content in the peraluminous granites is 1.96 ppm, while it reaches 5.65 ppm for eTh. The average eU content in the peraluminous pegmatites is 9.12 ppm, while the average eTh content is 21.76 ppm.

INTRODUCTION

Peraluminous granitic segregations are commonly associated with regionally metamorphosed terrains (Clemens and Wall, 1981), Debon et. al. (1986), Inger and Harris (1993). Numerous mechanisms have been proposed to explain the derivation of these segregations from the metamorphosed host rock. Partial melting of metapelites is still the most widely accepted model for the generation of these peraluminous granites (Holtez and Barbey, 1991). The breakdown of the hydrous silicates in these pelites (such as muscovite and biotite minerals) produces most of the water required for this partial melting process (Fyfe, 1969).
Four principal mechanisms for the formation of peraluminous granites have previously been advocated (Mohamed and Hassanen, 1997): (1) the peraluminous granite is directly linked to peraluminous source rocks, (2) the peraluminous granite may, at least in part, be the result of reaction with host rocks, (3) the peraluminous granite has been derived from meta-aluminous magmas by fractional crystallization and (4) the peraluminous granite is at least in part if not wholly, the result of interaction between late stage magmas or subsolidus rocks and hydrothermal fluids.

In Egypt, the peraluminous granites represent phases of orogenic to late orogenic. Their quartz veins are rich in -Mo, Sn, W, U, Nb and -Ta mineralization within the granitic rocks (Takla and Nowier, 1980).

Most of the pegmatites are usually associated with granitoid rocks, but little is incorporated with mafic-ultramafic rocks. The pegmatites can be roughly categorized according to their alkali concentration ratios, as follows: primitive pegmatites, intermediate pegmatites and evolved pegmatite (Jolliff et al., 1992).

Granitic pegmatite magma is peraluminous and characterized by enrichment in volatiles such as F, P, B and/or $H_2O$. It has been demonstrated that such volatiles have a significant influence on the evolution of the pegmatite magma, the temperatures of the solidus and liquids of the magma, the viscosity of the silicate melt, the crystallization sequence of minerals and also on the partition behavior of trace elements between fluid and melt (Černý and Meintzer 1985; Webster and Rebbert, 1998; London, 1987; Dingwell et al., 1998, Bai and Van Groos, 1999, Keppler and Wyllie, 1991 and Keppler, 1993).

Magnetite occurs in the peraluminous pegmatites and granites in many localities of W. El Gemal area, especially in El Mokhattata area. The Um Regeba area is the case study for this mineralization and this is the first record of magnetite mineralization in the area. Magnetite forms under a wide variety of conditions, crystallizing at high temperature from silicate, sulfide and carbonatite magmas or it can precipitate at lower temperatures from hydrothermal fluids. These different conditions may lead to distinctive trace element signatures for the magnetite. It is possible to use the trace element signature of magnetite as petrogenetic and provenance indicators (Dare et al., 2013).

The main target of this work is to study the magnetite mineralization as well as the hosting peraluminous granites and pegmatites of Um Regeba area geologically, geochemically, mineralogically and radiometrically.

**METHODS OF STUDY**

Detailed petrographic examination was carried out to study the mineral constituents and textural patterns of the rock. Fourteen samples (14) were chemically analyzed for major and trace elements from the peraluminous granites (9 samples) and peraluminous pegmatites (5 samples). The heavy minerals were separated using heavy liquid (bromoform), followed by magnetic separation using Frantz Isodynamic Separator. The obtained fractions magnetic and non-magnetic were investigated under binocular microscope. All analyses were carried out in the Laboratories of Nuclear Materials Authority (NMA), Cairo, Egypt. Some individual grains of magnetite were picked and analyzed by X-ray diffraction (XRD) method (in the Laboratories of NMA), and the backscattered electron images were performed at the Microscopy and Microanalyses Facility, University of New Brunswick (UNB), Fredericton, New Brunswick, Canada (model JEOL 6400 SEM).

**GEOLOGIC SETTING**

The studied area is located about 80 km SW of Marsa Alam city on the Red Sea Coast (Fig. 1), between lat. 24° 31' 40" - 24° 38' 20" N and long. 34° 37' 30"- 34° 50' E. It represents the southeastern most part of the Nucrus-Hafafit culmination in the south Eastern Desert (Figs. 1& 2).
The exposed rocks were classified (Greiling, 1990) into the following litho-tectonic units: 1) psammitic gneiss, mostly quartz rich meta-psammites, meta-conglomerates and subordinate meta-pelites; 2) Migif-Hafaft gneisses and associated ultramafic and calc-alkaline igneous assemblages, granitoids and metasediments, generally medium metamorphic grade; 3) white gneissic granodiorite, trondhjemite, tonalite complex; 4) peraluminous granites and peraluminous pegmatites bearing magnetite (the present study); 5) late-orogenic granitoids (microgranite, felsite and aplite), (Fig. 2).

The Um Regeba peraluminous granites are characterized by white colour, medium-to coarse-grained and occasionally pegmatitic. The former were emplaced into the older rocks in NNW-SSE trend (striking 350°) (Figs. 3 and 4) close to the major Nugrus thrust. The peraluminous granites contain - in parts - xenoliths from the older rocks; these enclaves form lenses usually exceeding 10 cm in length. The peraluminous pegmatites occur as dyke–like bodies of variable
dimensions intruding the granodiorite of the studied area with sharp contact (Fig. 3). They vary from few centimeters to few meters in width and length, and mostly concordant with the common NW-SE trend of the enclosing granites as well as the other country rocks all over the area (Fig. 4). The magnetite mineralization is associated with the peraluminous pegmatites (Figs. 5 and 6).

**PETROGRAPHY**

**Peraluminous Granites**

The peraluminous granites are medium-to coarse-grained, mainly composed of plagioclase, K-feldspar, quartz, biotite and muscovite. Sericite and chlorite are the secondary minerals, while allanite and zircon are the common accessories.

**Plagioclase** is presented by albite (An$_{5-10}$), which occurs as twinned subhedral to euhedral crystals exhibiting wide range of grain sizes, enclosing sometimes fine crystals of quartz (Fig. 7). The former shows varied degrees of alteration to clay minerals (Fig. 8). Sometimes, it shows corrosion boundaries with quartz (Fig. 9).

**K-feldspars** are represented by microcline and microcline microperthite. Microcline microperthite is observed in subordinate amount as anhedral to subhedral crystal showing the characteristic cross-hatching or tartan pattern (Fig. 10), as a
result of albite and pericline twins’ combination (Deer et al., 1992). Myrmekitic texture is occasionally present due to the replacement of plagioclase by K-feldspar (Fig. 11). 

Quartz occurs as subhedral to anhedral crystals interstitial between the feldspar crystals. Drop like inclusions of quartz are frequently poikilitically enclosed in the feldspar crystals. Biotite is the dominant mafic mineral, occurs as euhedral to subhedral crystals. It occurs as brown colour flakes (Fig. 12) variably altered to chlorite. Muscovite occurs as euhedral to subhedral colourless flakes. Allanite occurs as brown euhedral yellowish crystals associated with zircon and iron oxides. Zircon occurs as euhedral to subhedral prismatic crystals, associated with quartz and iron oxides.

Peraluminous Pegmatites

The pegmatite pockets are composed essentially of K-feldspar which is mostly represented by orthoclase. Orthoclase occurs as euhedral to subhedral crystals showing simple twinning and occasionally kaolinized. Quartz occurs as subhedral to anhedral crystals, some crystals show undulose extinction and irregular boundaries. Plagioclase is acidic in composition (An<sub>8-15</sub>) exists as euhedral to subhedral crystals. It exhibits albite and Carlsbad twinning and occasionally antiperthitic.
GEOCHEMISTRY

The data of chemical analyses (major oxides, trace elements and normative values) are given in Table (1). The general characteristics of the granitic rocks depend on the behavior and distribution of the major and trace elements. The average chemical composition of the studied peraluminous granites and peraluminous pegmatites when compared with Group II the younger granites of the Eastern Desert (Greenberg, 1981). They show increasing in Al₂O₃, MgO, CaO (PG), Na₂O and P₂O₅ decreasing in SiO₂, TiO₂, Fe₂O₃, CaO

Sericitization and kaolinization are encountered. Muscovite forms subhedral to anhedral flakey crystals, sometimes interstitially filled the space between the major constituents. Biotite occurs as subhedral flakey crystals stained with iron oxides. Zircon occurs as euhedral to subhedral prismatic crystals, associated with quartz, allanite and iron oxides (Fig. 13). Allanite occurs as euhedral yellowish brown crystals associated with zircon and iron oxides, and sometimes result from the alteration of epidote (Fig. 14). Titanite forms subhedral to anhedral rhombic crystals, associated with biotite. Magnetite occurs as subhedral to anhedral crystals usually associated with the mafic constituents.

![Fig. 11: Photomicrograph of peraluminous granites showing myrmikitic texture, XPL](image1)

![Fig. 12: Photomicrograph of peraluminous granites showing brown flake of biotite, XPL](image2)

![Fig. 13: Photomicrograph of peraluminous pegmatites showing association of zircon, allanite and magnetite, XPL](image3)

![Fig. 14: Photomicrograph of peraluminous pegmatites showing alteration of epidote to allanite and association with magnetite, XPL](image4)
(PP) and K. O. The average chemical composition of the studied peraluminous granites and peraluminous pegmatites show increasing in SiO, Na, MnO, (PP), K (PP) and P (PG) and decreasing in TiO, AlO, FeO, FeO, MnO, MgO (PP), CaO, K (PG) and P (PP) when compared with average of world granites (Le Maitre, 1976). When compared with G. Nasb Aluba (Saleh, 1992), they show increasing in SiO, MgO and NaO and decreasing in TiO, AlO, FeO, CaO, MgO (PG) K and P. When compared with the muscovite granite at Sikait I (Mahmoud, 2009), they show increasing TiO, AlO (PG), MnO (PP), MgO (PG), CaO (PG), K, NaO and P and decreasing in SiO, AlO (PP), MnO (PG), MgO (PP), CaO (PP), FeO. When compared with granitic rocks of Egyptian granite (Aly and Moustafa, 1984), they show increasing SiO, AlO, MgO, MnO, NaO, K, O (PP) and P (PG) and decreasing in TiO, FeO, MgO, FeO, MnO, K (PG) and P (PG). It is nearly compatible with the average chemical composition of Egyptian granites of Aly and Moustafa, 1984 (Table 2). On the Ab-An-Or ternary diagram (O’Connor, 1965), the studied peraluminous granites and peraluminous pegmatites lie in granite field (Fig. 15). On the R-R discrimination diagram of De La Roche et al. (1980), the peraluminous granites fall in the monzogranite field (Fig. 16).
alkaline, (one sample lie in the alkaline and highly fractionated calc-alkaline field), while the peraluminous pegmatites plot in syeno- to alkali feldspar granite. The studied peraluminous granites and peraluminous pegmatites have peraluminous characters according to the alumina saturation of Clarke (1981) on Shand’s index diagram (Fig. 17). On the discrimination plot of Sylvester (1989) the studied peraluminous granites lie in the calc-

Table 2: Comparison between the average chemical compositions of the studied peraluminous granites and some Egyptian and Worldwide granites

| Major Oxides | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------------|---|---|---|---|---|---|---|
| SiO₂         | 73.99 | 74.58 | 74.06 | 71.3 | 70.82 | 76.76 | 73.2 |
| TiO₂         | 0.05 | 0.04 | 0.15 | 0.31 | 0.29 | 0.02 | 0.22 |
| Al₂O₃        | 14.08 | 13.16 | 12.80 | 14.3 | 14.17 | 13.50 | 13.7 |
| Fe₂O₃        | 0.88 | 1.59 | 1.99 | 1.2 | n. d. | n. d. | 1.1 |
| FeO          | 0.56 | 0.23 | n. d. | 1.64 | 1.71 | 0.40 | 0.97 |
| MnO          | 0.04 | 0.06 | n. d. | 0.05 | 0.04 | 0.04 | 0.05 |
| MgO          | 0.71 | 0.24 | 0.11 | 0.71 | 0.45 | 0.39 | 0.46 |
| CaO          | 1.19 | 0.29 | 0.57 | 1.84 | 2.46 | 0.93 | 1.19 |
| Na₂O         | 4.01 | 4.23 | 3.99 | 3.68 | 3.86 | 3.59 | 3.84 |
| K₂O          | 3.88 | 4.39 | 4.62 | 4.1 | 4.46 | 3.82 | 4.28 |
| P₂O₅         | 0.19 | 0.03 | 0.05 | 0.12 | 0.19 | 0.12 | 0.11 |

n. d.: not detected.
1: Granites of the Um Regeba area, South Eastern Desert.
2: Pegmatites of the Um Regeba area, South Eastern Desert.
3: Group II younger granites of Eastern Desert (Greenberg, 1981).
4: Average of World granites (Le Maitre, 1976).
5: Average of granite in G. Nasb Alubah (Saleh, 1992).
6: Average of the muscovite granite of Sikait I, South Eastern Desert (Mahmoud, 2009).
7: Average of Egyptian granite (Aly and Moustafa, 1984)

Fig. 15: Ab-An-Or ternary diagram (O’Connor, 1965) for the studied peraluminous granites and peraluminous pegmatites

Fig. 16: R₃₋R₂ diagram for the studied peraluminous granites and peraluminous pegmatites, After De La Roche et al. (1980)

Fig. 17: Shand’s index diagram for the studied peraluminous granites and peraluminous pegmatites, After Clarke (1981)

alkaline, (one sample lie in the alkaline and highly fractionated calc-alkaline field), on the other hand the peraluminous pegmatites lie in the alkaline and highly fractionated calc alkali (Fig.18).

The studied peraluminous granites and peraluminous pegmatites lie in the I-type granite of Chapell and White (1974) (Fig. 19). On Pearce et al. (1984) discrimination diagram (Fig. 20), the studied peraluminous granites and peraluminous pegmatites lie in the within plate granite field. The studied peraluminous granites and peraluminous pegmatites are restricted to the syn-collision field (Fig. 21) after Batchelor and Bowden (1985). The Ab-Qz-Or normative ternary diagrams (Figs. 22&23)
reveal that the studied peraluminous granites and peraluminous pegmatites have water-vapor pressure (2 to 3 kb) and temperature from 760° to 800° C suggesting a formation at moderate levels in the crust. The Fe$_2$O$_3$/FeO ratio varies from 1.67 to 3.84 more than 1 (Table 1), suggesting that the rock originated under higher oxidizing condition (Shalaby, 1995 and Ali et al., 1998). The Rb/Zr ratio vs. SiO$_2$
Fig. 23: Ab-Qz-Or diagram for the studied peraluminous granites and peraluminous pegmatites, After Luth et al. (1964)

(Harries et al., 1986) (Fig. 24), reveals that the studied peraluminous granites and peraluminous pegmatites lie in the field of type III. It indicates that the studied peraluminous granites melts could be originated in the the LILE- enriched mantle wedge and contaminated by crustal melts.

The Rb versus K/Rb diagram (Fig. 25) for the studied peraluminous granites and peraluminous pegmatites, show that the Rb tend to be enriched relative to the K in the strongly differentiated granites (Imeokparia, 1981) and the K/Rb ratio ranges from 214.54 to 434.99 for the peraluminous granites while it is 195.10 to 240.40 for the peraluminous pegmatites. The ratio of Ba/Rb decrease with magmatic differentiation due to the crystallization of the feldspar (Fig. 26). In the studied peraluminous granites and peraluminous pegmatites, the Ba/Rb ratio ranges between 0.77 to 5.13 with an average of 1.98, and from 0.92 to 1.66 with an average of 1.20, indicating derivation from mantle origin contaminated with crustal materials.

Spiderdiagram of normalized elements data of peraluminous granites and peraluminous pegmatites relative to Chondrite of Sun and McDonough (1989) (Fig. 27), illustrating
ESEM techniques were used for the identification of the accessory and heavy minerals from the peraluminous pegmatites samples. Based on X-ray patterns and ESEM techniques, the minerals can be classified according to their anion into the following groups:

**Silicate Minerals**

**Zircon (ZrSiO₄)**

Zircon crystal showed different forms such as bipyramids, short prisms with brown or honey brown colour, may exists as normal or metamict. It is iso-structural with xenotime. It is confirmed by XRD-technique (Figs. 29-31).
**Phlogopite [K(Mg,Fe)$_3$AlSi$_3$O$_{10}$(F,OH)$_2$]**

It is reddish brown in colour and was detected by XRD-technique (Fig. 30).

**Phosphate minerals [Xenotime (YPO$_4$)]**

Xenotime is a widespread and important rare earth bearing mineral, where Y can substitute by U, Ca and Si. It is considered as iso-structural mineral with zircon. Khomyakov (1970) has considered the potential of coexisting monazite and xenotime as a geothermometer. El-Kammar et al. (1997a) considered xenotime is a good host for the rare earth elements, where it concentrates the heavy rare earths. This mineral is confirmed by XRD-technique (Fig. 31).

**Oxide Minerals**

**Magnetite (Fe$_3$O$_4$)**

Magnetite is a common, highly magnetic, black opaque mineral with a metallic luster and high specific gravity (4.9–5.2). It is one of the important iron ores and is a common constituent of igneous and metamorphic rocks. Due to its black colour, surface chemistry and strong magnetic property, it has found a great number of applications in industry. Magnetite crystals reach 2cm in size (Fig. 6). It is found as inclusions in the essential minerals or as secondary minerals filling cracks and cleavage planes. It is confirmed by XRD-technique (Fig. 32) and by ESEM techniques (Fig. 33) and contains

![Image 1](image1.png)

**Fig. 30**: X-ray diffraction pattern of zircon and phlogopite in the studied peraluminous pegmatites

![Image 2](image2.png)

**Fig. 31**: X-ray diffraction pattern of zircon and xenotime in the studied peraluminous pegmatites
91.74 % FeO, 0.3% MnO, 0.16% TiO₂ and 0.14 Al₂O₃.

Ilmenite (FeTiO₃)

Ilmenite occurs as accessory mineral in the studied peraluminous pegmatites associated with magnetite. It has an iron black or asphaltic colour as well as it is metallic with dull luster black streak and confirmed by ESEM (Fig. 34), it composed of 34.48 % FeO, 51.2% TiO₂, 16.39% MnO and 0.11 Al₂O₃.

MICROPROBE ANALYSIS OF MAGNETITE

Mineral compositions were determined on the JEOL JXA-733 Superprobe, operating conditions were 15 kv, with a beam current of 50 nA and peak counting time was 30 seconds for all elements at the Microscopy and Microanalyses Facility, University of New Brunswick (UNB), Fredericton, New Brunswick, Canada (Tables 3 to 7). The standards used are Hmt (for Fe), Ilm (for Ti), Grtpyr (for Al, Si, Mg), Bust (for Mn, Ca), Vmet (for V), Chr (for Cr), Comet (for Co), Gahnite (for Zn) and NiO (for Ni). Five magnetite grains were systematically selected named A, B, C, D and E. The five grains were chemically analyses by microprobe along profiles as seen in Figs. 35-39.

In the grain no. A; the magnetite is enrich in FeO, Al₂O₃, SiO₂, CoO and Cr₂O₃ (Table 3), whereas ilmenite in TiO₂, MnO, MgO, V₂O₃ and ZnO.
Fig. 34: ESEM backscattered data showing ilmenite in the studied peraluminous pegmatites.

Fig. 35: Back-scattered-electron image showing profile of spots of microprobe analyses in magnetite grain no. A, Um Regeba area, south Eastern Desert.

Fig. 36: Back-scattered-electron image showing profile of spots of microprobe analyses in magnetite grain no. B, Um Regeba area, south Eastern Desert.

Fig. 37: Back-scattered-electron image showing profile of spots of microprobe analyses in magnetite grain no. C, Um Regeba area, south Eastern Desert.

Fig. 38: Back-scattered-electron image showing profile of spots of microprobe analyses in magnetite grain no. D, Um Regeba area, south Eastern Desert.
In the grain no. B; the magnetite is enrich in FeO, Al$_2$O$_3$, SiO$_2$, MgO, CoO, V$_2$O$_5$ and Cr$_2$O$_3$ (Table 4), whereas ilmenite in TiO$_2$, MnO and ZnO (except spot no. 18).

In the grain no. C; the magnetite is enrich in FeO, Al$_2$O$_3$, SiO$_2$, MgO, CoO, V$_2$O$_5$ and Cr$_2$O$_3$ (Table 5), whereas ilmenite in TiO$_2$, MnO and ZnO.

In the grains no. D and E; the magnetite is enrich in FeO, Al$_2$O$_3$, SiO$_2$, MgO, CoO, V$_2$O$_5$, Cr$_2$O$_3$ (Tables 6 and 7), whereas ilmenite in TiO$_2$, MnO, V$_2$O$_5$, and ZnO.

In general the magnetite is enrich in FeO, Al$_2$O$_3$, SiO$_2$, CoO and Cr$_2$O$_3$ (Table 8), whereas ilmenite in TiO$_2$, MnO and ZnO. The values of V$_2$O$_5$ and MgO fluctuated from one grain to the other, where CaO and NiO contents are negligible.

### SPECTROMETRIC INVESTIGATION

The instrument used in the ground γ-ray spectrometric survey measurements is RS-230. Ground γ-ray spectrometric survey can detect dose rate (D.R.) in unit (nSvh$^{-1}$), potassium (K%), equivalent uranium content (eUppm) and equivalent thorium content (eTh ppm). Uranium mobilization (eUm) in the studied rock types can be calculated as follows; the uranium mobilization is calculated by the difference between the measured eU and the expected original uranium, which is calculated by dividing the measured eTh by the average eTh/eU ratio in the crustal acidic rocks (original uranium = eTh/3.5 according

| Wt%  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| FeO  | 89.28 | 90.58 | 91.13 | 33.31 | 33.64 | 34.59 | 90.76 | 89.27 | 91.03 | 32.21 |
| TiO$_2$ | 0.0698 | 0.03 | 0.4438 | 49.29 | 48.81 | 47.44 | 0.0608 | 0.0342 | 0.202 | 49.98 |
| Al$_2$O$_3$ | 1.358 | 0.3471 | 0.2412 | 0.0129 | 0.0237 | 0.0264 | 0.341 | 0.2324 | 0.2242 | 0.9297 |
| SiO$_2$ | 0.127 | 0.0435 | 0.0403 | 0.0082 | 0.0122 | 0.0134 | 0.038 | 0.1746 | 0.0391 | 0.0133 |
| MnO  | 0.1115 | 0.1118 | 0.1548 | 15.42 | 15.64 | 14.9 | 0.1165 | 0.1776 | 0.1476 | 14.45 |
| MgO  | 0.0066 | 0.0045 | 0 | 0.0085 | 0.0158 | 0.025 | 0 | 0.011 | 0.0047 | 0.0911 |
| CaO  | 0 | 0 | 0 | 0 | 0 | 0 | 0.0059 | 0 | 0 | 0 |
| V$_2$O$_5$ | 0.1154 | 0.1075 | 0.114 | 0.3128 | 0.3436 | 0.2146 | 0.1054 | 0.1123 | 0.1129 | 0.1375 |
| Cr$_2$O$_3$ | 0.008 | 0.0061 | 0.0075 | 0 | 0 | 0 | 0.0015 | 0.0048 | 0.0066 | 0 |
| CoO  | 0.0997 | 0.0943 | 0.1043 | 0.041 | 0.0384 | 0.0348 | 0.1044 | 0.0936 | 0.0999 | 0.0394 |
| ZnO  | 0 | 0.0015 | 0.0003 | 0.1264 | 0.1303 | 0.0968 | 0.0113 | 0.0196 | 0.0015 | 0.4365 |
| NiO  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 91.17 | 91.33 | 92.24 | 98.53 | 98.65 | 97.34 | 91.54 | 90.13 | 91.87 | 98.29 |
Table 4: Microprobe analysis of magnetite sample no. B

| Wt%  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 18  | 19  | 20  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| FeO  | 90.49 | 90.65 | 87.05 | 93.35 | 93.35 | 94.72 | 88.05 | 89.58 | 89.75 | 56.21 |
| TiO₂ | 0.038 | 0.0496 | 0.0982 | 49.04 | 48.59 | 48.21 | 0.1951 | 0.0486 | 0.1141 | 0.47 |
| Al₂O₃ | 0.24 | 0.312 | 2.495 | 0.0192 | 0.0183 | 0.0217 | 0.3578 | 2.1811 | 0.3038 | 0.021 |
| SiO₂ | 0.0384 | 0.0482 | 0.259 | 0.0146 | 0.0151 | 0.0142 | 0.2206 | 0.0514 | 0.037 | 0.0184 |
| MnO | 0.1442 | 0.1433 | 1.655 | 15.61 | 15.9 | 14.94 | 0.1155 | 0.1861 | 0.1507 | 13.63 |
| MgO | 0 | 0.0036 | 0.008 | 0.0084 | 0.0071 | 0.0082 | 0.0022 | 0.0792 | 0.0047 | 0.0513 |
| CaO | 0 | 0 | 0 | 0.0151 | 0 | 0.0005 | 0 | 0.0183 | 0 | 0 |
| V₂O₅ | 0.1045 | 0.114 | 0.1053 | 0.1042 | 0.0787 | 0.1037 | 0.1052 | 0.112 | 0.1048 | 0.1319 |
| Cr₂O₃ | 0.0081 | 0.0005 | 0.01 | 0 | 0 | 0 | 0.0096 | 0.0013 | 0.0067 | 0 |
| CoO | 0.0933 | 0.0954 | 0.0946 | 0.0245 | 0.0292 | 0.0348 | 0.0939 | 0.0996 | 0.0912 | 0.04 |
| ZnO | 0.0075 | 0.0087 | 0.0184 | 0.1256 | 0.1147 | 0.0891 | 0.0219 | 0.3685 | 0.0082 | 0.1123 |
| NiO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 91.16 | 91.42 | 88.08 | 98.31 | 98.11 | 98.14 | 98.87 | 98.71 | 90.58 | 97.89 |

Table 5: Microprobe analysis of magnetite grain no. C

| Wt%  | 21  | 22  | 23  | 24  | 25  |
|------|-----|-----|-----|-----|-----|
| FeO  | 87.47 | 90.95 | 29.27 | 88.95 | 91.63 |
| TiO₂ | 0.0658 | 0.3405 | 50.62 | 0.4456 | 0.0785 |
| Al₂O₃ | 0.5766 | 0.2234 | 0.0317 | 0.3617 | 0.2733 |
| SiO₂ | 0.2366 | 0.0436 | 0.0227 | 0.0465 | 0.04 |
| MnO | 0.1327 | 0.1263 | 17.44 | 0.1483 | 0.0862 |
| MgO | 0.0143 | 0.0013 | 0 | 0.0003 | 0.0033 |
| CaO | 0.0177 | 0 | 0 | 0 | 0.0006 |
| V₂O₅ | 0.1201 | 0.11 | 0.0784 | 0.1183 | 0.1114 |
| Cr₂O₃ | 0.0062 | 0.0105 | 0 | 0.0069 | 0.0107 |
| CoO | 0.0999 | 0.0965 | 0.0322 | 0.0926 | 0.1045 |
| ZnO | 0.1053 | 0.0235 | 0.2223 | 0.0009 | 0.0139 |
| NiO | 0 | 0 | 0.0023 | 0 | 0 |
| Total | 88.82 | 91.03 | 98.32 | 90.17 | 92.33 |

Table 6: Microprobe analysis of magnetite sample no. D

| Wt%  | 26  | 27  | 28  | 29  | 30  |
|------|-----|-----|-----|-----|-----|
| FeO  | 91.7 | 90.97 | 29.65 | 89.2 | 91.1 |
| TiO₂ | 0.076 | 0.1863 | 50.08 | 0.1862 | 0.0815 |
| Al₂O₃ | 0.5489 | 0.2825 | 0.075 | 0.2904 | 0.2733 |
| SiO₂ | 0.0597 | 0.0436 | 0.0322 | 0.1483 | 0.0458 |
| MnO | 0.1491 | 0.1556 | 17.91 | 0.1287 | 0.154 |
| MgO | 0.0237 | 0.0037 | 0.0028 | 0.0037 | 0.0075 |
| CaO | 0 | 0 | 0.0032 | 0.0082 | 0 |
| V₂O₅ | 0.1067 | 0.1045 | 0.1905 | 0.1147 | 0.1093 |
| Cr₂O₃ | 0.0046 | 0.0053 | 0 | 0.0079 | 0.0039 |
| CoO | 0.0981 | 0.1047 | 0.0217 | 0.0973 | 0.1031 |
| ZnO | 0.0197 | 0.0047 | 0.2236 | 0.0158 | 0.0045 |
| NiO | 0 | 0 | 0 | 0 | 0 |
| Total | 92.78 | 91.86 | 98.19 | 90.21 | 91.88 |

to Clark et al., 1966) to give the leaching values of uranium (eU= eU-eTh/3.5). Positive values indicate uranium addition by mobilization, whereas negative values indicated migration of uranium by leaching.

The eU contents in the studied peraluminous granites range between 0.6 and 3.20 ppm with an average of 1.96 ppm. The eTh contents range between 2.4 and 13.20 ppm with an average of 5.65 ppm, while the average of (eTh/eU) ratios are 3.32 ppm and (eU/ eTh) ratios are 0.42, and average of eUm is 0.35 indicating its magmatic origin (Table 9 and Fig. 40). The eU contents in the studied peraluminous pegmatites range between 6.2 and 11.9 ppm with an average 9.12 ppm. The
eTh contents range between 13.50 and 28.40 ppm with an average of 21.76 ppm, while the average of (eTh/eU) ratios are 2.43 ppm and (eU/eTh) ratios are 0.42, and average of eUm is 2.95 indicating addition of uranium from surrounding rocks (Table 9 and Fig. 40).

The comparison between the radioelement concentrations in the peraluminous granites and peraluminous pegmatites at Um Regeba area relative to those of the crustal igneous rocks after IAEA (1979) and Boyle (1982) are listed in Table (9). It is noticed that the concentration of eU and eTh in the peraluminous granites at Um Regeba area are relatively lower than normal case as the corresponding values in the crustal average, whereas in the peraluminous pegmatites are higher than normal case as the corresponding values in the crustal average.

The binary relations of eU, eTh, and eTh/

Table 9: The minimum, maximum and average of radiometric measurements of the Um Regeba peraluminous granites and peraluminous pegmatites, SED, Egypt.

|                | eU (ppm) | eTh (ppm) | K% | eTh/eU | eU/eTh | eUm       |
|----------------|----------|-----------|----|--------|--------|-----------|
| Peraluminous   |          |           |    |        |        |           |
| Min.           | 0.6      | 2.40      | 1.70 | 0.81   | 0.094  | 2.37      |
| Max.           | 3.20     | 13.20     | 6.70 | 10.67  | 1.24   | 2.39      |
| Peraluminous   |          |           |    |        |        |           |
| Min.           | 0.60     | 13.20     | 3.00 | 1.80   | 0.026  | -0.057    |
| Max.           | 9.12     | 21.76     | 4.17 | 2.43   | 0.42   | 2.90      |
| Aver.          | 4.50     | 18        | 4   | 4      | 0.25   |           |
| Crustal acidic |          |           |    |        |        |           |
| igneous rocks  |          |           |    |        |        |           |
| (after IAEA, 1979 and Boyle, 1982) |          |           |    |        |        |           |
was probably controlled by magmatic (Simpson et al., 1979). A poor negative relations ($r = -0.10$) exist between $e$Th and $e$Th/eU as shown on Fig. 42 indicating that uranium distribution in these rocks is not only controlled by magmatic processes but also by post-magmatic processes.

**CONCLUSIONS**

The exposed rocks in the study area can be classified into the following litho-tectonic units: 1) psammitic gneiss, mostly quartz rich meta-psammmites, meta-conglomerates and subordinate meta-pelites; 2) Migif-Hafafit gneisses and associated ultramafic and calc-alkaline igneous assemblages, granitoids and metasediments, generally medium metamorphic grade; 3) white gneissic granodiorite, trondhjemite, tonalite complex; 4) peraluminous granites and peraluminous pegmatites bearing magnetite; 5) late-orogenic granitoids (microgranite, felsite and aplite) (Greiling, 1990).

The peraluminous granites are emplaced into the older rocks of the area in a NNW-SSE trend-close to the major Nugrus thrust. The peraluminous granites are mainly composed of plagioclase (An$_{10}$), K-feldspar, quartz, biotite and muscovite. Allanite and zircon are common accessories.

The presence of cross-hatching (tartan pattern) as low-temperature transforming twinning in the studied peraluminous granites is consider as a product of a combination between albite and pericline twinning in peculiar relation. The chloritization and sericitization alteration are secondary textures in the granitic rocks arising from deuteric or later hydrothermal activity (Shelley, 1993).

The peraluminous pegmatites occur as pockets of variable dimensions vary from few centimeters to few meters in width and length, and mostly concordant with the common NW-trending of enclosing granites and other country rocks all over the area. The peraluminous pegmatites are coarse grained, composed essentially of K-feldspar, quartz, plagioclase (An$_{10}$), muscovite and biotite. Titanite, zircon, allanite and magnetite are common accessories.

Geochemically, the studied peraluminous granites and peraluminous pegmatites are monzogranite and syenogranite to alkali feldspar granite respectively. They have peraluminous character, calc alkaline and alkaline affinity respectively, emplaced in within plate setting, crystallized under water-vapor pressure (2-3 Kb) and temperature from 760° to 800°C, pertaining to the I-type granite originated by highly differentiated magma generated from upper mantle contaminated with some crustal materials. The studied peralu-
mineral granite originated under high oxidation condition.

Mineralogically, the identified heavy minerals are classified into groups according to their anion either they are radioactive or non radioactive; 1- Silicate minerals (zircon & phlogopite), 2-Phosphate mineral (xenotime), 3-Oxide minerals (magnetite and ilmenite).

The magnetite mineralization was disseminated within the peraluminous pegmatites. The magnetite of Um Regeba area represents a late stage magmatic product. The pegmatite segregates magnetite crystals and form masses of magnetite, concentrated in response to fractional crystallization and this phenomenon is repeated in the peraluminous granites of W. El Gemal, especially in El Mokhattata area.

Magnetite showed lamellar intergrowth with ilmenite. Ilmenite is visible with a hand lens in most magnetite samples. The magnetite is enrich in FeO, Al₂O₃, SiO₂, CoO and Cr₂O₃, whereas ilmenite in TiO₂, MnO and ZnO. The values of V₂O₅ and MgO fluctuated from one sample to the other, where CaO and NiO contents are negligible. The enrichment of magnetite and ilmenite by the previous elements due to a geochemical behavior (ionic substitution). The depletion in CaO due to Ca²⁺ ions cannot substitute for Fe²⁺ in the magnetite and ilmenite lattice because it is considerably larger than Fe²⁺ and also differ in physical properties. The depletion in NiO is due to the magmatic origin of the magnetite.

Radiometrically, the radioactivity increases from the peraluminous granites to the peraluminous pegmatites. The average eU content in peraluminous granites is less than twice the Clark value (4 ppm). The average eTh/eU ratio is 3.32; indicating the rock is not uraniferous, while the average eU content in the peraluminous pegmatites is more than twice the Clark value (4 ppm) indicating the rock is uraniferous.

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جيولوجية وإشعاعية للجرانيت الفوق الألوميني والبجمنت المصابيح الحاويين لمعدن المجانيت في منطقة
أصالة، جنوب الصحراء الشرقية، مصر

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وهذى النهج في دراسة الجرانيت الفوق الألوميني والبجمنت المصابيح له الحاويين تم تعميم المجانيت في منطقة أصالة، حيث يتبع جنوب الصحراء الشرقية. هنالك، يتم توزيع المجانيت في صخور الجرانيت الفوق الألوميني والبجمنت المصابيح، وهو نوع من الصخور الفوق أصلية وقابلة للدراسة. تتكون المنطقة من صخور البنسبيت، نابئ، مسجف - حقبتين رأسياً، وما يصاحبها من الصخور النارية الفوق قاعدياً، والكشكسة والجرانيت والرواسب المنحلّة حول توزيع النجمة، معالجًا الوجوه الأبيض والرملية. المجانيت، الجرانيت الفوق الألوميني والبجمنت المصابيح (الدراسة الحالية)، ثم المجانيت معالجات النجمة التي تشمل المجانيت، دقيق للحبوب، غليان، والألكان.

أوضح التجربة الجيولوجية والتربولوجية أن صخور الجرانيت الفوق الألوميني متوسط إلى خشن الحبيبات

أيضًا، يوجد متأتام في صفخ الجرانيت الفوق الألوميني مع وجود ح정보ال. يتكون من البلاجيكليز، النجوم، والبوتاسي. الدقيقة والجسيمات، بالإضافة إلى الألوان والزركون كمجانيت ضروري. بينما، صخر المجانيت عملياً غليان من تظهرش نقاط اتقاء مختلفة تتراوح من عدة نسبية إلى عدة مترات داخل صخور الجرانيت الفوق الألوميني. يتكون من العشب، و الصخوان فوران، و الألوان والمجانيت كما للجسيمات ضروري. الإشعاعية. 

وتظهر الدراسات الجيولوجية أن الجرانيت والبجمنت الفوق الألوميني ضروري بعد مفروضات. وADINGuturaالجرانيت الفوق الألوميني (فوق) بالترمتب ذو النوع (1) ودالتها في بيئة حيث مصدرها مادة الوعاء

وأخيرًا، توفر بعض مواد القدرة الأرضية. وتخفيضها أرباب بيئية للتحلل بين الأورات، حيث تتضمن تحت ضغط منخفض إلى

ويصل محتوى الوعاء لحوالي 200 درجة مئوية. ومن خلال تحليل العينات باستخدام حية الألغام البينية، المجكرس الكهربامي الماسح الألكتروني، تم الحصول على

مجمعة من المادة تم تقسيمها عند الأمون (الأزران والثدي). معاينة الفيبرات (الزران) معاينة الأكسيس (المجانيت والألماني). دراسة النشاط الإشعاعي في منطقة الوصول تبين أن الأشعاع يشتري من الجرانيت الفوق الألوميني إلى البجمنت حيث الجرانيت الفوق الألوميني يصل متوسط محتواه من الورانيوم إلى 9.12 جزء في المليون، ويبقى في الموئل بينما في المجانيت يصل متوسط محتواه من الأورانيوم إلى 8.7 جزء في المليون.

ودراسة المجانيت تحت المجهر الكهربامي كماسح الألكتروني، وجد صاحب لمعان الألمانيت. ومن خلال

دراسة مجهر المجانيت تحت المجهر الكهربامي كماسح الألكتروني، وجد أن مجانيت كماسح الألكتروني، أكسيس المجانيت، أكسيس الكولانيت، اكسيس الكولانيت، كماسح الألكتروني، اكسيس الكولانيت، كماسح الألكتروني، أكسيس المجانيت، وجد أن المجانيت عين في كماسح الكولانيت، أكسيس المجانيت، كماسح الكولانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كماسح المجانيت، كماسح الكولانيت، كمас..