Tow Mica Granites, Southeastern Desert, Egypt: Geochemistry and Spectrometric Prospecting

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Research Article

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ABSTRACT

Tow mica granites of the Abu Rusheid - Eir Arib district in the Southeastern Desert of Egypt, cut pre-existing faults, and their contacts with the country rocks are sharp and lack contact metamorphism. They were intruded into a low - to high grade metamorphosed ophiolitic mélangé and a high - grade metamorphosed meta-sedimentary succession of biotite schist. Petrographically, the phase is strikingly similar and consists of alkali feldspar, quartz, plagioclase, muscovite and biotite. Zircon, garnet, apatite, allanite, titanite and opaque’s are accessories. Abu Rusheid - Eir Arib tow mica granites are characterized by strongly peraluminous compositions; contain mioralitic cavities and pegmatitic patches, suggesting the release of aqueous fluids from the down going slab during subduction. The investigated rock has low K/Rb and high Zr /Y ratios reflecting a typical mature continental - arc environment. The REEs pattern is characterized by fractionated LREEs and relatively flat HREEs with pronounced negative Eu anomalies. The geochemistry of REEs reflects the behavior of accessories and key major minerals such as garnet and feldspars, and may therefore give valuable information about the conditions of partial melting, melt segregation and crystallization of granite magmas in different crustal regimes. The study presents the surface distribution of the total gamma radiation Tc, K, U and Th in Abu Rusheid - Eir Arib two – mica peraluminous granites. The geochemistry of Zr/U, Zr/Th, Ce/U and Ce/Th against either U or Th in suite exhibits significant negative correlations, indicating that both elements are not preferentially hosted in accessory zircon or monazite, but could be associated with major rock forming minerals such as biotite, muscovite, plagioclase and quartz, or U is situated within labile sites within the granites. The distribution of uranium, thorium and their ratios in the garnetiferous granite reveal that this granite is considered as fertile granites and reflects the amount of remobilization that took place within the granites.

Keywords: Tow mica granites, Magmatic differentiation, Total gamma radiation and Egypt.

INTRODUCTION

Tow mica peraluminous granitoids are present and in some cases abundant in orogenic belts of various ages. The Neoproterozoic mobile belts of the Arabian-Nubian Shield (ANS) have been recognized as a typical example of an accretionary orogen defined by juvenile terranes. They yield Neoproterozoic Nd model ages (Stern, 2002) and have experienced a complete Wilson cycle (Stern, 1994). Although strongly tow mica peraluminous leucogranites are of limited distribution in the Egyptian Shield, they have close spatial association with gneisses and migmatites. They may be used to relate high- grade metamorphism and magmatism with tectono-metamorphic events in the Eastern Desert of Egypt. Many papers have been devoted to tow mica peraluminous granitoids and related intrusive rocks (Clarke, 1981). Syn-collision tow mica peraluminous granitic segregations are commonly associated with regionally metamorphosed terranes (LoNoo, 1992, Inger and Harris, 1993, Ibrahim et al., 2001, Saleh et al., 2002, Clarke et al., 2004, Moghazi et al., 2004, Stevens et al., 2008, Chudik et al., 2008, Tartès and Boulvais, 2009, Procházk et al., 2010). Numerous mechanisms have been proposed to explain the derivation of these segregations from the metamorphosed host - rock, but partial melting of metapelites (Barbey et al., 1990) is still the most widely accepted model for the generation of these tow mica peraluminous leucogranites. Four principal mechanisms for the formation of tow mica peraluminous granites have previously been advocated: (1) the composition of the peraluminous granite is directly linked to peraluminous source rocks, (2) the composition of the peraluminous granite may, at least in part, the result of reaction with host rocks (3) the composition of the peraluminous granite has been derived from meta-luminous magmas by fractional crystallization and (4) the composition of the peraluminous granite is, at least in part if not wholly, the result of interaction between late stage magmas or sub-solidus rocks and hydrothermal fluids . Tow
mica peraluminous granitoids are chemically defined as rocks having molar proportions of $\text{Al}_2\text{O}_3$ in excess of the combined molar proportions of $\text{CaO}$, $\text{Na}_2\text{O}$ and $\text{K}_2\text{O}$. The aluminum saturation index (ASI) is the chemical discriminant between tow mica peraluminous granitoids (>1) and metaluminous granitoids (<1) (Zen, 1988). Many mechanisms have been suggested for generation of peraluminous magmas (Miller, 1985). Some moderately to strongly tow mica peraluminous granites occur as a minor component of dominantly metaluminous granitoids suites that form large plutons or batholiths. These are produced through closed - system fractional crystallization of amphibole and clinopyroxene in metaluminous magmas or hybridization of metaluminous magmas by assimilation of aluminous sedimentary rocks during emplacement (Cawthorn and Brown, 1976). The late Precambrian granitoids of the Arabo Nubian Shield in Egypt were exposed by Early to Middle Tertiary uplift and ensuing erosion during the Red Sea rifting event. There are a number of effective and relatively successful schemes for the classification of Egyptian granites (Hassan and Hashad, 1990, Saleh, 2001). These granites were subdivided by many authors adopting different criteria into three major groups (1) older synorogenic grey or subduction-related I-type, low-k, magnetite granites, showing a wide compositional spectrum dominated by diorites and represented the plutonic equivalents of mature, ensimatic island arcs, (2) a younger late to post-orogenic pink, red or sutured related S - type ilmenite granites. Both groups are calc-alkaline and were formed in compressional environment. The third group is post-orogenic alkaline to peralkaline, extensional, of intraplate or anorogenic setting (A-type granites). The distribution of U, Th and REE in tow mica peraluminous granites are firstly controlled by the magmatic stage (Cathelineau, 1988). In strongly tow mica peraluminous low Ca-granites, uraninite may host up to 90% of the bulk - rock uranium, but only insignificant portions of the thorium concentrations which are predominantly controlled by monazite-group minerals (Friedrich et al., 1987). Uranium with an average concentration of 1.0 ppm in crust needs certain geologic environments to accumulate, however, its ore deposits occur in nearly every major rock type in the crust, and nearly all igneous, metamorphic and sedimentary processes are capable of its concentration or dispersion. As the solubility of monazite and xenotime remains very low regardless of aluminosity (Pagel, 1981), phosphorus-rich peraluminous melts become saturated in monazite and xenotime at low REE concentrations. The nature abundance and distribution of accessory minerals crystallizing from melt depend on four groups of parameters (Pagel, 1981): the trace element contents (a) chemical features (b) of the magma, (c) the degree of magma evolution, (d) and the physical chemical conditions of magma crystallization. The present study deals mainly with the geochemistry and spectrometric prospecting of the tow mica peraluminous granites, SED, Egypt. In the present light shed on the regional geologic setting, geochemical characteristics and in situ spectrometric prospecting of the tow mica granites of the Abu Rusheid - Eir Arib district in the Southeastern Desert of Egypt, and throw some light on their origin U and Th data.

Geologic setting and petrography

A- Abu Rusheid two-mica granites

The Abu Rusheid two-mica peraluminous granites lies along the NE margin of the Migif - Hafafit metamorphic core complex. The rocks exposed in the Abu Rusheid area (Fig.1a) comprise metagabbros, ophiolitic mélangé, cataclastic rocks, granitic rocks and post-granitic dikes and veins. Abu Rusheid granitic pluton elongates in NW-SE (long 6 km) and thinning in NE-SW (width 2.5 km). The southern part of the pluton is surrounded by layered metagabbros thursed over ophiolitic mélangé taking capital letter U-shaped. On the opposite trend of the pluton (NW), more thinning is common giving rise to reverse V-shaped. Cataclastic rocks occupy the core of granitic pluton and carrying a roof pendant of mafic-ultramafic rocks. The concave side of the U-shaped points toward the muscovite granite, whereas the reverse V-shaped points towards porphyritic biotite granite at the end of W. Sikeit followed by highly deformed biotite granite and two-mica peraluminous granite with gradational contacts due to cataclastic rocks (Saleh 1997, Ibrahim et al., 2004). The granites are slightly foliated mainly at the periphery of the pluton and become equigranular, none deformed towards the center. Small xenoliths of mafic up to 1x0.5 m as well as roof pendants of mylonites are recorded in the porphyritic granite Abu Rusheid two - mica peraluminous granites are fine- to medium-grained, jointed and show different shades of red colour from brownish at the periphery to creamy in the center of the pluton.. Acidic dikes and pegmatite veins cut the peraluminous granites. Two types of lamprophyre dikes cross cut both the cataclasites and granitic rocks in E-W to ENE- WSW direction (Fig.1b). The fresh lamprophyre is fine-grained, dark grey in color bifurcate and characterized by onion structure. They are mainly extruded in the two mica peraluminous granites and vary in thickness from 5-10 m and about 1.0 km long (Ibrahim et al., 2007).
B- Eir Arib two-mica granites

Eir Arib two-mica peraluminous granites lie along the Red Sea coast, about 130 km southwest of Shalatin city (Fig.1c). It is dominantly covered by a Precambrian metamorphic sequence that is intruded by younger granitic intrusion. Within the mapped area, a wide range of lithologies are identified in the metamorphic sequence including meta-volcanoes ortho-amphibolite and garnetiferous biotite schists. The two-mica peraluminous granites contain two kinds of xenoliths (1) large angular enclaves (5 to >15m) occur essentially at the margins of the intrusions and (2) rare small xenoliths which usually do not exceed 15cm in length and often form lenses distributed all over the rock. They are essentially composed of muscovite ± fibrolitic biotite. The distribution of these xenoliths is very irregular and is not related to the distance to the margin of the pluton. Acidic dykes cut the granites rocks at the southeastern part of the mass. The acidic dykes are highly affected by kaolinization and hematitization with the presence of carbonate and manganese oxides as thin films along fracture planes. Petrographically, the two-mica peraluminous granite at both Abu Rusheid-Eir Arib AR are composed essentially of plagioclase (An$_{7-21}$), quartz, potash feldspars, biotite and muscovite (3-8 Vol.%) in order of decreasing abundances. Accessories are zircon, monazite, xenotime, apatite, garnet, fluorite and ilmenite. Plagioclase is represented by anhedral, highly altered, red stained crystals, with weakly defined fine albite twinning, and densely replaced by scarcely aggregates of muscovite or embayed by both quartz and microcline. Quartz is represented by clear interstitial anhedral crystals with sutured boundaries and usually gathered in a seriate texture, sometimes enclosed some feldspar crystals. Microcline occurs as anhedral to subhedral crystals perthitically inter-grown with plagioclase. Biotite occurs as a flaky shape enclosed zircon and partially altered to chlorite. The presence of both biotite and muscovite indicate prevailing hydrous conditions. Biotite flasks is commonly altered, either partially or completely to chlorite. Muscovite occurs as long or small prisms, euhedral to subhedral flakes, or as inclusions in other crystals. Sometimes, subordinate muscovite flakes occur as bokets (reflects the peraluminous nature). It is noticed that chlorite corrodes even the latest crystallization phases (e.g. quartz) indicating that the event chloritization is very late, possibly due to deuteric alteration. However, there are some differences e.g. (a) Perthitic and antiperthitic textures occurring along side the same sections of Abu Rusheid-Eir.
Arib, may indicate relatively the same early crystallization period of plagioclase and microcline, (b) Slight bending and micro-faulting in the fine albite twinning of plagioclase, (c) Myrmekite texture occurs only in the much finer-grained varieties. Myrmekite appears to have results from deformation-induced K-feldspar replacement, and (d) Garnet and opaque’s are the earliest accessory phases to be crystallized. Graphic texture represents subsolvus crystallization at higher water pressure. The graphic intergrowth may be produced by the simultaneous crystallization of quartz and k-feldspar (Haapala, 1977 and Saleh et al., 2002). Allanite, slightly pleochroic from brownish yellow to yellow in color, It occurs as subhedral to euhedral grains and varies in size from less than 90 µm up to 450 µm in diameter. Monazite varies in size from less than 40 µm up to 130 µm in diameter. Small grains are of monazite anhedral with a reddish-brown color, whereas large grains are subhedral to euhedral and invariably zoned optically with yellow cores and brown rims. Monazite alteration callarite and replacement by REE-carbonates is also a rather common process in granites (Cathelineau, 1988) submitted to strong alteration processes such as quartz dissolution and albition, or intensive biotite chloritization. Xenotime occurs as small colorless euhedral prismatic grains, usually associated with zircon and thorite. It varies in size from 30 µm up to 150 µm in diameter. Subhedral to euhedral zircon grains vary in size from less than 50 µm up to 200 µm in diameter, mostly uniformly distributed in K-feldspar, quartz and biotite. In the Abu Rusheid-Eir Arib two mica-peraluminous granites, zircon is partially altered to amorphous thorite and xenotime, probably due to the effects of radioactivity of U and Th (Pupin, 1980 and Cathelineau, 1988). Garnet occurs commonly as pale pink small equidimensional crystals free from quartz inclusions. It shows high relief, and is isotropic. Sometimes, faint layering of muscovite and garnet are locally encountered. It is argued that the increase in the hydroxyl and fugitive constituents as well as, silica's and alkali as well as the relative decrease in ferromagnesian (Fe and Mg) would discourage the development of biotite, but favour the development of muscovite and garnet (Haapala, 1977, Saleh et al., 2002 and Moghazi et al., 2004). Apatite crystals usually contain small inclusions of monazite and some apatite grains display pronounced zonation. Opaque minerals are the common accessory minerals. They occur as subhedral grains, as well as irregular granules, mostly enclosed by ferromagnesian minerals.

GEOCHEMISTRY

Analytical techniques

The present study is based on 21 samples, collected mainly from the Abu Rusheid-Eir Arib two-mica peraluminous granites. Whole rock powders were analyzed for major elements by an inductively coupled plasma-atomic emission spectrometer (ICP-AES), while, the trace elements were analyzed using both the atomic absorption spectrometer (AAS) and X-ray fluorescence (XRF) spectrometer. The REEs were analyzed using an ICP-AES spectrometer. Absolute accuracy has been assessed by comparison with international reference materials analyzed along with the samples and is generally better than 2% for major elements and 5% for trace elements. Loss on ignition (LOI) was calculated by heating about 3g of a rock powder in a porcelain crucible at about 1000°C for 4 hours. All analyses were carried out at the ACME analytical laboratories LDT, Canada and the geochemical lab of the Earth Resources Engineering Dept., Faculty of Engineering, Kyushu University, Japan.

Major and trace elements geochemistry
Figure 2. (a) A-B diagram characteristic mineral diagram (after Debon and Le Fort, 1983). I-S line is the boundary between I- and S-type granites (Villaseca et al., 1998); (b) The shand index of the Abu Rusheid-Eir Arib tow mica peraluminous granites after Maniar and Piccoli (1989) and (c) $\text{Al}_2\text{O}_3$ vs. $\text{CaO}/\text{Na}_2\text{O}$ for the Abu Rusheid-Eir Arib tow mica peraluminous granites; the field of strongly peraluminous granite of Sylvester (1998) is shown for comparison.

Debon and Le Fort (1983), the studied samples are peraluminous and correspond to leucogranite field in the A-B diagram (Fig. 2a). They have chemical composition similar to typical S- type granites (Fig. 2a) from the Lachlan Fold Belt (White and Chapell, 1989) and to melts produced experimentally from meta-sedimentary rather than meta-igneous protoliths (Vielzeuf and Holloway, 1988). Figure 2b shows the plots of the examined samples in the Shand Index diagram according to Maniar and Piccoli (1989). It indicates that the rock is predominantly peraluminous. The strongly peraluminous character is also shown on the $\text{Al}_2\text{O}_3$ vs. $\text{CaO}/\text{Na}_2\text{O}$ diagram (Fig. 2c), where the leucogranite samples are very similar to strongly peraluminous post - collision granites in other orogenic belts (Sylvester, 1998). In contrast, $\text{Al}_2\text{O}_3/\text{TiO}_2$ changes little because biotite stability is not affected by the addition of $\text{H}_2\text{O}$. The low $\text{CaO}/\text{Na}_2\text{O}$ and the wide variation in $\text{Al}_2\text{O}_3/\text{TiO}_2$ in the investigated leucogranites suggest their formation by dehydration partial melting according to the melting experiments of Holtz and Johannes (1991). The peraluminous magmas are generally produced by partial melting of crustal rocks (Ibrahim et al., 2000, Fig.3a). Based on tectonic discrimination diagrams proposed by Pearce et al. (1984), the Abu Rusheid - Eir Arib peraluminous granite is classified as intrusive in a volcanic arc granites and syncollisional setting reflecting the restricted range of S-type granites (Figs. 3b and 3c). Magmatic temperatures of the studied samples can be obtained from the apatite and zircon saturation estimates (Watson and Harrison, 1983 and Saleh et al., 2002). These estimates are based on models of the temperature of
apatite and zircon saturation using $P_2O_5$ and $Zr$ concentration in the granites (Figs. 4a and b). The higher temperatures of the apatite model ($800 - >1080 \, ^\circ C$) probably represent the initial temperature of the melt, whereas the lower temperature estimates from zircon suggests that these granites were initially under-saturated with respect to zircon, and hence the calculated temperatures would not closely resemble original magmatic temperatures. In Fig. 4b, the concentration of Zr in the Abu Rusheid - Eir Arlb peraluminous granites is compared to the proportions of Zr that can be dissolved in granitoid melts of various compositions at different temperatures. The low concentration of Zr in the studied peraluminous granites (< 100 ppm) suggests relatively low temperatures of formation. A possible magma source of the studied granitic rocks could be inferred from Figure 4c that shows that the Abu Rusheid - Eir Arlb peraluminous granite was formed by partial melting of amphibolitic and sedimentary sources (predominantly metagraywackes) that is found in the deeper part of the crust and is consistent with the composition of the lower crust of the Arabian Nubian Shield. The K/Rb ratio, Rb and Sr are useful parameters for comparing samples of different sources (Figs. 5a and b). Abu Rusheid peraluminous granites show high Rb and present the lowest Sr content, whereas Eir Arlb peraluminous granites present a large overlap of composition and limited values of Rb and Sr concentrations. As this plot shows the same trend for all members of the petrogenetic sequence, they could be produced by a single process. Conversely, lower Rb/Sr (< 5) suggests the participation of biotite during melt production of other leucogranites samples. In both leucogranites types, the high contents of Rb reflect biotite and muscovite breakdown (Icenhower and London, 1996, Saleh et al., 2002 and Moghazi et al., 2004). The strong positive correlation between Zr vs. Sr and TiO$_2$ vs. Sr in the leucogranites (Figs. 5d and e) is best explained by different degrees of partial melting due to increasing temperature. Chemical analyses of the host meta-sediments illustrate compositional homogeneity of the sequence with values of Al$_2$O$_3$, CaO and Na$_2$O very similar to greywacke. Major and trace element data (Table 1) show no chemical differences between granite samples collected from the two occurrences (Abu Rusheid and Eir Arlb). The variation diagrams of some major and trace elements presented in Fig. 6 illustrate the compositional features of the peraluminous granites and their meta-sediments. In general, both lithologies define roughly linear arrays on most plots with the meta-sediments deviating towards the silica-poor end of this array. Relative to the meta-sediments, the peraluminous granites are rich in Rb and Na$_2$O + K$_2$O and poor in CaO, Fe$_2$O$_3$, MgO, TiO$_2$, Cr, Sr and Zr. The relative stability of plagioclase during melting has a major effect on the resultant melt compositions. At higher water contents, melt composition is controlled by the breakdown of plagioclase, leading to enrichment in Al$_2$O$_3$. Figure 7 compares between Al$_2$O$_3$ and SiO$_2$ contents with compositions of the Abu Rusheid - Eir Arlb peraluminous granites. The diagram exhibits an increase in Al$_2$O$_3$ with increasing pressure in the experimentally generated melts. Both Abu Rusheid - Eir Arlb peraluminous granites show decrease in Al$_2$O$_3$ (less than 15 %) and line in the field of low H$_2$O experiments, suggesting dehydration melting conditions of amphibolites (Fig.7).
Table 1. Representative major, trace, and REEs elements analyses of peraluminous granites from Abu Rusheid – Eir Arib area, southeastern Desert, Egypt.

|    | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    | 17    | 18    | 19    | 20    | 21    | 22    |
|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| SiO₂| 73.42 | 73.10 | 76.71 | 75.83 | 75.65 | 75.12 | 72.08 | 75.38 | 76.82 | 75.51 | 74.27 | 75.90 | 74.92 | 73.55 | 74.74 | 75.28 | 75.55 | 74.66 | 73.79 | 69.02 |
| TiO₂| 0.02  | 0.21  | 0.07  | 0.02  | 0.02  | 0.01  | 0.47  | 0.05  | 0.05  | 0.06  | 0.24  | 0.06  | 0.12  | 0.16  | 0.17  | 0.26  | 0.05  | 0.06  | 0.03  | 0.10  | 0.25  | 0.6   |
| Al₂O₃| 13.86 | 15.68 | 12.07 | 13.67 | 13.04 | 14.76 | 14.53 | 13.99 | 13.05 | 10.83 | 13.47 | 13.41 | 13.05 | 14.69 | 13.70 | 14.04 | 13.42 | 13.87 | 14.76 |
| FeO | 0.33  | 2.17  | 0.64  | 0.47  | 0.57  | 0.71  | 1.45  | 0.67  | 0.66  | 0.50  | 3.43  | 1.05  | 1.07  | 1.32  | 1.12  | 2.05  | 0.51  | 0.70  | 0.69  | 1.81  | 1.94  | 2.18  |
| MnO | 0.03  | 0.02  | 0.06  | 0.05  | 0.08  | 0.03  | 0.05  | 0.07  | 0.02  | 0.03  | 0.01  | 0.04  | 0.02  | 0.06  | 0.03  | 0.01  | 0.01  | 0.02  | 0.02  | 0.02  | 0.09  |
| MgO | 0.99  | 0.37  | 0.20  | 0.31  | 0.05  | 1.68  | 0.09  | 0.17  | 0.13  | 0.11  | 0.03  | 0.19  | 0.43  | 0.54  | 0.30  | 0.33  | 0.25  | 0.34  | 0.43  | 0.51  | 0.69  |
| CaO | 0.65  | 0.03  | 0.72  | 0.11  | 0.96  | 0.05  | 0.16  | 0.10  | 0.03  | 0.59  | 0.39  | 0.25  | 0.65  | 0.44  | 0.21  | 1.02  | 0.26  | 0.19  | 0.17  | 0.20  | 1.02  | 1.86  |
| Na₂O| 2.91  | 4.91  | 4.53  | 3.92  | 3.52  | 3.85  | 3.62  | 3.52  | 3.47  | 3.62  | 3.52  | 3.78  | 3.52  | 3.62  | 3.52  | 3.78  | 3.52  | 3.62  | 3.52  | 3.78  | 3.52  | 3.62  |
| K₂O | 5.47  | 2.48  | 1.46  | 1.78  | 1.20  | 1.28  | 1.32  | 1.20  | 1.19  | 1.28  | 1.20  | 1.19  | 1.28  | 1.32  | 1.20  | 1.19  | 1.28  | 1.20  | 1.19  | 1.28  | 1.32  | 1.20  |
| P₂O₅| 0.03  | 0.09  | 0.03  | 0.02  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  | 0.03  |
| L.O.I| 0.15  | 0.43  | 0.19  | 0.14  | 0.58  | 0.07  | 0.11  | 0.24  | 0.57  | 0.55  | 0.43  | 0.55  | 0.51  | 0.22  | 0.24  | 0.22  | 0.21  | 0.17  | 0.19  | 0.14  | 0.19  | 0.14  |
| Total | 99.83 | 99.96 | 99.89 | 99.91 | 99.86 | 99.88 | 100.25 | 99.91 | 99.84 | 99.92 | 99.37 | 99.25 | 99.23 | 99.58 | 99.79 | 99.79 | 99.70 | 99.79 | 99.91 | 100.49 |

1-10 = Eir Arib tow mica peraluminous granites, 11-21 = Abu Rusheid tow mica peraluminous granites.

22= (average 4 samples) = Meta-sediments (Moghazi et al., 2004).
Rare Earth Elements (REEs) geochemistry

The REEs data (Table 1) and the chondrite-normalized REEs diagram (Fig. 8a) shows that the host meta-sediments display distinct patterns (Moghazi et al., 2004). The meta-sediments have total REE of 102 to 208 ppm and have REE pattern similar to that of the upper continental crust (Taylor and McLennan, 1985), with LaN/YbN ratios of 9 to 14, moderately fractionated LREEs (LaN/SmN= 3-5), weakly fractionated HREEs (GdN/YbN= 1.9-2.7) and a weak negative Eu anomaly (Eu/Eu*= 0.5-0.9). The REEs contents of some selected samples (Abu Rusheid) are given in (Table 1). The REEs normalized to chondrite compositions (Bonytont, 1984) are displayed (Fig. 8b). The patterns are characterized LREE enrichment ([La/Sm] N = 4.6, with a normalized La value of about 82 times chondritic levels) and a relatively flat pattern for the HREEs ([Tb / Lu] N=1.9, with a normalized Lu value of about 2.8 times chondritic levels) with marked strong negative Eu anomalies (Eu/Eu*= 0.3 - 0.6), which are similar to granitic melts modeled from partial melting of sedimentary sources (Gromet and Silver, 1983). The overall REEs abundances are relatively low compared to typical granites (La = 18 - 98 x chondrite, Yb = 0.3 - 8 x chondrite). There is a strong enrichment of the LREEs with respect to the HREEs ([La/Yb] N = 12-29) and a consistent pattern of fractionation with LREEs and HREEs groups ([Gd/Yb] N = 2.5 - 9). The negative Eu anomalies resulted from plagioclase feldspar fractionation, together with the low Sr content (103 ppm on average). The principal carriers of REEs in most granites are the accessory minerals such as monazite, zircon, apatite, xenotime and tianite in addition to plagioclase in the case of Eu (Gromet and Silver, 1983, Saleh et al., 2002 and Moghazi et al., 2004), therefore, fractionation of accessory minerals would result in a lowering of REEs content. The REEs contents of these granites are very similar to other leucogranites worldwide (Vidal et al. 1984 and Saleh et al., 2002). The best interpretation to explain the weak chemical variations in each granitic unit is crystal fraction of early mineral phases (biotite or plagioclase). More well-defined geochemical evolution in other two mica peraluminous granitoids of southern Egypt clearly results from crystal fractionation phenomena (Ibrahim et al., 2001). Two different interpretations can be suggested to explain the chemical variation between each granitic unit (1) these units might be the result of successive magma pulses, derived from a single great deeper situated magma chamber or (2) might correspond to unrelated magma batches generated from distinct source rocks or under different melting conditions. In two-mica granites, the REE (except Eu) are essentially concentrated in accessory minerals. Monazite controls most of the LREEs, zircon controls most of the HREEs (Charoy, 1986), apatite seems to control the intermediate REEs pattern (Hanson, 1978). Because of their very low solubility in peraluminous melts (Montel, 1986), these minerals are mostly inherited and are therefore trapped in early crystallized minerals like biotite.

Uranium - Thorium distribution

In situ gamma–ray spectrometry measurements have been carried out using a GS-256 spectrometer (made in Czechoslovakia) with a 3 x 3 sodium iodide (Thallium) [NaI (TI)] crystal detector. Before field measurements the spectrometer is calibrated on concrete pads containing known concentrations of K, U and Th. This calibration provides for correction of the measured K, eU and eTh. The term “equivalent” or its abbreviation “e” is used to indicate that equilibrium is assumed between the radioactive daughter isotope monitored by the spectrometer, and its relevant parent isotope. Gamma rays emitted by $^{214}$Bi at 1.76 Mev were measured for $^{238}$U and gamma rays emitted by $^{207}$Tl at 2.41 Mev were measured for $^{232}$Th. Within the detector, an internal $^{137}$Cs source allows the spectrometer to automatically maintain system stability, is measured over a large body of water. The spectrometric data reveal that the two-mica peraluminous granites is most favourable host rock for uranium and thorium mineralization in the Abu Rusheid-Eir Arib Correlation between eU and eTh concentrations within the Abu Rusheid-Eir Arib two-mica granites, they are illustrated in (Fig. 9). It can be seen from this figure that the relationships of eU with eTh and of eU with eU/eTh in the Abu Rusheid-Eir Arib two-mica granites reflect a direct relation (positive), while the relation between eTh and eU/eTh shows a random distribution. The ratio (eU/eTh) in Abu – Rusheid two-mica peraluminous granites (1-5) is more in Eir Arib two-mica peraluminous granites (0.1-1). This indicates that U-content Abu – Rusheid granites is more than Eir Arib granites. The more differentiated rocks have the highest U/Th ratio and greater uranium content (Chatterjee and Muecke, 1982). K contents of the studied rock types are positively correlated with eU and eTh values (Figs. 9 d and e). Consequently, the relationship of the contoured radiocarbon element and the distribution of the major anomalous lithological units have formed the basis for the present interpretation. The U/Th ratio shows insignificant variation with both U (positive) and Th (random) (Figs.10 a and b) which indicates that the radiocarbon distribution of both elements are governed by a magmatic process and they have not been redistributed after the granite intrusion, the same conclusion which is obtained from the field spectrometric data. To test the effects of the accessory minerals, (zircon and monazite) on the distribution of U and Th in the Abu Rusheid-Eir Arib two-mica peraluminous granites, binary relations of Zr/U, Zr/Th, Ce/U and Ce/Th against either U or Th have been plotted in Figs. (10 c – f). U and Th show significant negative correlation with these trace elements ratios indicating that both elements are not preferentially hosted in the accessory minerals of these rocks. Instead, U and Th of the studied
granite could be associated with major forming minerals such as biotite, muscovite, plagioclase and quartz, or U was situated within labile sites within granite. The correlation matrix between U, Th and some major and trace elements for the Abu Rusheid - Eir Arib two - mica peraluminous granite was calculated in order to study the inter relationships between these elements. Based on this matrix, a bar diagram is shown in Figs. (11 a and b). Both U and Th correlate similarly with other major and trace elements, reflecting their geochemical coherence during the crystallization of the magma. The positive correlations of U and Th with SiO$_2$, Al$_2$O$_3$, FeO and K$_2$O and their negative correlations with other major elements (Figs. 11 a and b) are a further indication for their magmatic evolution.

CONCLUSIONS

The Abu Rusheid-Eir Arib two-mica peraluminous granite shows most of the petrological characteristics of S-type granites. On the other hand, these rocks are peraluminous and characterized by high temperature type and high A/CNK (Alumina saturation index) for the two-mica peraluminous granite can be interpreted as a result of aqueous fluid effects released from the down-going slab in a subduction zone. The geochemical and mineralogical characteristics of the granitic rocks indicate that their melts originated in the LILE- enriched mantle wedge by partial melting and are contaminated by crustal melts, as indicated from the high proportion of sedimentary components in the plutons. Fractional crystallization of plagioclase and K-feldspar from the derived partial melt could be the subsequent reliable mechanism which might be responsible for the marked depletion of Ba and Sr and the enrichment of Rb contents in the granite relative to the anatectic melts. The accessory assemblage of Abu Rusheid-Eir Arib two-mica peraluminous granites is composed of monazite, xenotime (in low-Ca varieties), apatite and zircon. Although the nature and distribution of such minerals are controlled by magma features, they may be significantly affected by subsolidus alteration. It occurs throughout the entire comagmatic series of strongly two mica peraluminous S-type Li-mica granites and has been discovered in more evolved transitional I-S type biotite and two-mica peraluminous granites, but is rare in those of A-type affinity. Interpretation of Abu Rusheid two-mica peraluminous granites REEs patterns and modeling of granite fractionation is difficult because, REEs are strongly partitioned into accessory minerals. Partition coefficients are not always known and where available depend on the chemical composition of the muscovite-biotite granite, there are different generations of the accessory minerals with different chemistries, and the accessory minerals are frequently chemically zoned. The Abu Rusheid-Eir Arib two-mica peraluminous granites contain primary muscovite, which formed when residual melts approached saturation as a result of earlier crystallization of mainly anhydrous phases. Saturation of a residual interstitial melts with H$_2$O and subsequent loss of the volatile phase resulted in the formation of eutectoid intergrowth textures involving muscovite, biotite, alkali feldspar and quartz. However, detailed field and geochemical studies on the Abu Rusheid-Eir Arib two-mica peraluminous granites emphasize the importance of melt extraction from the source rock and migration towards higher levels in the crust. This study is a trial to define the right granite types that may be associated with uranium deposit (fertile granite) as depicted from the studies of the U-producing granites in the world. A general systematic increase in U and Th is evident in progressing from rocks of two-mica peraluminous granites to the garnet bearing muscovite granites.

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Figure 3. (a) Nb-SiO$_2$ discrimination diagram (Pearce and Gale, 1977) for the Abu Rusheid-Eir Arib tow mica peraluminous granites; (b) Nb-Y diagram (after Pearce et al., 1984) and (c) Rb-SiO$_2$ diagram (after Pearce et al., 1984). Abbreviations: Syn-COLG = syn-collision; VAG = volcanic-arc granites; ORG = Oceanic ridge granites and WPG = within-plate granites.
Figure 4. (a) $P_2O_5$ vs. $SiO_2$ %, apatite saturation temperature estimates; (b) $Zr$ vs. $M\ (Na+K+2Ca)/(Al\times Si)$ showing the proportion of $Zr$ that can be dissolved in granitoid melts of various compositions at different temperatures (Watson and Harrison, 1983) for the Abu Rusheid - Eir Arib tow mica peraluminous granites and (c) $K_2O-SiO_2$ of the Abu Rusheid - Eir Arib tow mica peraluminous granites. Field of partial melts of different rock sources are after Gerdes et al., (2000) and references there in.
Figure 5. (a) K/Rb vs. Rb. Differentiation trend is based on decreasing compatibility of elements in minerals in the order K - Rb; (b) Sr vs. Rb. It is evident that both of the Abu Rusheid - Eir Arib tow mica - peraluminous granite has comparable Sr values; (c) Sr vs. Rb variation diagram and (c and d) Zr vs. Sr and TiO$_2$ vs. Sr variation diagrams for the Abu Rusheid - Eir Arib tow mica - peraluminous granites.
Figure 6. Harker variation diagrams of some major and trace element contents for the Abu Rusheid - Eir Arib tour mica peraluminous granites.
Figure 7. Variation of SiO$_2$ versus Al$_2$O$_3$ in the Abu Rusheid - Eir Arib tow mica peraluminous granites compared with experimental results of the melting of a basaltic/amphibolitic source. The diagram shows compositional similarities between the investigated granites and experimental results of 20-50% dehydration melting of amphibolites at 900-1000°C (Beard and Lofgren, 1989, 1991).

Figure 8. Chondrite-normalized REEs plots. (a) studied metasediments (Moghazi et al., 2004) compared to the upper continental crust (Taylor and McLennan, 1985) and (b) the Abu Rusheid tow mica peraluminous granites.
Figure 9. Binary diagrams showing of (a) $eU$ vs. $eTh$, (b) $eU$ vs. $eU/eTh$ (c) $eTh$ vs. $eU/eTh$, (d) K vs. $eU$ and (e) K vs. $eTh$ for the Abu Rusheid - Eir Arib tow mica peraluminous granite.
Figure 10. Binary relations between U and Th vs. U/Th, Zr/U, Zr/Th Ce/U and Ce/Th, for the Abu Rusheid - Eir Arib tow mica peraluminous granite.
Figure 11. Bar diagram showing the correlation coefficients of some major and trace elements with U and Th for the (a) Abu Rusheid tow mica peraluminous granite and (b) Eir Arib tow mica peraluminous granite.

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