Sci. J. Fac. Sci. Minufia Univ., 2009, Vol. XXIII, 107-129

GEOLOGICAL AND GEOCHEMICAL STUDIES ON THE MUSCOVITE GRANITES AT WADI EL GEMAL AREA, SOUTH EASTERN DESERT, EGYPT.

SOLIMAN, F. A; IBRAHIM, M.A* ABD EL WAHED A.A, MAHMOUD, M.A.M;***

* Nuclear materials authority, Cairo, P.O.Box 530.

** Suez of Canal University

ABSTRACT

Wadi El Gemal area is composed of ultramafics, metagabbros, ophiolitic mélange. metasediments, biotite granites, muscovite granites and post granite dikes and veins. The muscovite granites are exposed at different sub-areas namely; Wadi (W.) Umm Seleimat, W. Sikait, W.Umm El Kheran, W. Umm Baanib and W.Umm Addebaa.

These muscovite granites were affected by sericitization, greisenization, silicification and fluoritization processes. The mineralogical study of the muscovite granites reveals the presence of uranophane, pyrite, garnet, columbite, tantalite, tourmaline, beryl, wolframite and fluorite minerals.

They are strongly peraluminous, posses high content of LILE (Rb, Sr, Ba, Y, Zr & Nb) and have a moderate to high content of HFSE (Cu, Zn, Pb, Hg, Cd, As, Sb, Sn, Bi, Mo & W). They were crystallized from relatively soda rich magma, calc-alkaline in nature, belong to A-type and emplaced during within plate tectonic setting.

Key words: Wadi El Gemal, Uranium, peraluminous.

INTRODUCTION

Leucogranites, peralumious granites with near-eutectic composition, are common in collisional orogens, where they were produced by partial melting of deformed and metamorphosed accretionaly-wedge and ocean-floor sediments. Whilst there is a general agreement that leucogranites are anatectic of pelitic crustal sources.The heat sources for their production have remained controversial (e.g. Royden, 1993 and Thomposon and Connolly, 1995).

Collisional leucogranites are characterized by peraluminous compositions and very low concentrations of CaO, MgO & FeO. In leucogranites, muscovite is a characteristic mineral, along with tourmaline or biotite. Almandine-spessartine garnet and minor sillimanite can also occur. Tourmaline and biotite are often exclusive of each other (Nabelek et al., 2001).Most of uranium occurrences in Egyptian are associated with high K-calc alkaline biotite granites (G.Gattar , G. Um-Ara and G. El- Misskat) except G. El-Sella peraluminous two mica granites (Ibrahim et al, 2003)

The present study is concerned with the geology, mineralogy and geochemistry of muscovite granites at Wadi El Gemal area. The study area is located at the northern part of the Southeastern Desert. At the study area, the muscovite granites crop out at five localities; Wadi (W.) Umm Seleimat, W. Sikait, W. Umm El Kheran, W. Umm Baanib and W. Umm Addebaa and two exposures of muscovite granites are common At W. Sikait.

GEOLOGIC SETTING

On the basis of field observations and structural relations, the exposed rocks in the study area (Figs. 1-6) are ultramafic-mafic rocks, ophiolitic mélange, metasediments, biotite granite, muscovite granite and post granite dikes and veins.

The muscovite granites form small- to large bosses intruded in the metasediments, ophiolitic mélange and biotite granitic rocks. These bosses are localized in six exposures within the area, namely; Umm Seleimat, Sikait (two bosses), Umm El Kheran, Umm Baanib and Umm Addebaa. They are generally sheared, exfoliated white in color, fine- to coarse grained with obvious large crystals of feldspars, muscovite flakes and garnet. The presence of garnet and muscovite flakes reflects the peraluminous nature.

At Umm Seleimat area, the muscovite granites cut the biotite granite and ophiolitic mélange closes to the major Nugrus thrust. They possess sharp contacts truncating the foliations of the ophiolitic mélange at high angle. The muscovite granites appear either as small offshoot of boss-like bodies or as dike-like bodies(up to 1-2 km in length and 200-300 m in width) and as a huge semi-circular mass (> 1 km^2), which form domal shape around W. Umm Seleimat.

At W.Sikait sub-area (I), the muscovite granite intrudes the biotite granite and ophiolitic mélange with sharp contacts. It is small in size (< 1.0 km^2), up to about 250-300 m in length and 50-100 in m in width. They occur as masses, bosses with rounded tops and elongated shape.

At W.Sikait sub-area (II), the muscovite granite intrudes the ophiolitic mélange. It occurs as low topographic masses or bosses, small in size (< 1.0 km^2), and emplaced along NW-SE fault trend. Reddish, brecciated and highly deformed quartz veins (N 40° E – S 40° W) cut these muscovite granites.

At W. Umm El Kheran area, the muscovite granite cuts the ophiolitic mélange and metagabbro, large in size (> 1.0 km^2), reaching about 1.5 -2.5 km in length and 300-500 m in width.

At W. Umm Baanib the muscovite granite intrudes only the ophiolitic mélange. It is small in size (< 1.0 km^2) and occurs as dike-like bodies; reaching 10-20 m in width and 10-100 m in length and striking NW-SE.

At W. Umm Addebaa area, the muscovite granite is emplaced into ophiolitic mélange as boss or dike-like body (<1.0 km^2) along N-S fault trend, about 100 m. in length and 50 m in width. Some beryl-bearing quartz veins and basic dikes of different trends cut the studied muscovite granites.

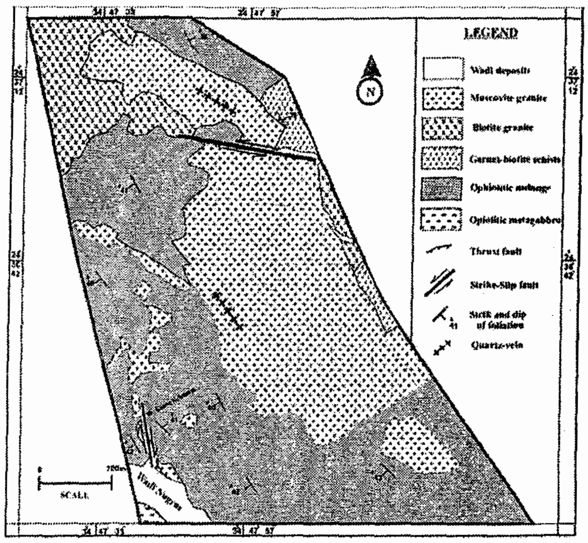

Fig. 1: Detailed geologic map of Umm Seleimat area

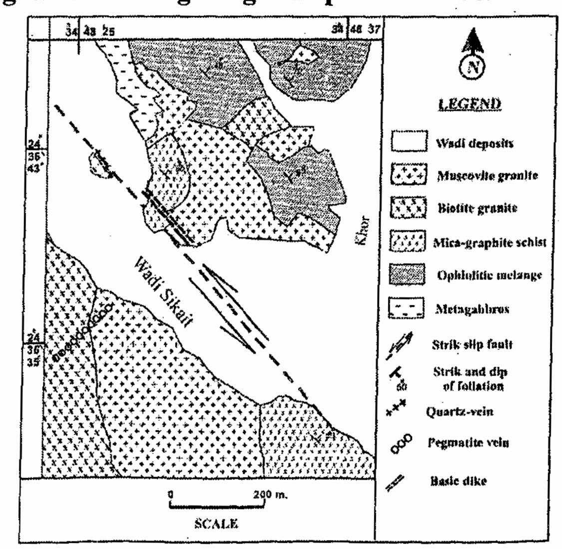

Fig. 2: Detailed geologic map of Sikait I area.

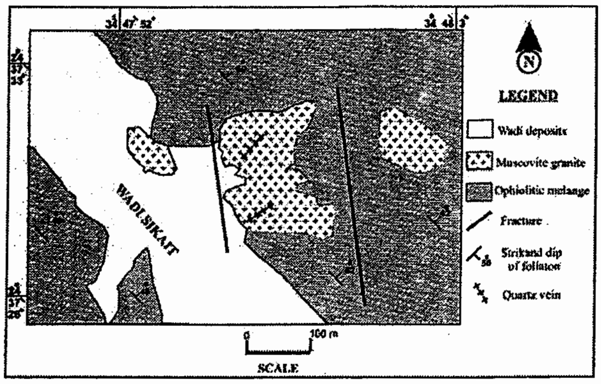

Fig. 3: Detailed geologic map of Sikait II area

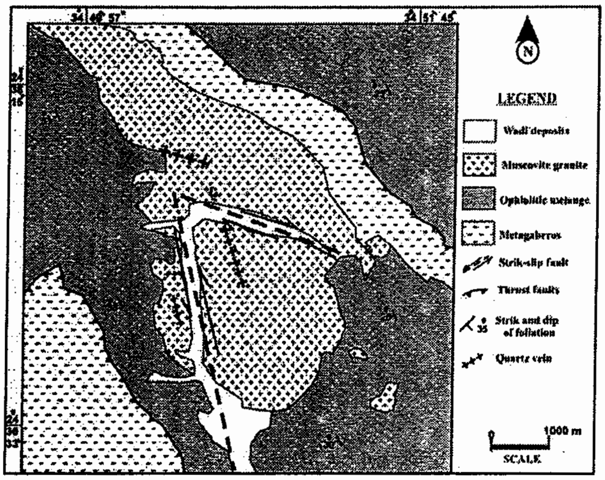

Fig. 4: Detailed geologic map of Umm El Kheran area

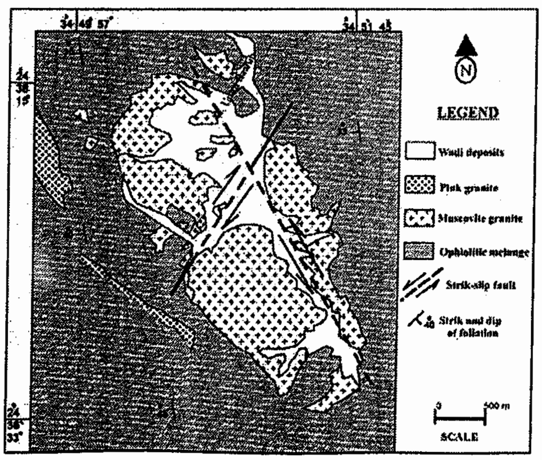

Fig. 5: Detailed geologic map of Umm Baanib area

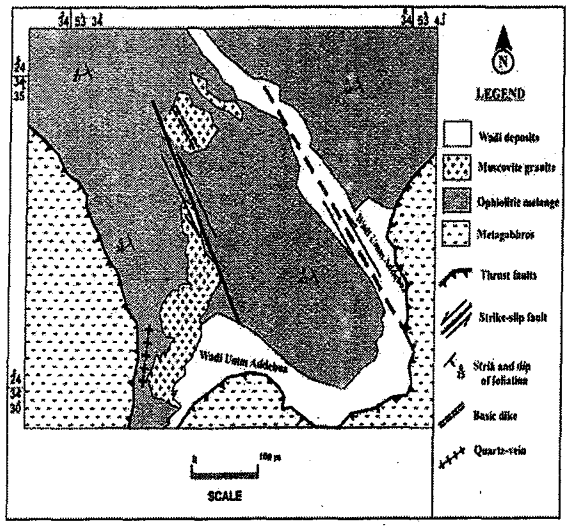

Fig. 6: Detailed geologic map of Umm Addebaa area.

Petrographical study indicates:

1- The muscovite granites are generally characterized by the scarcity of ferromagnesian minerals giving rise to a leucogranitic types. The presence of muscovite as flakes reflects the peraluminous nature of these granites.

2- The presence of two feldspars suggests that the muscovite granites are mostly subsolvus and crystallized under high water pressure (Greenberge, 1981 and Deer et al., 1992).

3- The textural features of the muscovite granites are expressed by bent plagioclase lamellae, distorted microcline twinning deformed mica flakes, strongly undulatory quartz development of myrmekite and recrystallization of feldspars into fine-grained aggregates. All these features point to subsolidus deformation (Paterson et al., 1989). Such deformation should be the result of extensive regional thrusting (Greiling et al., 1987), to which the area had been subjected.

Comparison study between the muscovite granites of six exposures at the study area.

Exposures	Essentially minerals	Secondary minerals	Accessory minerals	Textures
Umm Seleimat exposure	Feldspars (plagioclase content = K-feldspars content). Quartz Muscovite Biotite	Sericite Chlorite	Garnet Allanite Opaques Zircon Monazite	Perthitic texture
Sikait I exposure	Feldspars (plagioclase content = K-feldspars content). Quartz Muscovite Biotite & phologobite	Seircite Chlorite	Garnet Zircon Monazite Opaques	
Sikait II exposure	Feldspars (plagioclase content > K-feldspar content). Quartz Muscovite Biotite & phologobite	Seircite Chlorite	Garnet Zircon Monazite Opaques	Perthitic texture
Umm El Kheran exposure	Feldspars (plagioclase content = K-feldspars content). Quartz Muscovite	Biotite Sericite Chlorite	Garnet Zircon Monazite Opaques	
Umm Baanib exposure	Feldspars (plagioclase content > K-feldspar content). Quartz Muscovite	Sericite Chlorite	Opaques Zircon Monazite	
Umm Addebaa exposure	Feldspars (plagioclase content > K-feldspars content). Quartz Muscovite Biotite	Sericite Chlorite	Garnet Tourmaline Allanite Zircon Opaques	Myrmekite texture

4- In general, albite twinning is more abundant in the muscovite granites than other plgioclase feldspars, and this may be taken as a reflection for low temperature deformation associated with emplacement of studied granites (Shelley, 1993).

5- The absence of zoning in plagioclase may be attributed either to the development of lamellar twinning, which destroys zoning in plagioclase crystals (Emmons, 1953), or to the presence of perfect equilibrium between plagioclase and the melt. Such equilibrium leads to produce the unzoned plagioclase crystals of the same composition as the original melt (Shelley, 1993).

6- Perthite texture is coarser as secondary textural product formed as a result of unmixing mechanism in granitic rocks. In the muscovite granites, perthite was observed as perthite and microcline-perthite. The presence of coarse variety such as patchy perthite in the muscovite granites may be ascribed to deuteric alteration at temperature below 400°C (Parsons and Brown, 1984). This may be supported by the presence of partial alteration to kaolin in some perthitic crystals.

7- The presence of cross-hatching (tartan pattern) as low-temperature transforming twinning as that described in the microcline and microcline perthite in the muscovite granites is consider as a product of a combination between albite and perciline twinning in peculiar relation (Deer et al., 1992). Such twinning is taken as evidence that the microcline crystals first crystallized with monoclinic symmetry (high symmetry) and subsequently became triclinic (lower symmetry), (Deer et al., 1992 and Shelley, 1993). Also the familiar coarsening cross-hatching is considered a result of tectonic strain (Brown and Parsons, 1989).

8- The petrography study of the felsic minerals and biotite revealed that these minerals have been subjected to polyphase of deformation during a long span of time and a wide range of temperature conditions. Three phases could be determined as follows; the first phase took place at high temperature and it is indicated by the presence of quartz crystals with irregular shapes, most probably developed through crystal boundary migration during cooling at high temperature. The second phase probably took place at low temperature than the first phase. This phase is indicated by the presence of glide twining in plagioclase, and by the presence of flame-type perthite (Pryer, 1993). The third phase most probably took place at very low temperature conditions. This phase is evidenced by the presence of brittle fractures in grains, undulose extinction, and re-deposition of material in fractures and veins; in addition to intercrystalline deformation including faults and bent cleavage planes and twins (Fig. 32).

9- Almandine garnet occurs in three distinct habits; A) Garnet occurs as large euhedral evenly distributed crystals, which are free from inclusions . Occasionally, some crystals have been fractured partly sheltered and filled with recrystallized plagioclase and quartz. B) Forms aggregates of fine-grained euhedral crystals which commonly enclose randomly oriented inclusions forming sieve texture. These garnet aggregates are segregated in thin bands. C) Garnet form skeletal randomly distributed crystals with irregular grain-shape which partly enclose the finer quartz and feldspars grain of the groundmass. The explanation of these concentrations of garnet in some exposures of the sheared white muscovite granites in the study area indicate that a residual enrichment in Fe, and Mn at lower fO_2 caused the garnet crystals to form, as suggested by Mahood et al. (1996).

10- Myrmekite textures are observed at Umm Addebaa exposure. The presence of myrmekitic texture represents strong evidence for metasomatic origin, which are common in magmatic granite (Smith, 1974). Myrmekitic texture was formed due to the action of metasomatic processes with the exsolution around the margins of feldspar phenocrysts (Ashworth, 1979).

11- The mineralogical study of the muscovite granites reveals the presence of uranophane, pyrite, garnet, columbite, tantalite, tourmaline, beryl, wolframite and fluorite minerals.

MINERALOGY

The mineralogical study was performed through choosing one average sample from the six exposures of the studied muscovite granites. These samples were crushed to 0.23-0.5 mm. in size. The heavy minerals were concentrated employing a shaking table, bromoform (sp. gr. 2.8) and magnetic separation. The heavy fractions were further purified by hand picking under the binocular microscope. Then the mineral identification was confirmed by Environmental Scan Electron Microscope (ESEM) techniques at Nuclear Materials Authority laboratories (NMA).

The results of the identified minerals in the studied muscovite granites at W. Gemal are confirmed by XRD and ESEM techniques and listed in (Table 1):

Table (1): Results of the main mineralization recorded in the muscovite granites at W. El–Gemal area.

Secondary uranium	Base metals	Nb-Ta minerals	Garnet minerals	Accessory minerals
Uranophane ($CaO.2UO_3.2SiO_2.6H_2O$)	1- Pyrite (FeS_2) 2-Wolframite (Fe, Mn) WO_4	1-Niobium – Tantalum 2-Columbite [$(Fe,Mn)(Nb,Ta)_2O_6$] 3-Pyrochlore (Nb, Y, Ta, U, Al, Mg, REE) 4-Tantalite	1-Almandine 2-Spessartine 3-Pyrope 4-Andradite	1- Fluorite (CaF_2) 2- Beryl [$Be_3Al_2(Si_6O_{18})$] 3- Ilmenite (FeO-TiO_2) 4- Magnetite (Fe_3O_4)

GEOCHEMISTRY

The geochemical study was carried out through the analyses of five samples from each sub-area of the six exposures of the studied muscovite granites. The major and trace elements were determined through methods using the by Rigaka X-Ray Fluorescence spectrometer (3100), at department of Earth Resources Engineering, Kyushu University, Fukuoka, Japan, during the Post-Doctor Fellowship of the third author.

Preliminary interpretations of the geochemical data are presented below based on various geochemical discriminate plots and the average data are shown in Table (2).

A- Major oxides

Major oxides data (Table 2 &3) indicates:

1- The major elements composition of the studied muscovite granites in the different localities display very limited variations.
2- The muscovite granites have high alkali content (K_2O + Na_2O) ranging from 6.03% at Umm Baanib exposure to 7.60% at Umm Seleimat exposure. They posses high Al_2O_3 content ranging from 13.12% to 16.92% averaging 14.15 % and relatively low TiO_2, MgO, CaO, FeO & MnO contents, but MnO has higher content at Umm Addebaa exposure and CaO has higher contents at Umm Baanib exposure than the other exposures (Table 2).
3- The Agpaitic ratio [= molar (Na_2O + K_2O)/Al_2O_3] is <1.0 (Table 3 & Fig.7), means that the muscovite granites are Miaskitic in nature (Goldschmidt, 1954

4- The homogeneity and the leucocratic nature of the muscovite granites are well documented by the differentiation index (D.I) (Table 1) of Thornton and Tuttle (1960), which ranges between 82.1 and 94.0.
5- The average K_2O/ Na_2O ratio (Table 2) in the muscovite granites is 1.2; this indicates that the muscovite granites have crystallized from relatively soda rich magma.
6- Both the molar ratio of A/CNK [Al_2O_3 / (CaO + Na_2O + K_2O)] and the molar ratio of A/NK [Al_2O_3/ (Na_2O + K_2O)] are higher than 1.00, with K_2O/Na_2O ratio ranging from 0.23% to 4.43% (Table 2), thus the studied muscovite granites are best classified as strongly peraluminous granites. Corundum (relatively >1) is calculated in the CIPW norm composition (Table 1), and confirm the peraluminous nature.
7- The relative higher Fe values coincide with relative high nickel values. It should also be noted that the Fe values are due to both sulfide and silicate minerals.
8- The muscovite granites exhibit high normative Ab & Qz contents and fairly low normative Or & An contents. The muscovite granites have low contents of normative Hy and very low content of il. (Table 2).

B- Trace elements

The geochemical distribution, bar diagrams and some ratios of average values of trace elements in Table (2 & 3) and figures (8-9) show the following: -

1- The muscovite granites in the study area have a low to moderate content of compatible elements such as V, Cr, Co, & Ni.
2- The muscovite granites in the study area have a high content of HFSE such as Rb, Ba, Sr, Zr, Y & Nb. The muscovite granites have a high content of Rb in all exposures except Umm Baanib exposure, which have a low content and a narrow range of Rb. Ba and Sr contents reached to the highest value and have a wide range at Umm El Kheran and Umm Baanib exposures respectively. Ba, Sr and Rb concentrations seemed to be controlled by crystal fractionation, where Ba and Sr decrease, while Rb increases in residual fluids, upon increasing crystallization.
3-Umm Seleimat and Umm Addebaa exposures have a high content of Y relative to other exposures in the study area. Umm Seleimat and Umm Addebaa exposures possess a high and wide range of Zr content, while Umm El Kheran and Umm Baanib exposures possess a low and narrow range of Zr. Zircon (Zr) contents decrease steadily during differentiation, indicating that zircon was present throughout crystallization. This is in agreement with the expected low solubility of zircon in low–temperature peraluminous melt (Waston & Harrison, 1983).

Table 2: The average of major oxides in wt%, trace elements in ppm and some CIPW norm values of the muscovite granites in six exposures at the study area.

	Umm Seleimat exposure	Sikait I exposure	Sikiat II exposure	Umm El Kheran exposure	Umm Baanib exposure	Umm Addebaa exposure
Samples			Major oxides (in wt%)			
SiO_2	76.23	76.76	78.38	76.11	72.69	77.52
TiO_2	0.03	0.02	0.01	0.01	0.07	0.01
Al_2O_3	13.56	13.50	13.12	14.27	16.92	13.45
FeO	0.52	0.40	0.14	0.26	0.38	0.71
MnO	0.95	0.04	0.03	0.04	0.01	0.27
MgO	0.35	0.39	0.35	0.39	0.53	0.40
CaO	1.03	0.93	1.02	0.85	2.55	0.90
Na_2O	3.97	3.59	5.11	3.38	4.81	5.36
K_2O	3.63	3.82	1.23	3.99	1.22	0.99
P_2O_5	0.02	0.01	0.01	0.01	0.03	0.02
LOI	0.49	0.45	0.31	0.53	0.57	0.27
Total	99.89	99.92	99.71	99.84	99.73	99.90
ALK	7.60	7.41	6.34	7.37	6.03	6.35
A/CNK	1.1	1.2	1.2	1.3	1.3	1.2
A/Nk	1.3	1.3	1.3	1.5	1.9	1.4
			CIPW norm values			
Quartz (Qz)	36.34	38.54	41.49	38.82	33.80	39.46
Orthoclase(Or)	21.62	22.72	7.32	23.78	7.30	5.90
Albite (Ab)	33.74	30.52	43.42	28.79	41.09	45.45
Anorthite (An)	5.11	4.66	4.86	4.23	12.78	4.32
Corundum (C)	1.22	1.75	1.61	2.85	3.15	1.99
Hyperthene(Hy)	1.88	1.78	1.10	1.51	1.93	2.75
Ilmenite (il)	0.06	0.04	0.02	0.03	0.14	0.02
D.I	91.7	91.8	92.2	91.4	82.1	90.8
			Trace elements (ppm)			
V	3.6	4.2	9	8	10.4	0.40
Cr	-	1	4	2	1.8	-
Co	2.6	15.6	17	13.2	1.4	16.2
Ni	4.2	3.6	5	4	2.4	6.8
Cu	4.4	2	3.4	6.2	3.6	9
Zn	24.2	31	12	10.8	14.6	22.2
Pb	29.6	43	18.6	40.6	20.8	31.6
Ag	7.8	2.6	3	5.4	1.8	1
Hg	-	0.8	3.2	0	2	-
Cd	-	0.4	-	1.2	-	1
As	7.4	2.4	6.6	8.4	6.6	10
Sb	11.8	4.6	9.2	13	10.2	9
Sn	13.4	25.2	7.8	28.40	13.6	20.8
Bi	2.8	12.2	3	4.6	0.8	18.6
Mo	4.8	2.4	2.2	2.6	8.8	2.6
W	14.2	8.8	4	11	57.2	18.4
Rb	144	221	74.4	119	28.20	92.6
Sr	132	39	64	176	806	62
Ba	456.4	44.8	20.6	1078.6	198.4	59.2
Y	94.3	56	27.8	42.6	33.2	89.8
Zr	63	15	38	26	76	86.8
Nb	25.6	31.8	56.4	16.6	43.4	38.4

ALK. = K_2O+Na_2O A/CNK = $[Al_2O_3/ (CaO + Na_2O + K_2O)]$

A/NK = $[Al_2O_3/ (Na_2O + K_2O)]$ D.I. = Differentiation inde

Table: 3: Averages of some values and elemental ratios of the major and trace elements in all exposures of the muscovite granites at the study area.

	Umm Seleimat	Sikait I	Sikait II	Umm El Kheran	Umm Baanib	Umm Addebaa	Average
Alkalis	7.60	7.41	6.34	7.37	6.03	6.35	6.91
K_2O/Na_2O	0.91	1.08	0.29	0.86	0.27	0.23	1.2
Agpaitic ratio	0.77	0.74	0.74	0.70	0.55	0.74	
Ca/Y	94.0	125.3	300	146.5	603.2	97.2	
Ca/Sr	138.1	174.6	331.5	81.9	32.1	172.9	
Rb/Sr	5.18	5.97	1.45	1.81	0.03	2.06	
Ba/Rb	5.26	0.21	0.25	16.11	7.00	0.50	4.3
Sr/Ba	1.2	5.3	1.5	0.45	6.3	0.23	
D.I	91.7	91.8	92.2	91.4	82.1	90.8	

Alkali = $(Na_2O + K_2O)$ Agpaitic ratio =molar $[(Na_2O+K_2O / Al_2O_3]$

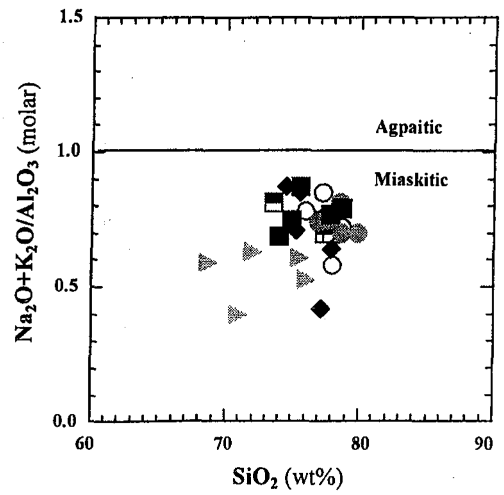

Fig. 7: The Agpaitic index diagram of Bailey and MacDonald (1969) of the muscovite granite exposures at the study area.

Umm Seleimat Sikait I Sikait II
Umm El Kheran Umm Baanib Umm Addebaa

4- Nb is abundant in the muscovite granites, and reach its highest and wide range content at Sikait II, but Umm El Kheran has lowest content of Nb.

5- The muscovite granites in the study area have a moderate to high content of HFSE such as Cu, Zn, Pb, Au, Ag, Hg, Cd, As, Sb, Sn, Bi, Mo & W.

Cu, As and Bi are abundant in the muscovite granites and have moderate values and wide range especially at Umm Addebaa exposure. Zn & Sn are determined in the muscovite granite at the study area. Pb, Ag, Hg & Sb are wide spread HFSE, they have low to moderate values and narrow to wide range in all exposures of the muscovite granites.

The muscovite granites possess a low content of Mo and relative high content of W. The constant low Mo contents in all granites, even in the stage of extreme differentiation represented by melt inclusions in these granites (Webster et. al., 1997), are consistent with the observation that Al-rich magmas typically contain less Mo than peralkaline magmas (Lowenstern et. al., 1993). The low Mo contents are obvious in the muscovite granites in all exposures at the study area.

6- According to El Gaby and Habib (1982), Ca/Y ratio decreases continuously and reach its minimum value in the most differentiated granites. Umm Addebaa muscovite granite shows low Ca/Y ratios.

7- Sr tends to increase relative to Ca during fractionation, hence Ca/Sr decreases during magmatic crystallization (Taylor 1965). High plagioclase content in some exposures caused abnormal increase in the Sr content and hence low Ca/Sr ratios are recorded.

8- Rb/Sr ratios are good manifestation of a typical magmatic differentiation trend, where Rb remains in the liquid phase while Sr is being incorporated in plagioclase during fractional crystallization (Houghton, 1985 and Jelink et. al., 1989). Rb/Sr ratios increase towards the end of differentiation at Sikait I and Umm Addebaa exposures.

9- Mason (1966) stated that the average Ba/Rb of crust is equal 4.4, which suggests that their magmas were enriched in Ba relative to Rb. The average Ba/Rb ratio of the muscovite granites in all exposures of the study area is 4.3 that equal to the value of the crust.

Geochemical classification

The normative Ab-Or-An ternary diagram was used by Barker (1979) as shown in figure (10). On this diagram, the muscovite granite samples lie in trondhjemite and granite fields.

Brandock (1969) constructed a binary diagram between normative quartz (Qz) and normative anorthite (An) to discriminate between calc-alkali and alkali-calc rocks (Fig. 11), the most samples of muscovite granites are belong to calc-alkali series.

The A/NK vs. A/CNK binary diagram was constructed by Maniar and Piccoli (1989) to distinguish the different peraluminous, metaluminous and peralkaline magma types. The muscovite granite samples in all exposures fall in the peraluminous field (Fig. 12).

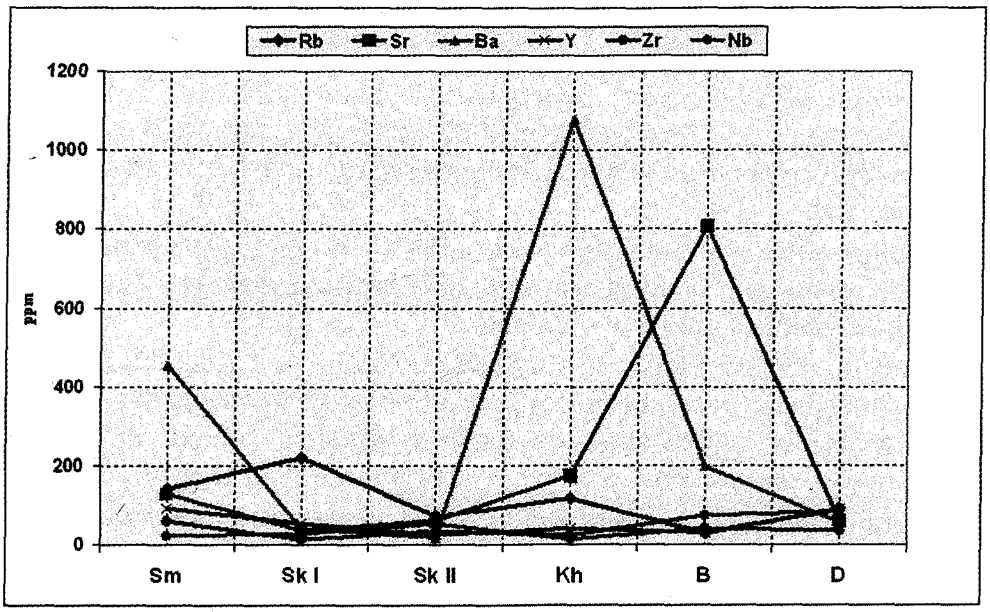

Fig. 8: Geochemical profiles showing the distribution of lithophile trace elements in the muscovite granites at the study area. Symbols as in Fig. 16.
Sm = Umm Seleimat exposure SkI = Sikait I exposure SkII= Sikait II exposure
Kh = Umm El Kheran exposure B = Umm Baanib exposure D = Umm Addebaa exposure

A-B diagram was used by Debon and Le Fort (1983), where A= molar Al-(K+Na +Ca) and B= molar (Fe+Mg+Ti). In this diagram (Fig. 13), the muscovite granites in all exposures are peraluminous in nature with muscovite > biotite. The degree of differentiation is indicated by the decrease in the B-parameter which represents the amount of biotite + magnetite in the rocks.

Chappell and White (1974), to discriminate I-type and S-type granite, constructed binary variation diagram of K2O against Na2O. On this diagram, the muscovite granite in all exposures belongs to I-type granite (Fig. 14).

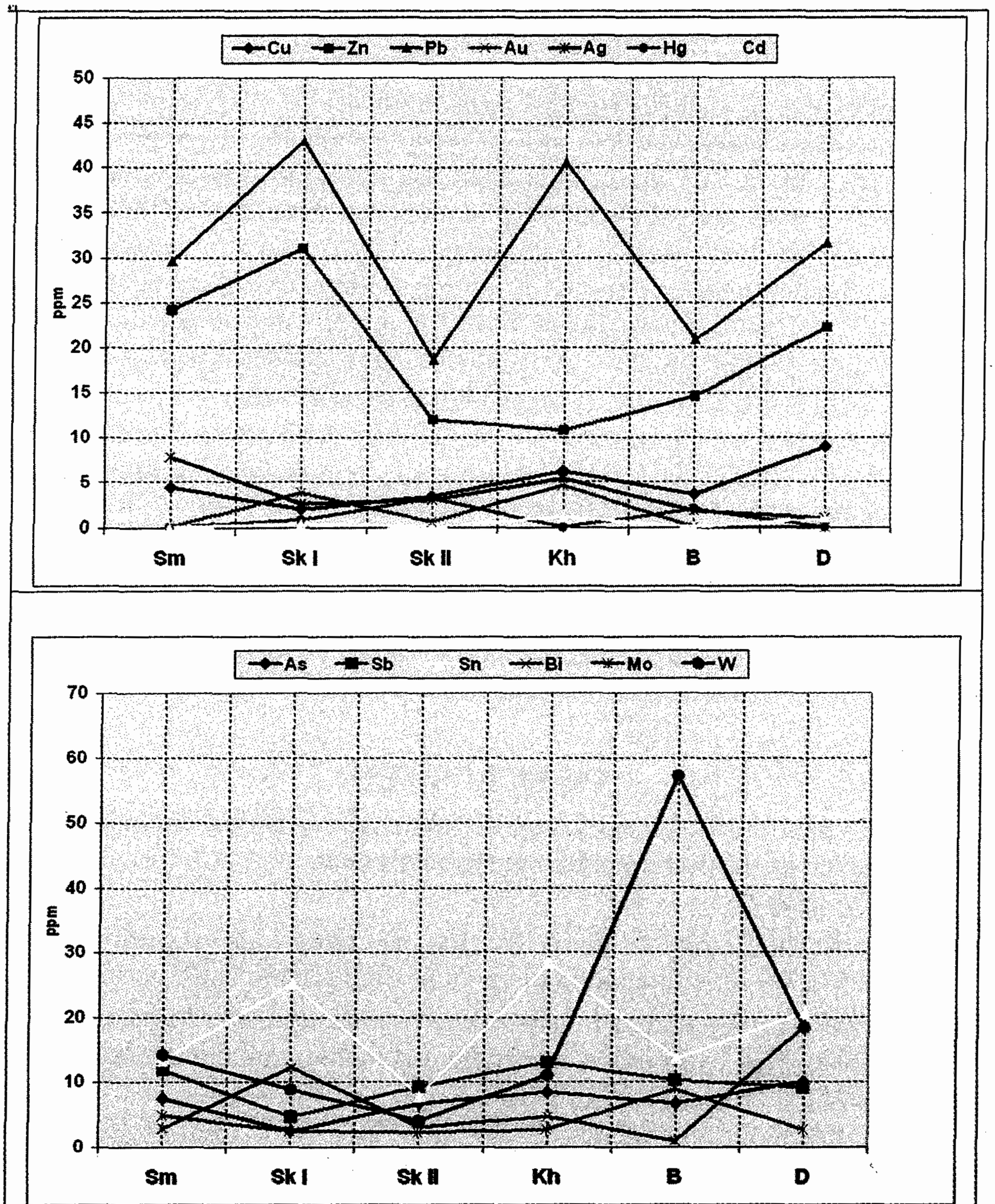

Fig. 9: Geochemical profiles showing the distribution of chalcophile trace elements in the muscovite granites at the study area. Symbols as in Fig. 16.

Na_2O aganist K_2O binary diagram (Fig. 15) reveals three types of granite in three fields; I-type and S-type after White and Chappell (1984) and A-type after Liew et al. (1989). Most of the examined samples of muscovite granites plot in the I-type field with some distinct samples at the border of the A-type field.

Rb against Y+Nb and Nb against Y discrimination diagrams (Figs. 16& 17) were used by Pearce et. al. (1984) to distinguished four tectonic fields of granite; Within plate granite (WPG), Syn-collision granite (Syn-COLG), Volcanic arc granite (VAG) and Oceanic ridge granite (ORG). On the two diagrams, the muscovite granites in all exposures belong to within plate tectonic setting field with boundary of volcanic arc granite field. On the previous tectonic discriminate plots, it is apparent that the muscovite granites show affinity towards a single and clearly isolated tectonic environment; (within-plate granites).

Rb and Sr are distributed in the granitoids rocks based on the abundance of K-feldspar (for Rb) and Ca-plagioclase (for Sr). Both K-feldspar and Ca-plagioclase are directly related to crustal fractionation and hence to its thickening where the thickness of crust increases with the increase Rb and Sr contents. Rb against Sr binary diagram, which established by Condie (1973) is used to determine the crustal thickness during the intrusion of any magmatic rocks. Based on this diagram, the muscovite granites in most exposures are intruded in a continental crust with thickness average about 20-30 km. (Fig. 18).

CONCLUSIONS

1-The rocks exposed in the study area, are ultramafics, mafics, ophiolitic mélange, metasediements, biotite granite, muscovite granite and post granite dikes and veins (youngest).

2- The muscovite granites were affected by subsolidus alteration processes represented by sericitization, greisenation, silicification and fluoritization.

3- Due to the hydrothermal solutions, some of mineralization have been recorded and represented by uranophane, pyrite, columbite, tantalite, beryl, wolframite and fluorite.

4- The studied muscovite granites posses high SiO_2, Al_2O_3 and alkali contents, but posses low TiO_2, MgO, CaO, FeO & MnO contents.

5- The studied muscovite granites are strongly peraluminous in nature, with corundum more than one.

6- The muscovite granites have a high content of lithophile trace elements such as Rb, Sr, Ba, Y, Zr & Nb.

7- The studied muscovite granites are crystallized from relatively soda rich magma, calc-alkaline in nature and belong to I-type granite with distinct samples at the border of the A-type field.

8- The muscovite granites in all exposures belong to within plate tectonic setting and intruded in a continental crust with thickness average about 20-30 km.

9- Garcia et. Al., (1994) showed that peraluminous granites likely do not result from anatexis of aluminous shales but originate from igneous rocks in the calc-alkalic suite.

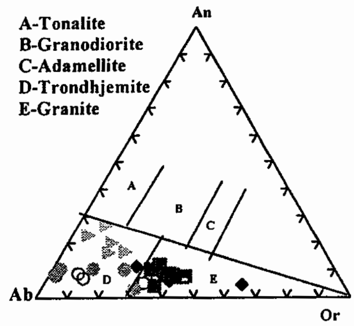

Fig. 10: Normative Ab-Or-An ternary diagram (Barker, 1979) of the muscovite granite exposures at the study area.

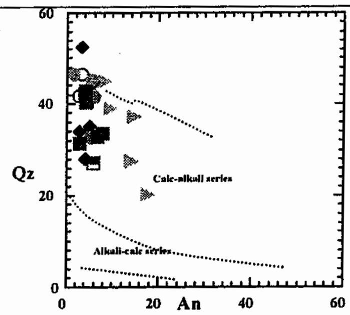

Fig.11: Normative quartz (Qz) vs. normative anorthite (An) for chemical classification of rock series (Brandock, 1969).

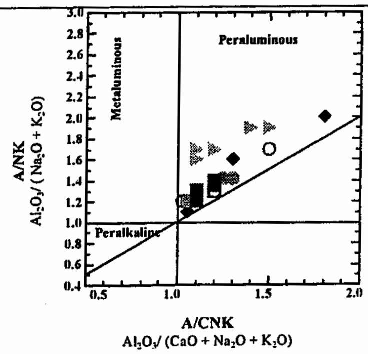

Fig. 12: A/NK vs.A/CNK discrimination binary diagram (Maniar Piccoli, 1989).

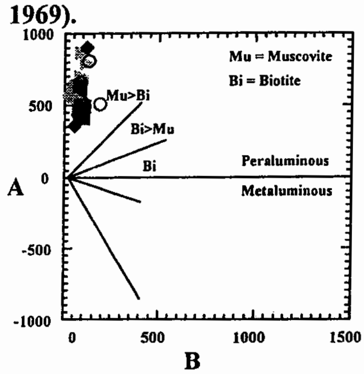

Fig. 13: A – B multi-cationic diagram of the studied granites (Debon and LeFort, 1983).

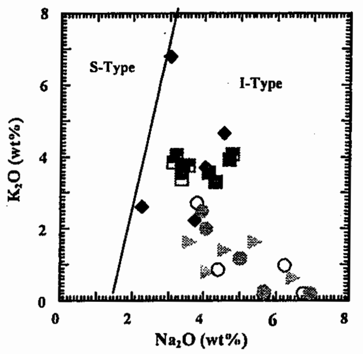

Fig. 14: K_2O vs. Na_2O binary variation diagram for the muscovite granites at the study area (Chappel and White, 1974)

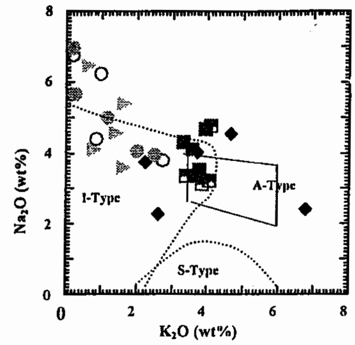

Fig. 15: Na_2O vs. K_2O binary diagram for the muscovite granites at the study area (White and Chappell, 1984), modified by Liew et. al., 1989).

■ Umm Seleimat | Sikait I | Sikait II
◆ Umm El Kheran | Umm Baanib | ○ Umm Addebaa

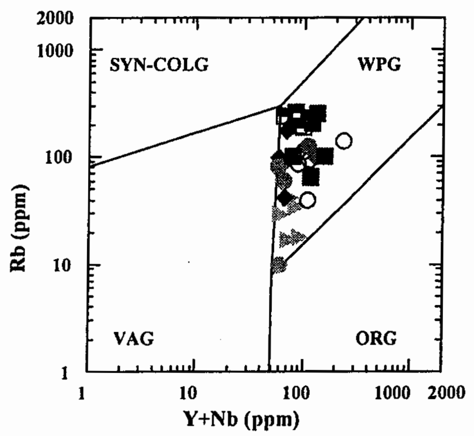

Fig. 16: Rb vs. Y+Nb discrimination diagram for tectonic settings (Pearce et al., 1984).

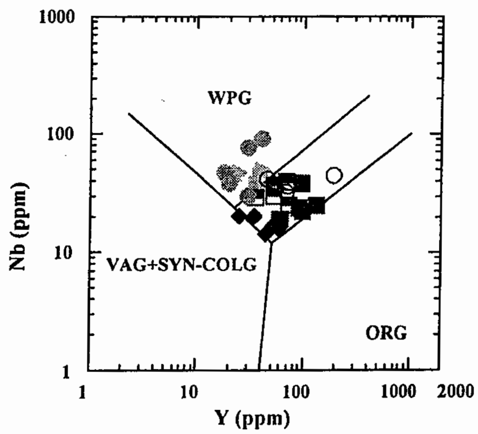

Fig. 17: Nb vs. Y tectonic discrimination diagram, (Pearce et al., 1984).

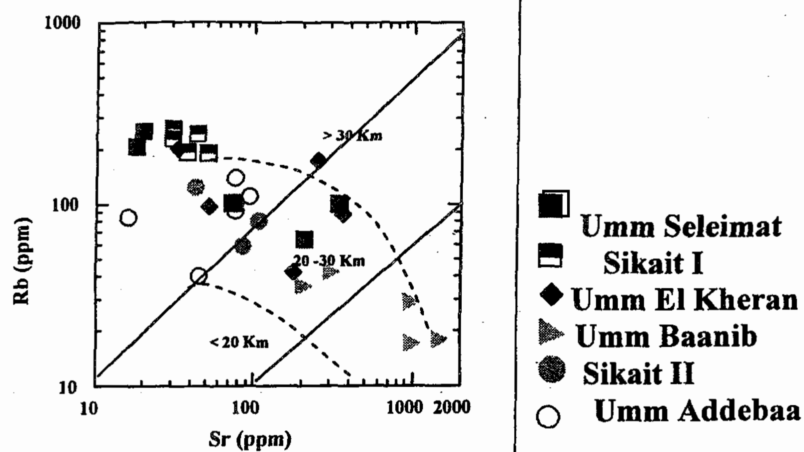

Fig. 27:Rb vs. Sr binary diagram for the studied granites (Condie, 1973).

The presence of primary muscovite and garnet in the muscovite granites imply that they crystallized from peraluminous magma. For many geologists, peraluminous magma is equivalent to S-type granites. In a recent study, Barbarin (1996) mentioned that some rare muscovite-bearing granitiods can be produced by extreme fractionations or local contamination of metaluminous magma. The muscovite – bearing zone in W. El Gemal area probably corresponds to this type. Moreover he (op. cit) added that "Some moderately to strongly peraluminous granites occur as a minor component of dominantly metaluminous granitiods suite. Form the previous studies the authors can conclude that the petrogenesis of the studied muscovite granites agree with the models of Garcia et al., (1994) and Barbarin (1996).

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