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Uranium Geochemistry in Peraluminous Leucogranites of Wadi El-Shallal Area, Sinai, Egypt

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Abstract. The two mica granites of El-Shallal area being emplaced into biotite schists, which underwent high temperature low pressure metamorphism. The two mica granite is peraluminous leucoadamellite to leucogranite in composition, Fe-rich sub-alkaline, with low contents of Ba, Ce and Sm and high contents of Rb, U and K. These facts substantiate the geochemical characteristics of S-type granites. The field observations and petrochemical characteristics are consistent with the derivation of El-Shallal two mica granites from biotite schists.

Many of geochemical and mineralogical characteristics of El-Shallal two mica granites are similar to those of fertile Granites Uranifere Français (G.U.F). The average uranium and thorium contents of the two mica granites are relatively high (17 and 32 ppm respectively) and increase during late magmatic stage (72 and 134 ppm respectively) close to basic dykes (chemical traps for U-bearing solutions) compared to the average granitic rocks and exceed the international average content in the crustal rocks. El-Shallal leucogranites may represent the source for uranium occurrences at Um Bogma formation as a result of leaching and remobilization by circulated meteoric water and precipitated simultaneous with and after sedimentation.

Introduction

The granitoid rocks of Sinai and Eastern Desert massif are mainly of Pan African age emplaced at a time span between 417 and 780 Ma. They are classified into older (synorogenic) and younger (late to post-orogenic) granites (El Shazly, 1964; and El Ramly, 1972). The synorogenic older granitoids (OG) are of dioritic-tonalitic to granodioritic composition, calc-alkaline I-type and range in ages between 610 and 711 Ma (Dixon *et al.,* 1979; Stern and Hedge, 1985). They get as old as 780 Ma in Sinai (Stern and Manton, 1987). The younger granitoids (YG) are considered as the final stage of the Pan African magmatism ceased at the end of the Precambrian at 550 Ma (El-Shazly *et al.,* 1980). The YG plutons in age between 549-597 Ma, while some alkali plutons get as young as 417 Ma (Stern and Hedge, 1985). The source and genetic relationship between the OG and YG is still constrained.

Most of the Post-tectonic YG are K- and LILE-enriched, calc-alkaline to midly alkaline rocks with I-type affinity. A part of the YG has been recently classified as A-type granitoids (Eby, 1992).

Economic uranium deposits genetically related to granitoids are mostly located in anatectic melts or in strongly peraluminous two mica leucogranites (Cuney *et al.,* 1984; and Poty *et al.,* 1986). U deposits associated with peraluminous granites occur as veins or disseminations principally in the European Hercynian Belt (Moreau, 1977; Cuney, 1987; Leroy, 1978; Cathelineau, 1981; and Poty *et al.,* 1986), in the north American Hercynian Belt (Chatterjee & Strong, 1984), in the Yanshan granitoids of southeastern China (Jiashu & Zehong, 1984) and in Argentina (Rodrigo & Belluco, 1981).

Most of Egyptian uranium occurrences (Um Ara, Gattar, Missikat and Erediya) belong to slightly peraluminous granites (biotite only or biotite with subordinate secondary muscovite, calc-alkaline in nature and equivalent to A-type (Ibrahim, 1996). Uranium deposits associated with A-type granites are less common (example in China) than those associated with S-type granites (example, Central Massif of France, Cuney, 1998) and the size of the U-deposits is generally smaller in the first type (some hundreds to some thousands of metric tons uranium metal).

This work is a contribution to the understanding of U geochemistry in two mica granites. The data is provided by analyses of the two mica granites (14 samples), the hornblende-biotite granitoids (12 samples) and the biotite schists (3 samples). U and Th have been measured radiometrically by using multichannel analyzer γ-ray detector (Gamma-spectrometer technique).

Geologic Setting & Petrography

The rocks in Wadi El-Shallal area can be chronologically arranged with the oldest as follows: Schists, gneisses and migmatites, hornblende-biotite granitoids, Dokhan volcanic rocks (porphyritic rhyolites), two mica granites and post granitic dykes.

The metamorphic assemblage minerals; garnet, cordierite, sillimanite and staurolite which present in both schists and biotite gneisses may suggest that, the schists have been exposed to different subsequent stages of regional metamorphism (Ibrahim, 1997). The syntectonic semi-rounded porphyroblast garnet is mainly Mn-rich, while the cordierite, sillimanite and staurolite are formed in Al-rich pelites under high temperature, low to medium pressure of metamorphism in amphibolite facies (Ibrahim, *op. cit.*).

Hornblende-biotite granitoids (653 ± 26 Ma on the basis of K/Ar dating by Abdel Kariem & Arva-Sos, 1992) covering about 54 km^2 and form moderate to high relief (699 m a.s.l.). The Paleozoic sediments unconformably overlie these rocks. They are usually medium- to coarse-grained, grey to darkish grey in colour, highly fractured and sheared, sometimes filled by calcite veinlets, iron oxides and epidote. They also enclose xenoliths of variable dimensions and shapes ranging in composition from gneissic diorite to amphibolite through gneiss and migmatite. These sharp xenoliths are mostly ovoidal in shape, sometimes elongated or angular to sub-rounded, with massive and gneissose structures and sometimes without assimilation.

Petrographyically, the hornblende-biotite granitoids are ranging in composition from diorite, quartz diorite, trondhjemite, tonalite and granodiorite without contacts in between. They are consisting mainly of plagioclase ($An_{16\text{-}32}$), hornblende, biotite, quartz and potash feldspars (orthoclase, micro-perthite) in decreasing order. Sphene, zircon, apatite, prehnite and magnetite are the main accessory minerals (Table 1).

TABLE 1. Modal composition of the examined granitoid rocks, Wadi El-Shallal area.

Ser. no.	Sam. no.	Qz	K-Feld	Plag.	Bio.	Hb	Mus.	Acces.	Q	A	P
1	143	31.19	55.66	11.18	0.39	–	0.96	0.62	31.8	56.8	11.4
2	200	35.04	60.76	2.99	0.05	–	0.91	0.25	35.5	61.5	3
3	29	40.27	48.58	10.13	0.58	–	–	0.44	40.7	49.1	10.2
4	153	30.04	56.18	9.64	0.26	–	0.5	3.38	31.3	58.6	10.1
5	172	25.28	48.75	25.03	0.53	–	0.06	0.35	25.5	49.2	25.3
6	179	38.4	43.32	15.66	2.45	–	0.04	0.13	39.4	44.5	16.1
Average		33.37	52.21	12.44	0.71	–	0.41	0.86	34.0	53.3	12.7
7	9	33.17	40.16	25.78	0.68	–	–	0.21	33.5	40.5	26
8	130	43.84	23.76	30.76	0.35	–	0.42	0.96	45	24	31
9	184	32.8	41.7	24.21	0.9	–	0.08	0.31	33.2	42.2	24.5
10	193	39.63	32.44	25.32	2.28	–	0.21	0.12	40.7	33.3	26

Table 1. Contd.

Ser. no.	Sam. no.	Qz	K-Feld	Plag.	Bio.	Hb	Mus.	Acces.	Q	A	P
Average		37.36	34.52	26.5	1.05	–	0.18	0.39	38	35.1	26.9
11	66	2.86	3.53	60.35	6.45	26.29	–	0.52	4.3	5.3	90.4
12	72	2.04	2.7	53.19	7.35	33.38	–	1.34	3.5	4.7	91.8
Average		2.45	3.2	56.77	6.9	29.83	–	0.99	3.9	5.1	91
13	30	13.79	4.19	71.75	8.42	1.51	–	0.34	15.4	4.7	89.7
14	76	10.94	3.54	63.93	11.16	9.57	–	0.86	14	4.5	81.5
15	84	12.55	2.88	64.9	10.55	8.73	–	0.39	15.6	3.6	80.5
16	104	5.23	4.66	69.29	10.37	10.11	–	0.34	6.6	5.9	87.5
Average		10.63	3.82	67.47	10.12	7.48	–	0.48	13	4.7	82.5
17	7	5.41	8.26	56.1	12.24	17.43	–	0.56	7.7	11.8	80.4
18	92	6.71	7.91	46.85	11.82	25.66	–	1.05	11	13	76
19	97	8.64	9.38	60.04	6.65	14.8	–	0.49	11.1	12	76.9
Average		6.92	8.52	54.33	10.23	19.3	–	0.7	9.9	12.2	77.9
20	211	16.34	3.39	56.66	16.59	6.6	–	0.43	21.4	4.4	74.2
21	12	19.83	2.67	59.76	12.59	4.58	–	0.57	24.1	3.3	72.6
22	108	14.95	3.63	51.85	17.64	11.65	–	0.28	21.2	5.2	73.6
Average		17.04	3.23	56.09	15.61	7.61	–	0.41	22.3	4.2	73.5
23	5	28.86	7.11	45.74	15.84	2.14	–	0.31	35.3	8.7	56
24	54	24.1	10.47	54.52	7.15	3.51	–	0.25	27.1	11.8	61.2
25	81	23.03	13.98	50.37	6.82	5.4	–	0.4	26	16	58
Average		25.33	10.52	50.21	9.94	3.68	–	0.32	29.4	12.2	58.4

Ser. No = Serial Number, Sam. No.= Sample Number, Qz = Quartz, K-feld. = Potash feldspar including perthite, Plag. = Plagioclase, Bio. = Biotite, Hb. = Hornblende, Mus. = Muscovite, Acces. = Accessory including opaques, Q = quartz content, A = potash-feldspar content and P = plagioclase content.

1-10 = Two mica granites (1-6 = Syenogranites and 7-10 = Monzogranites)

11-25 = hornblnde-bitite granitoids (11-12 = Diorites, 13-16 = Quartz diorites, 17-19 = Trondhjamite, 20-22 = Tonalites and 23-25 = Granodiorites).

Note: All values are in volume percent.

The two mica granites are medium to coarse-grained, pink in colour, sheared, cavernous, highly weathered and exposed in the central to southeastern part of the mapped area (Fig. 1), covering about 70 km^2 and occur as narrow elongated sheets. They form high relief (1039 m a.s.l.), intruded in older rocks with sharp intrusive contacts, sometimes occur as apophyses into the older rocks and enclosed schist enclaves.

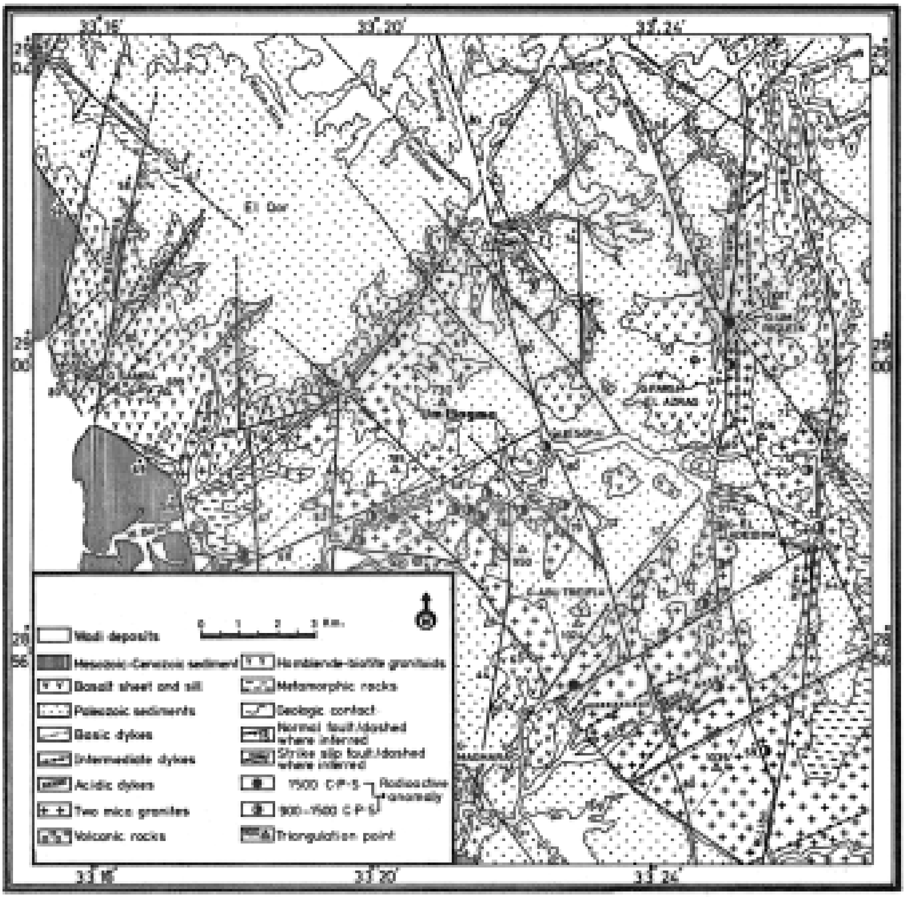

FIG. 1. Geological map of Wadi El-Shallal area.

Petrographyically, the two mica granites are essentially composed of quartz, potash feldspars, plagioclase, biotite and muscovite. Fluorite, ilmenite, allanite, zircon, sphene and monazite are accessories. Quartz occurs as anhedral crystals. Some crystals show uniform extinction manifesting secondary phase filling the interstices between the feldspars crystals. Potach feldspars are mainly displayed by perthite and orthoclase prthite. They are mostly flamy, patchy and string types, with fractures filled by ilmenite and sericite. They are often stained with dusty brown kaolinite and iron oxides due to alteration. Plagiocalses are represented by albite-oligoclase (An_{6-18}) in composition, and often enclose muscovite, fluorite, quartz and secondary epidote. Biotite is pleochroic as X = yellowish brown, Y = brown and Z = dark brown and greenish brown. It is partly altered to pale green chlorite and replaced by iron oxides along its cleavage planes. Muscovite occurs in three forms; euhedral tabular crystals, usually associated with biotite and ilmenite, or as interstitial filling space between other minerals or as fine inclusion in quartz and feldspar grains. Zircon occurs as euhedral prismatic crystals (0.1 × 0.2 mm) enclosed in quartz, feldspars and mica with pleochroic halos.

Apatite is less abundant, sphene forms aggregates (0.1 × 0.3 mm) closely related to goethite and mica. Fluorite varying from colourless to pale pink in colour, present as lensoidal shape enclosed between mica cleavage, or as interstitial filling space between essential minerals enclosing zircon, allanite and quartz.

All the granitoid rocks are invaded by dyke swarms of variable composition, including acidic, intermediate and basic types. Aplitic, quartz veins and pegmatite pockets (20 × 120 cm) are also recorded. They are dissected by several normal faults (N-S, NNW-SSE and NW-SE trends), and generally the granitic rocks capped by Paleozoic sedimentary sequences ranging from Cambro-Ordovician to Carboniferous and attain thickness of 200-375 m. (Kora, 1984). The lower Carboniferous Um Bogma Formation is subdivided into three members: Upper and Lower dolomite members separated by a middle member (4-10 m) composed of intercalations of siltstone, marl, sandy dolomite and shale (Kora, *op. cit.*). The middle carbonate rock units (Um Bogma formation) have visible uranium showing (El Assay *et al.,* 1986).

Analytical Methods

The major oxides were measured using conventional techniques of Shapiro and Brannock (1962), with some modification given by El Reedy (1984). The SiO_2, TiO_2, Al_2O_3 and P_2O_5 were analyzed using Unicam UV2/100 Spectrophotometer while Na_2O and K_2O were analyzed using PFP-7 Flame Photometer and MnO analyzed by GBC 932/933 Atomic Absorption Spectrophotometer. The XRF technique, Philips X' Unique model II was used. The Zr, Y, Sr, Rb and Nb were measured by calibrating the system under the conditions of W-radiation, LIf-220 crystal, 70 kV and 1.5 mA. The Ba was measured under the same conditions except kV and mA are 100 and 10 respectively. The radiometric measurements was carried out using a Bicron Scintillation detector NaI (TI) 76 × 76 mm. All the analyses were carried out in Nuclear Materials Authority (NMA). An X-ray diffraction unit (PW 3710/31), with generator (PW 1830), Scintillation counter (PW 3020), Cu target tube (PW 2233/20) and Ni filter at 40 kV and 30 mA were used for identifying the separated heavy mineral fraction.

Major Element Geochemistry

Chemical analyses were carried out for 29 samples, collected from El-Shallal area. The analyzed samples include three samples from the biotite schists, twelve samples from hornblende biotite granitoids and fourteen samples from the two mica granites. The results are given in Tables 2 & 3.

TABLE 2. Chemical analyses for the hornblende-biotite granitoids, Wadi El-Shallal area.

Sample no.	Hornblende-biotite granitoids											
	12	72	66	104	54	108	30	211	76	81	84	97
SiO_2	61.18	54.45	54.70	54.91	63.65	62.81	65.00	65.17	61.14	63.43	63.23	64.75
TiO_2	0.19	0.28	0.31	0.21	0.16	0.20	0.18	0.19	0.21	0.22	0.13	0.11
Al_3O_3	15.61	16.18	15.81	16.31	15.13	16.01	13.99	14.65	16.1	15.66	15.61	14.98
Fe_2O_3	4.85	8.15	7.14	6.18	4.11	5.16	4.77	4.09	5.61	4.79	5.01	4.16
FeO	1.03	1.32	1.77	2.01	0.91	0.71	0.82	0.74	0.91	0.91	0.91	0.80
MnO	0.08	0.08	0.10	0.08	0.04	0.05	0.03	0.02	0.03	0.03	0.02	0.03
MgO	2.71	4.15	4.32	4.18	2.18	1.91	1.87	1.61	2.04	1.91	2.07	1.76
CaO	4.31	6.34	6.18	7.01	4.61	4.18	3.98	4.18	4.16	4.26	4.42	4.17
Na_2O	4.89	4.91	5.16	4.89	4.61	4.80	4.73	4.51	5.01	4.61	4.26	4.36
K_2O	3.63	2.78	3.16	3.16	3.21	3.08	3.37	3.71	3.61	3.25	3.19	3.71
P_2O_5	0.26	0.19	0.17	0.20	0.17	0.16	0.09	0.20	0.19	0.16	0.11	0.18
L.O.I	1.23	1.06	1.12	0.94	1.16	0.94	1.23	0.89	0.91	0.79	1.02	0.99
Total	99.97	99.89	99.94	100.08	99.94	100.01	100.06	99.96	99.92	99.94	99.92	99.98
Rb	63	40	33	60	52	58	80	74	42	58	52	46
Sr	420	460	490	459	432	387	462	328	511	508	475	474
Ba	921	1091	1039	460	533	879	726	460	961	753	1063	921
Zr	215	193	210	243	205	188	268	211	231	278	229	210
Y	28	25	21	25	26	26	31	31	24	26	26	26
Nb	22	20	17	20	21	20	23	24	20	21	21	22
Zn	70	65	68	72	37	63	70	41	71	69	68	59
Cu	16	26	23	21	21	12	15	14	15	12	14	13
Ce	109	90	106	119	93	107	142	107	96	141	113	78
Sm	5	15	15	10	4	8	4	4	10	5	11	11

TABLE 3. Chemical analyses for two mica granites and biotite schist, Wadi El-Shallal area.

Sample no.	Tow mica granites														Average schist (n = 3)
	193	184	172	138	127R	143	29	140	168G	200	153	130	179	181	
SiO_2	72.05	72.43	72.01	74.13	74.18	73.67	73.85	73.34	74.28	73.22	72.71	75.00	74.02	74.16	70.49
TiO_2	0.11	0.13	0.09	0.12	0.10	0.08	0.09	0.10	0.16	0.09	0.13	0.17	0.2	0.09	0.50
Al_3O_3	13.65	13.74	14.22	14.1	13.7	13.65	13.94	14.91	13.62	14.11	14.61	13.91	13.75	13.91	13.30
Fe_2O_3	1.75	2.01	1.27	0.81	0.75	1.01	0.81	0.41	0.57	0.92	1.07	0.85	0.71	1.08	4.10
FeO	0.46	0.39	0.50	0.46	0.51	0.61	0.72	0.63	0.71	0.61	0.51	0.49	0.52	0.49	–
MnO	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.04	0.02	0.03	0.02	0.01	0.10
MgO	0.81	0.80	0.73	0.42	0.36	0.33	0.49	0.61	0.45	0.31	0.57	0.41	0.60	0.41	2.20
CaO	1.85	1.62	1.74	0.89	1.02	0.91	0.75	1.31	0.82	1.01	0.94	0.72	0.93	0.82	3.15
Na_2O	3.70	3.36	3.81	4.00	3.89	4.03	3.75	3.77	3.91	4.01	3.71	3.27	3.87	3.91	3.30
K_2O	4.89	4.78	5.01	4.98	4.81	5.13	4.79	4.09	4.82	4.89	5.07	4.51	4.62	4.39	2.0
P_2O_5	0.16	0.20	0.18	0.20	0.09	0.15	0.16	0.09	0.20	0.13	0.12	0.11	0.17	0.15	–
L.O.I	0.51	0.48	0.46	0.38	0.52	0.41	0.50	0.61	0.43	0.52	0.49	0.47	0.51	0.48	0.70
Total	99.97	99.97	100.04	100.51	99.95	100.00	99.88	99.89	99.98	99.96	99.95	100.02	99.98	99.90	99.84
Rb	204	214	211	261	216	219	146	249	243	119	199	230	134	207	40
Sr	113	94	114	109	88	125	92	99	112	107	94	100	104	104	250
Ba	379	494	376	356	420	362	380	304	467	418	383	311	382	363	510
Zr	177	180	177	179	146	185	180	168	188	181	161	165	160	176	220
Y	44	44	45	48	40	49	38	47	54	38	45	46	36	44	60
Nb	27	26	27	29	24	30	26	26	30	27	26	26	24	27	
Zn	42	35	51	30	77	16	31	41	118	22	53	18	33	32	
Cu	23	14	19	17	21	36	19	17	25	20	14	17	18	17	
Ce	16	11	10	3	14	22	5	8	20	5	3	23	2	2	
Sm	1	2	2	1	1	1	1	1	2	2	1	1	1	1	

a – Granitic Typology

The R_1-R_2 diagram (Fig. 2) of De La Roche *et al.* (1980) shows clearly that all the samples of El-Shallal granitoids lie between the alkaline and calc-alkaline suites. This situation is typical of evolved, Fe-rich sub-alkaline suite, as defined by Pagel and Leterrier (1980).

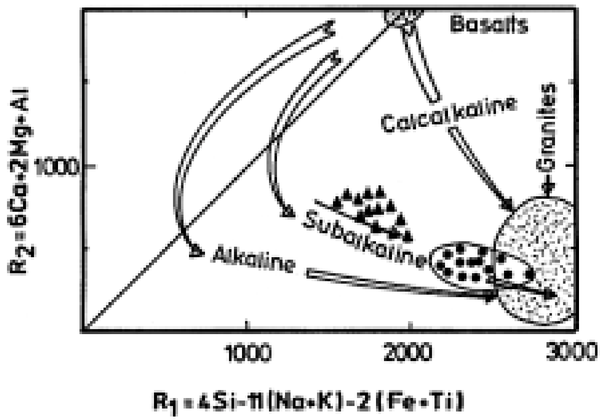

FIG. 2. R_1-R_2 chemical and mineralogical classification diagram (De la Roche *et al.,* 1980). o = two-mica granites and ▲ = hornblende-biotite granitoids. Symbols are fixed in all diagrams.

On the A-B and Q-P multicationic variation diagrams (Fig. 3&4) after Debon and Le Fort (1983), all the hornblende-biotite granitoid samples are monzodioritic in composition, metaluminous in characters (I-type), whereas, most of the two mica granitic samples correspond to peraluminous (S-type) leucoadamillites and leucogranites (Fig. 3&4) with biotite ≥ muscovite. Argillic alteration (H^+ metasomatism) is not indicated in the A-B diagram (Fig. 3) where it characterized by high values of the A parameter (decrease of alkali content in relation to alumina; A = Al – (K + Na + 2Ca) and most of the investigated samples show low values of A parameter. In contrast, three samples (Nos. 172, 143 & 193) of the two mica granites show increase in alkali content in relation to alumina and situated in metaluminous domains.

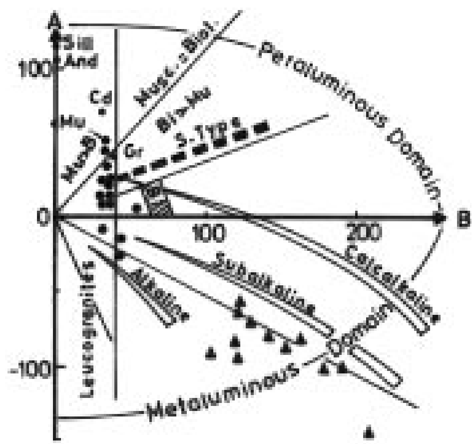

FIG. 3. A-B diagram for El-Shallal granitoid rocks, after Debon and la Fort (1983).

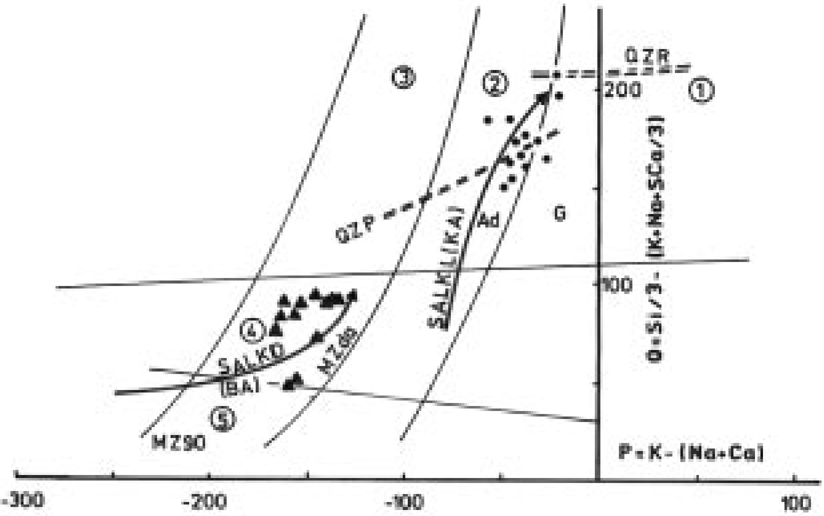

FIG. 4. Q-P diagram for El-Shallal granitoid rocks. G = granite, AD = adamellite, GD = granodiorite and MdQ = quartz monzodiorite.

b – Magmatic Evolution

On Q-B-F or "quartz – dark minerals – feldspars + muscovite" diagram (Fig. 5) show two domains for hornblende-biotite granitoids and two mica granites with fractionation of biotite, Fe-Ti oxides and plagioclase (decrease of B factor Fig. 5). During this evolution, the anorthite content of the plagioclase decreases, whereas the quartz and potash feldspar increases (increases of Q and F factors, Fig. 5). The composition of the studied two mica granites is relatively similar to those of the two mica granites of the Granites Uranifere Français (G.U.F) as indicated from Fig. 5.

On the ACF diagram (Fig. 6) where A= Al_2O_3-Na_2O-K_2O, C = CaO and F = FeO + MgO (in molar values), after White and Chappell (1977). The studied hornblende-biotite granitoids fall in I-type field, while the two mica granites fall in S-type granitic field. White and Chappell (1983) concluded that the S-type granites probably were formed near continental margin environment from anatexis of sediments at the base of a thickened crust during continental collision, whereas the I-type granites probably assumed as products of Cordilleran subduction post orogenic uplift regimes (Pitcher, 1983).

S-type granites are commonly associated with regionally metamorphosed terranes (Debon *et al.,* 1986; and Inger & Harris, 1993). Numerous mechanisms have been proposed to explain the derivation from the metamorphosed host-

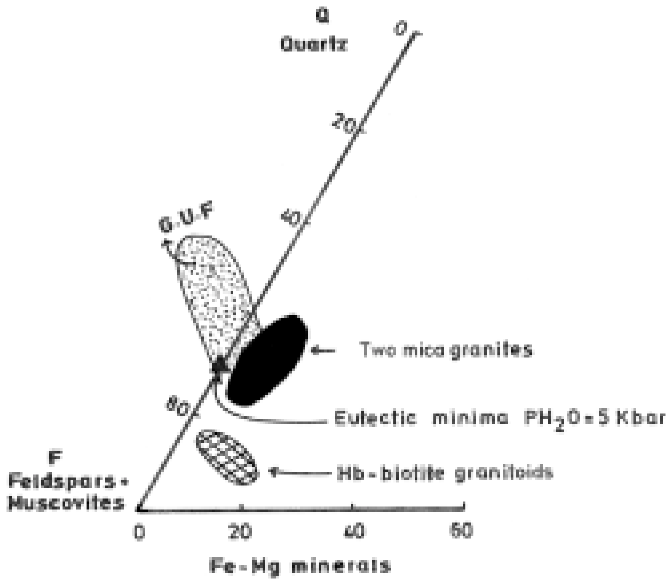

FIG. 5. Q-B-F diagram for El-Shallal granitoid rocks. The dotted field responds to 80% of G.U.F. (granites uraniferous français).

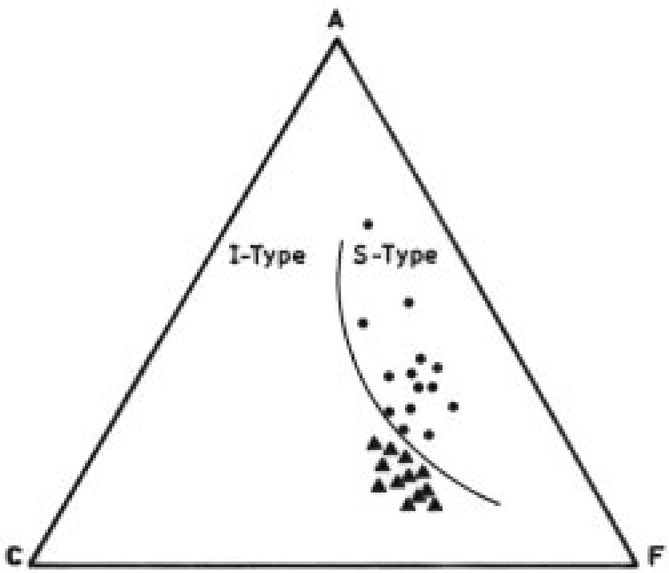

FIG. 6. ACF discrimination diagram between I- and S- type granitic field, after White and Chappell (1977).

rocks, but partial melting of metapelites (Holtz & Barbey, 1991; and Inger & Harris, 1993) is still the most widely accepted model for the generation of these peraluminous leucogranites. Most of the water required for this partial melting process may be derived from the breakdown of hydrous silicates in these metapelites (e.g., biotite and muscovite), (Fyfe, 1969).

According to field observations, the presence of numerous schist enclaves within El-Shallal two mica granites, suggest that the biotite schists are assumed to be the potential source lithologies for the two mica leucogranite. The average composition of the biotite schist is used as the normalizing factor to construct the trace element normalized spider diagram (Fig. 7). It is clearly noticed that the leucogranite is markedly depleted in Ba, Ce, Sm, Ti and Y with some enrichment in Rb, Th, U and K. The particular depletion in Ce in the two mica leucogranite is due to fractionation of LREE-rich phases such as monazite, allanite, zircon and apatite and uranium will be liberated.

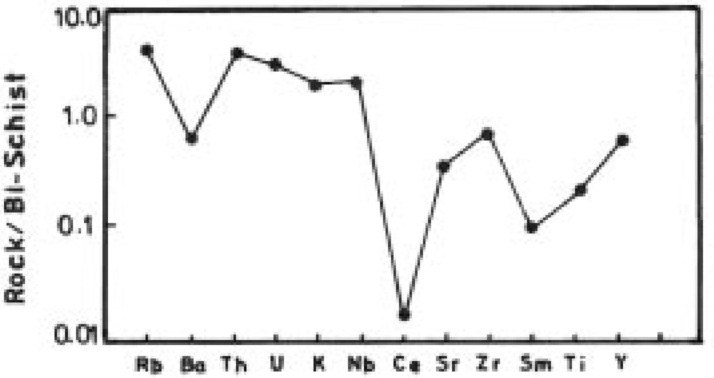

FIG. 7. Incompatible elements spider diagrams for El-Shallal two mica granites normalized to the average composition of biotite schist.

Uranium and Thorium Geochemistry

In Wadi El-Shallal area (Table 4) the U content of the granites increases with magmatic evolution. Uranium content and Th/U ratio increases with Th from hornblende-biotite granitoids to two mica granites (Fig. 8a&b). This type of behaviour indicates that U in the two mica peraluminous leucogranites is mostly located in Th- rich accessory minerals such as monazite.

It is well known that Rb, Y, U, Th and Nb have a large radii or higher electric charges. These ions do not easily to substitute for major ions in common silicate minerals (Krauskopf, 1979), so they are segregated and concentrated in late stage of the granitic melt. If magmatic processes controlled U and Th contents, these elements would be expected to increase. The relations between Rb-U and Y-U (Fig. 9a&b) show that, the U contents increase with the increase of Rb and Y contents, a fact which is related to incompatible behavior during magmatic processes. The positive correlation between U and Y as well as Th and Nb (Fig. 9c) indicate that, the magma from which the two granitic mass developed was emplaced at shallow depths (Briqueu *et al.,* 1984).

TABLE 4. U- and Th- contents in ppm and K content in % in the granitoid rocks and high radio-active anomalies within two mica granites, Wadi El-Shallal area.

Rock types	Radiometric measurements				
		U ppm	Th ppm	K %	Th / U
Hornblende-biotite granitoids (12 Samples)	Max.	6	7	2.11	6.93
	Min.	1	2	0.12	0.44
	Average	4	5	1.56	1.89
Two mica granites (25 Samples)	Max.	40	43	4.08	6.15
	Min.	5	13	2.98	0.33
	Average	17	32	3.52	2.21

Anomaly no.	Sample no.	Radiometric measurements			
		U ppm	Th ppm	K %	Th / U
(1) Pegmatitic pockets	80	13	140	1.49	10.77
	80 G	10	126	0.45	12.6
	80 R	16	136	1.24	8.5
Average		13	134	1.06	10.62
(2) Along fractured granites	177 R	23	57	3.34	2.49
	177 G	59	58	3.69	0.98
	172 R	37	52	4.65	1.41
	140 G	56	40	0.99	0.72
Average		44	52	3.17	1.4
(3) Along fault zone	195	38	14	0.79	0.37
	195 R	48	14	1.01	0.29
	195 G	72	9	1.11	0.13
Average		53	12	0.97	0.26

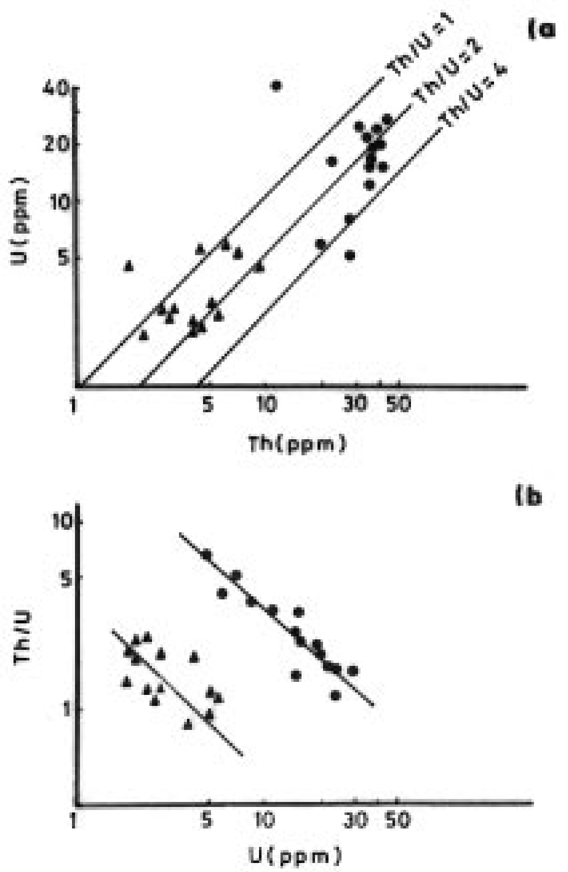

FIG. 8. U-Th (a) and Th/U-U (b) variation diagrams for the studied granitoid rocks, Wadi El-Shallal area.

The hornblende-biotite granitoids show normal U (1-6 ppm) contents and poor Th (2-7 ppm) ones compared with the average concentrations in the crustal rocks reported by IAEA (1979) and Clark value (U = 3-4 ppm, Th = 12-14 ppm). The two mica granites show wide variation in U and Th contents (Table 4) from 5-40 ppm with an average of 17 ppm and from 13 - 43 ppm with an average of 32 ppm respectively. They have highly variable Th/U ratios (< 1 to > 4) and could be considered as fertile or uraniferous granites. When Th/U ratio of the magma is low, excess uranium is incorporated in low-thorium uraninite (Pagel, 1981), whereas if the magma has high Th/U ratios, any exess uranium, not substituted in the main minerales or common accessories, is incorporated in uranothorite.

Radiometric Lab. measurements provide evidence of large increase in U content (23-72 ppm, Table 4) and Th content (9-58 ppm) close to basic dykes

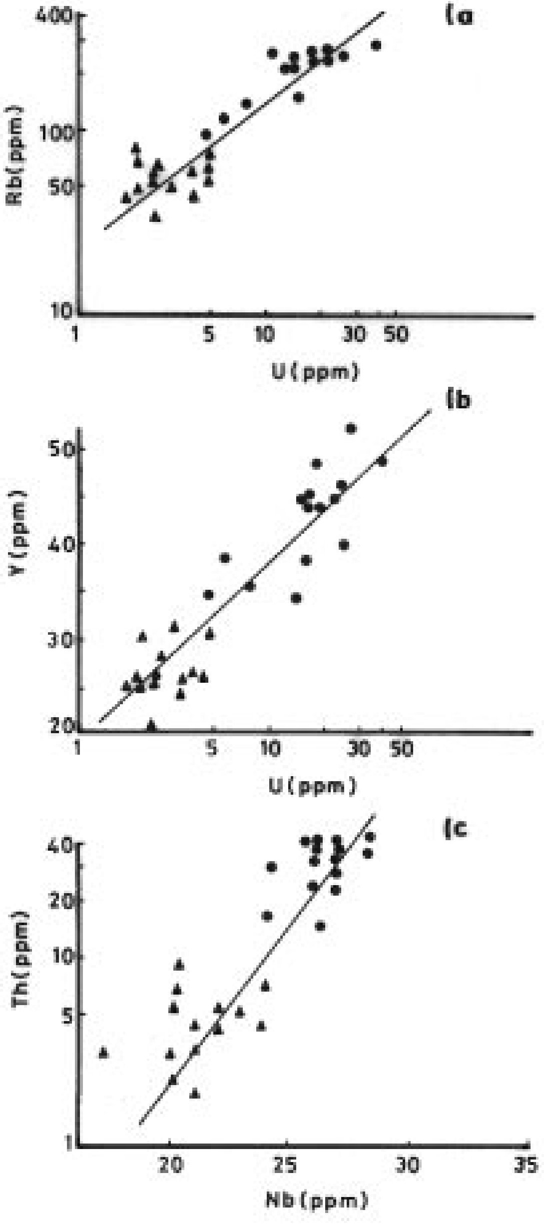

FIG. 9. U versus Rb & Y (a&b) and Th versus Nb (c) variation diagrams for the studied granitoid rocks, Wadi El-Shallal area.

(chemical traps for U-bearing solutions). The increase of U-content in the two mica granites is commonly associated with pyrite, goethite, fluorite, tapiolite, zircon and monazite as indicated from X-ray diffraction analysis. The latter paragenesis leading to a hypothesis assigning a magmatic origin to uranium.

Discussion and Conclusion

El-Shallal igneous rocks include metaluminous sub-alkaline granitoids and peraluminous fertile leucogranites, probably non-cogenetic. Each granite group may represent individual magma batches. The hornblende-biotite granitoids fall in I-type field, while the two mica granites fall in S-type granitic field. Uranium distribution actually observed in peraluminous granitoids results from five main processes: partial melting, magmatic differentiation, late-magmatic, hydrothermal and meteoric alterations processes (Friedrich *et al.,* 1987).

Ranchin (1971) and Pagel (1982) concluded that the peraluminous leucogranites with U content close to 20 ppm; 25-35% of the uranium is incorporated mainly in zircon, monazite and apatite, and 5-6% is in disseminated and adsorbed form. Uraninite may account for an average of 60% of the whole rock uranium.

If the U content is below the Clark value (3-4 ppm) most of it is located in accessory minerals such as zircon, apatite and monazite. The U contained in these minerals is difficult to remove in some Na-metasomatic processes. In contrast, when the uranium content exceeds the Clark value, (the present study) initial magmatic uranium strongly fractionates into the melt during partial melting and may crystallize as uraninite (Cuney, 1987). for example, in U-rich peraluminous leucogranitets (about 20 ppm U) 70-90% of the uranium is located in uraninite, which is easily leachable by hydrothermal solutions. The transportion of U depends on the geochemical characteristics of the fluids (temperature, pressure, oxygen fugacity fo_2, concentration of complexing anions, and pH) and on the amount of fluids (water/rock ratio), which in turn is partly related to the number and size of channel ways which are controlled by the tectonic activity (Cuney, *op. cit.*).

The present study provide also evidence of a strong increase in U content during late magmatic stage (swarms of acidic, intermediate and basic dykes).

Mineral fractionation, defined by chemical-mineralogical diagrams, indicates the simultaneous fractionation of Fe-Mg minerals (Fig. 5) and monazite (Fig. 7). This type of relation, together with the low solubility of monazite in peraluminous melt (Cuney and Friedrich, 1987) and the absence of cordierite and/ or garnet, suggests that biotite and monazite were essentially restitic minerals, scavenged by the magmas from the anatectic zone (White and Chappel, 1977).

However, this type of fractionation is very different from S-type granites of Australia (White and Chappel, *op. cit*), which show a much higher content of mafic minerals (B parameter, Fig. 3) and a simultaneous decrease of the peraluminous character (A parameter, Fig. 3) and the mafic mineral content.

The low solubility of monazite, zircon and apatite in highly peraluminous melt leads to a rapid depletion of the magma in P, Zr and LREE (Ce & Sm). The abundances of these minerals decreases with differentiation (Cuney and Friedrich, 1987)

El-Shallal leucogranites may have undergone subsolids alteration (either hydrothermal or meteoric), these alterations may strongly disturb the primary U content especially in supergene conditions. It is noticeable that the U content increases (23-72 ppm) during late magmatic stage close to basic dykes and associated with pyrite, fluorite, tapiolite, and goethite.

The Paleozoic rocks unconformably overlie the peraluminous granites, consist of three units; Lower Sandstone, Middle Carbonate and Upper Sandstone Units (Barron, 1907). The middle member of Um Bogma Formation (intercalated siltstone, marl, sandy dolomite and shale, Kora, 1984) is the most important unit from the radioactive point of view. The occurrence of secondary U mineralizations restricted to both Quaternary rocks and the middle dolomitic unit in the Carboniferous Um Bogma formation, and the absence of any significant mineralizations along fractures or fault lines within the sedimentary rocks itself (Hussein *et al.,* 1992, Abdel Monem *et al.,* 1997), indicate that U mineralizations occurred as a result of leaching of pre-existing uranium rich- accessory minerals in peraluminous leucogranites by circulating meteoric water and precipitated simultaneous with and after sedimentation.

Finally, El-Shallel peraluminous two mica granites could represent a favorable source for U-deposits, but total uranium content does not automatically give a measure of fertility. An accurate specification of the percentage of U host minerals is required in the different stages of magma evolution.

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جيوكيميائية اليورانيوم في الليكوجرانيت البيرالمنس (فوق الألوميني) بمنطقة وادى الشلال – سيناء – مصر

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المستخلص. يتداخل جرانيت منطقة الشلال ذو الميكا الثنائية مع صخور البيوتيت شست المتحولة المتعرضة لدرجة حرارة عالية وضغط قليل . يتراوح الجرانيت ذو الميكا الثنائية في التركيب بين الجرانيت إلى أداميليت فاتح متوسط القاعدية الغني بالحديد وذي محتوى قليل من الباريوم والسيلينيوم والسامريم ، ومحتوى عالي من الروبيديوم واليورانيوم والبوتاسيوم ، وهذه الخصائص تعطي انطباعًا بأن الجرانيت من نوع (S-type).

كثير من الخواص التمعدنية والجيوكميائية للجرانيت ذي الميكا الثنائية مشابه للجرانيت الخصب . محتوى متوسط اليورانيوم والثوريوم لهذا الجرانيت عال نسبيا (١٧–٣٢ جزء في المليون على التوالي) ، ويزيد في مراحل الصهير المتأخرة (٧٢ و ١٣٤ جزء في المليون على التوالي) بالقرب من القواطع القاعدية (مصائد كيميائية للمحاليل الحاملة لليورانيوم) بالمقارنة بمتوسط صخور الجرانيت ، ويتعدى محتوى المتوسط العالمي لصخور القشرة . ومن المحتمل أن اليورانيوم الموجود بصخور الشلال هو مصدر وجود اليورانيوم بمنطقة تكون أم بجمة نتيجة الإذابة وإعادة الترسيب أثناء وبعد ترسيب الصخور الرسوبية .