Petrogenesis of late Precambrian younger granites from southwst Sinai, Egypt

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The paper represents the field, petrographic and geochemical characteristics of late Precambrian granites of Wadi Baba-Wadi Seih area in southwestern Sinai. They are composed of biotite granites and leucogranites. The biotite granites are fluorite non-bearing, vary from monzo- to syenogranites, which cut by felsic dykes, and probably correspond to the phase II of Egyptian Younger Granites. The leucogranites are fluorite bearing, range from syenogranites to alkali feldspar granites, cut the phase II and felsic dykes and belong to the phase III granites.

Petrographic and geochemical data reveal a peraluminous type and potassic-sodic character of the present younger granites. They were originated at 20- >30 km depth as shallow- to moderate- level intrusives. They were mostly originated in intraplate environment with extensional regime.

In general, the biotite granites have alkaline character, probably exhibit the features of S-type granite, and are derived by partial melting of the lower crustal materials. On the other hands, the leucogranites have strong alkaline and peralkaline charcters, largely similar to the A-type granite with high silica, alkalis and normative acmite, and were formed through partial melting of lower crustal materials followed by crystal fractionation of a fluorine-rich I-type magma.

Keywords: Biotite granites, Leucogranites, S-type, A-type, Petrography, Geochemistry, Petrogenesis, Sinai, Egypt.

I. Introduction

Precambrian granites are the most predominant rock-type (about 70%) in the basement complex of Sinai. Akaad *et al.*, (1979), Abu El Leil (1980) and Rogers and Greenberg (1983) subdivided the younger granites of the Eastern Desert into three phases or groups. Hussein *et al.* (1982) proposed that the majority of the younger granite plutons were formed by partial melting of the lower crust probably with some additions from the mantle by collision, a few are intraplate anorogenic alkaline granites. Noweir *et al.* (1990) subdivided the Egyptian younger granites into four groups: Group (1) less differentiated calc-alkaline to weakly alkaline I-type granodiorite and monzogranite;

Group (2) normal alkaline A-type monzogranite to syenogranite and Group (3) strongly alkaline A-type alkali feldspar granite, whereas the Group (4) includes the "Apogranites". A-type granites are considered as latest phase intrusives in the main younger granites (Ragab, 1987) as post-kinematic shallow cauldron complexes (El-Gaby *et al.*, 1988). These granite plutons, in Sinai, are grouped together with alkaline monzonite and rhyolite as Katherina Province (Bentor, 1985). Moreover, a good relationship between fluorine and latest pulses of the Egyptian younger granites have been recently discussed by Bentor (1985), Ragab (1987) and Fasfous *et al.* (1992). Mabrouk *et al.* (1988) and Higazy *et al.* (1989) gave detailed studies on the nearby granitic rocks in SW-Sinai. El-

Fig. 1. Geological map of the Late Precambrian younger granites from SW-Sinai, after El-Aref *et al.* (1988) and Abdel-Karim and Arva-Sos (1992) with modifications.

1, Wadi deposits; 2, Mesozoic sandstone; 3, Triassic and Jurassic basalts; 4, Cambrian, Ordovician and Carboniferous sandstone; 5, Basalt dykes; 6, Phase-III younger granites; 7, Felsic dyke swarms; 8, Phase-II younger granites; 9, Mafic dyke swarms; 10, Older granites; 11, Metagabbro-diorite association; 12, Gneiss/migmatites; 13, Continuous contact; 14, discontinuous contact; 15, Shear zone.

Aref *et al.* (1988) defined the present granites, on the basis of the field and petrographic description, as a second phase younger granite. K-Ar dating of the examined granites gave a late Precambrian age ranging between 609 and 568 Ma (Abdel-Karim and Arva-Sos, 1992), which is consistent with the Pan-African event.

The present study is an attempt to clarify the field relations, petrography, geochemistry and petrogenesis of the younger granite plutons of the Wadi Baba-Wadi Seih area in SW-Sinai district (Fig. 1). Their field and compositional characteristics are similar to the phase II and phase III of the Egyptian Younger Granites (Akaad *et al.*, 1979; Abu El-Leil, 1980). Phase-II represents by a biotite (fluorite non-bearing) granite while phase-III is a leuco-

granite (fluorite-bearing).

II. Geologic setting

The younger granites of Wadi Baba-Wadi Seih area belong to the last major magmatic phase of a Pan-African event exposed out in southwestern Sinai (Fig. 1). The plutons form high rugged mountains distributed in Wadis Baba, Samra, Lahian, Sahu, Budra, Shellal, Iqna, Atima and Seih. The granite plutons show extremely sharp contact with the country rocks (gneisses, migmatites, metagabbro-diorite, older granites and late Precambrian mafic dyke swarm). However, few isolated amphibolitic enclaves and net veining can be observed within the examined plutons particularly at Wadi Samra. Some of these plutons have been

overlain by post Cambrian beds.

The younger granites are further subdivided according to the field relation and the mineralogical composition into phase-II (biotite granites) and phase-III (leucogranites) of the Egyptian Younger Granites (Akaad *et al.*, 1979; Abu El Leil, 1980). The field contact between phase II and phase III granites is usually gradational. Commonly, apophyses, offshots and dykes extend from the younger granites into the country rocks. Their outcrops, generally show homogeneous texture with no distinct mineral orientation, thermal effects are sometimes observed.

1. Biotite granites (Phase-II)

The biotite granites (75 km²) crop out at Wadis Baba, Sahu, Iqna and Seih. They comprise coarse grained granites, occasionally this granites have various rock facies such as fine grained and porphyritic and show pale pink greyish red colour and include monzogranites and syenogranites. These granites are mostly fluorite non-bearing. Generally, they have high to moderate relief irregular masses, different shapes of bouldery weathering, and particularly widespread cavities. These granites are condensely jointed by either primary and secondary joints in different directions, while NE-SW, NW-SE trends are dominated. The second phase granites intrude the gneiss, migmatite and older granites of Wadis Baba, Atima, Lahian and Bala with sharp contacts. Thermal effects are occasionally observed. They are cut by the third phase granites of Wadis Baba, Shellal, Lahian and Seih with gradational contacts (Fig.1). They are also crosscut by a number of felsic dykes trending NNW-SSE and E-W.

2. Leucogranites (Phase-III)

The leucogranites (25 km²) consist of several large irregular shape masses of different

Table 1. Modal analysis of the younger granites, SW-Sinai

	Sample	qz	k-fs	plag.	biot.	amph.	fluor.	musc.	chl.	acces.
Phase-II granites										
Coarse-grained granites	1	26.7	37.2	29.6	4.7	-	-	0.7	-	1.1
	2	39.4	28.4	27.1	4.5	-	-	0.4	-	0.1
	3	45.5	19.6	30.2	4.3	-	-	0.2	-	0.2
	4	49.5	26.6	18.8	5.0	-	-	-	-	0.1
	5	37	28.6	27.1	5.9	-	-	-	1.1	0.3
	6	33.7	35.9	23	6.1	-	-	0.8	0.5	-
	7	34	30	24.1	12.8	-	-	-	-	0.1
	8	33.8	35.2	22.5	8.2	-	-	0.1	-	0.2
	9	42.1	31.3	20.2	6.0	-	-	-	-	0.4
Medium-grained	10	34.2	35.6	21.4	7.0	-	-	1.3	-	0.5
	11	28.7	47.7	18.8	4.3	-	-	0.4	0.1	-
Porphy. granites	12	42.7	34.8	16	6.1	-	-	0.2	0.1	0.1
	13	36.9	38.5	17.8	5.9	-	-	0.4	0.3	0.2
Phase-III granites										
Medium to coarse grained	1	32.5	52.7	14.0	0.5	-	0.8	-	-	0.3
	2	42	48.8	6.5	0.1	1.6	-	-	-	1.0
	3	41.1	50.5	4.3	0.5	0.4	1.8	-	-	0.5
Porphy granites	4	33.3	56.2	6.6	0.5	-	3.5	-	-	1.2
	5	38.7	45.3	11.0	0.3	1.5	1.7	-	-	2.1
Granophy granites	6	41.6	46.3	9.4	0.7	0.6	2.2	-	-	1.7
	7	38.3	44.0	12.8	0.5	0.5	1.6	-	-	1.3

dimensions, dissected by Wadis Samra, Lahian, Shellal and Seih (Fig. 1). They are collectively composed of syenogranites and alkali feldspar granites. They are medium to coarse grained, occasionally porphyritic and granophyric and show pink to red colour. These rocks are extensively fractured, highly jointed and weathered. The plutons exhibit extremely sharp contact with country rocks including gneiss, migmatite, older granites, mafic dykes and overly, in places, by post Cambrian sediments. Their contacts with the biotite granites (phase-II) are gradational. This result suggests that they may represent later differentiates of the biotite granite magma. Phase-III younger granites are rarely crosscut by felsic dykes compared with phase-II.

The leucogranites are fluorite-bearing rocks. They are mostly confined to tectonically weakened zones. These granite plutons are strongly alkaline nature. Fluorite shows a wide variation in grain size, distribution and frequency. Fluorite occurrences are vein-like type or as fine aggregates disseminated in the host granites.

The present younger granites and their sedimentary cover are invaded by basaltic flows

Fig. 2. Classification scheme for the studied granites (after Streckeisen, 1976).
A) Modal A-Q-P diagram. B) Normative Ab-Or-An diagram.

(at Farsh el-Azraq and Iqna) and crosscut by dykes of basalts (at Wadi Iqna). These dykes trend NE-SW and rarely NW-SE and N-S.

III. Petrography

The modal composition of younger granites of Wadi Baba-Wadi Seih area are given in Table 1 and plotted in the classification diagram of Streckeisen (1976) (Fig. 2A). It is clear from the figure that the second phase granites fall in the monzogranite and syenogranite fields. The third phase granites plot in the fields of syenogranite and alkali feldspar granite. The colour index of the investigated rocks ranges from 4.3–12.8% in the second phase granites which probably correspond to the biotite granite and from 0.5–1.8% in the third phase granites which consider as leucocratic type or leucogranites (Fig. 2).

The younger granites under study are generally equigranular, coarse- to medium-grained with hypidiomorphic texture. They are characterized by a gradual increase of K-feldspar over plagioclase from the second phase to the third one. Biotite is more abundant in phase II granite than phase III granite. Alkali amphibole is only rarely recorded in the phase III

granite.

1. Monzogranites and syenogranites (Ph-II)

These rocks (biotite granites) comprise normal granite (subsolvus) and perthitic granite (hypersolvus). They are hypidiomorphic granular texture. Porphyritic texture is common, too. The normal granite consists essentially of alkali feldspar, quartz and plagioclase with subordinate biotite, whereas the alkali feldspar and quartz with minor plagioclase and biotite and muscovite are the main components of the perthitic one. Zircon, iron oxide, allanite, titanite, apatite and topaz ± chlorite are accessories. Alkali feldspar is represented by fine patchy and veined structure orthoclase-microperthite in normal granite and fine flame and veined structure orthoclase-perthite in perthitic granite. Quartz forms idiomorphic inclusions in the feldspar crystals and as younger coarse xenomorphic crystals filling the interspaces between the feldspar. Plagioclase (An_{15-22}), occurs as subhedral prismatic crystal, slightly undergone kaolinization. They are mostly twinned, while zoned crystals are sometimes observed. Biotite is the main mafic mineral forming subhedral brown flakes variable alter-

ed to chlorite and iron oxides and containing inclusions of zircon and titanite. Biotite is rarely bleached to muscovite. The occurrence of quartz, muscovite and topaz association perhaps due to the affect of these plutons by late stage alteration (greisenization).

2. Syenogranites and alkali feldspar granites (Ph-III)

These rocks are mostly perthite granites (hypersolvus). They exhibit hypidiomorphic-granular texture. Granophyric and porphyritic textures are common, too. The perthite granites consist mainly of perthitic alkali feldspar and quartz with minor plagioclase, biotite, alkali amphibole relict and fluorite. Iron oxide, topaz, titanite, monazite and apatite are the main accessory minerals.

The alkali feldspar is characterized by patchy, flamey and stringy structure orthoclase perthite with minor microcline perthite. Quartz occurs as fine inclusions in the feldspar or as interstitial grains between feldspar crystals. Plagioclase is albite (An_{5-8}), commonly fresh and twinned. Biotite occurs as brown interstitial flakes. Alkali amphibole forms bluish green anhedral pseudomorph relics. Fluorite occurs as yellowish, highly relief and isotropic crystal aggregates, mostly associated with quartz and biotite, disseminating in the hosting granites. Coarse crystals of fluorite are embedded in quartz matrix. In the porphyritic varieties, megacrysts (up to 6.5-9.5 mm in diameter) of perthitic alkali feldspar, quartz and plagioclase are embedded in a microgranitic groundmass consisting of quartz, alkali feldspar, plagioclase, biotite, alkali amphibole, fluorite and iron oxide. Granophyric granites consist of small amounts of megacrysts of alkali feldspar, quartz and plagioclase embedded in a fine-grained graphic and granophyric groundmass composed of the same minerals of porphyritic one.

IV. Geochemistry

Twenty one analyzed samples from the younger granites of southwestern Sinai plutons were carried out for their major element constituents using the standard wet chemical techniques. Also, fourteen of these samples were analyzed for Rb, Sr, Y, Nb, Zr and Ce by the atomic absorption and optical atomic spectrophotometric methods. The analyses of major and trace elements were carried out in the laboratories of the Hungarian Geological Survey and Eotvos University in Budapest. The obtained results appear in Table 2.

1. Geochemical characteristics

The studied younger granites have a wide range of chemical composition. This is best reflected in variation of SiO_2 contents, which range from 72-76.8% in ph-II younger granites (biotite granites) and from 74.2-78.4% in ph-III (leucogranites); CaO contents which range from 0.4-0.8% in ph-II and from 0.9-1.5% in ph-III. This chemical variation may indicate the differentiation or assimilation of the younger granites. Correlation between the average chemical composition of the studied biotite granites (ph-II) with that given by Turekian and Wedepohl (1961) for the low- CaO granite (Table 2) reveals that, the present granites appear in good parallelism with the low- Ca granites of Turekian and Wedepohl (1961) with slight enrichment in SiO_2 , TiO_2 , Sr and Y and depletion in FeO_t , CaO , MgO , P_2O_5 and Rb and Ce contents relative to the reference low- CaO granites. The leucogranites can be correlated with the A-type granites of Collins et al. (1982) with slight enrichment in CaO , MgO , Na_2O , Nb, Y and Zr contents while other chemical component values of the former granites lie between the two corresponding rock values (Table 2).

Table 2. Chemical composition of the studied

Phase-II (biotite granites)													Average	Ref.*
	1	2	3	4	5	6	7	8	9	10	11	12		
SiO ₂	76.80	76.60	76.50	76.00	75.90	75.80	75.50	75.00	74.90	74.80	74.50	72.00	75.36	74.23
TiO ₂	0.13	0.11	0.09	0.07	0.17	0.07	0.17	0.30	0.33	0.23	0.09	0.17	0.16	0.02
Al ₂ O ₃	12.60	12.30	12.80	12.40	12.30	12.30	12.30	12.40	12.40	13.30	13.30	13.30	1.67	13.61
Fe ₂ O ₃	0.25	0.40	0.73	0.36	0.50	0.60	1.40	0.84	1.39	0.89	0.32	1.69		
FeO	0.26	0.71	0.27	1.15	0.98	0.82	0.44	0.61	0.80	0.26	1.42	1.06	1.48	2.03
MnO	0.02	0.03	0.02	0.05	0.05	0.05	0.29	0.04	0.03	0.03	0.05	0.03	0.06	0.05
CaO	0.26	0.54	0.53	0.40	0.56	0.46	0.46	0.59	0.51	0.61	0.81	0.75	0.53	0.71
MgO	0.11	0.10	0.08	0.06	0.10	0.13	0.04	0.11	0.09	0.06	0.11	0.16	0.10	0.27
Na ₂ O	4.06	3.27	3.48	3.90	3.38	2.95	3.53	3.28	3.53	4.29	3.40	3.65	3.56	3.48
K ₂ O	4.09	4.99	4.24	4.57	4.45	5.09	4.86	4.88	4.86	4.58	4.72	5.03	5.08	5.06
+H ₂ O	0.77	0.81	0.75	0.84	1.06	0.76	0.67	1.06	0.73	0.58	0.81	0.99		
-H ₂ O	0.06	0.09	0.11	0.08	0.16	0.08	0.09	0.05	0.08	0.07	0.11	0.10		
P ₂ O ₅	0.01	0.02	0.01	0.01	0.03	0.07	0.01	0.03	0.01	0.02	0.01	0.03	0.02	0.05
total	99.42	99.97	99.61	99.89	99.64	99.95	99.40	99.40	99.19	99.71	99.65	99.26		
Rb		125	80	115		170	165	105		70	82		114	170
Sr		175	250	165		225	305	413		362	305		275	100
Y		82	72	70		85	60	67		58	73		71	40
Nb		25	20	28		33	37	27		29	35		29	21
Zr		97	104	118		110	135	185		193	180		140	175
Ce		35	52	50		62	48	38		55	43		48	92

Ref. *: low-CaO granites after Turekian and Wedepohl (1961)

2. Geochemical Classification

Figure (2B) illustrated the chemical classification of the younger granites which is represented on the basis of their normative Ab, Or and An (Streckeisen, 1976). On this diagram, the analyzed samples of the biotite granites fall in the syenogranite and monzogranite, while the leucogranites fall in the alkali feldspar granite and alkali granite fields. This chemical classification confirms the modal one (Fig. 2). Furthermore, the studied granites confirm an excess of Al₂O₃ with respect to Na₂O+K₂O+CaO (i.e. A/CNK ratio=1.3-1.6 for biotite granites and 0.91-1.23 for leucogranites) revealing that the majority of present granites fall in the peraluminous field. Over-saturation in alumina is reflected in the occurrence of normative corundum (C=0.4-1.6) in the biotite granites, a typical feature of subsolvus granites. These rocks are enriched in alkalis and strongly depleted in iron and magnesium (Table 2), these features probably result from their classic magma differentiation. More-

over, the parallel distribution of the analyzed samples close to the AF side of the AFM diagram perhaps indicates an extensional tectonic setting (Petro *et al.*, 1979) for the investigated younger granites. Thornton and Tuttle DI of the rocks is very high (i.e. 90-95 for biotite granites and 91-96 for leucogranites). These peculiarities probably indicate that the present granites were derived from extremely fractionated parental magma.

Pitcher (1993) suggested a shear zone model can be developed on the basis that the tensional opening within a zone provide potential spaces for the accumulation of magma. The peraluminous granite magma may be one of the favourable magma that tend to accumulate in this zone. Therefore, a regional ductile shear mechanism is much more likely to have developed of the peraluminous magma.

3. Magma type

The examined granites are plotted on the K₂O-Na₂O diagram (Fig. 3A) which show that

younger granites from SW-Sinai

Phase-III (leucogranites)											
	1	2	3	4	5	6	7	8	9	Aver.	A-type*
SiO ₂	78.40	78.00	76.75	76.60	75.90	76.00	74.80	75.08	74.24	76.20	77.21
TiO ₂	0.10	0.10	0.10	0.10	0.10	0.10	0.17	0.10	0.10	0.11	0.19
Al ₂ O ₃	11.00	11.43	10.13	10.75	12.10	11.70	11.90	10.75	10.38	11.13	11.79
Fe ₂ O ₃	1.06	0.25	0.78	0.37	0.82	0.95	0.63	0.87	0.88	0.73	0.36
FeO	0.33	0.21	0.81	0.82	0.27	0.26	0.66	0.65	0.57	0.51	0.85
MnO	0.01	0.01	0.03	0.02	0.02	0.01	0.04	0.04	0.03	0.02	0.03
CaO	0.25	0.49	0.73	0.88	0.67	0.87	1.45	0.75	1.90	0.89	0.39
MgO	0.10	0.13	0.15	0.12	0.10	0.06	0.10	0.10	0.13	0.11	0.04
Na ₂ O	3.96	4.40	3.56	3.82	4.67	4.45	4.85	3.84	4.10	4.18	3.08
K ₂ O	5.33	4.37	6.03	5.62	4.72	4.99	4.50	5.52	5.35	5.16	5.00
+H ₂ O	0.00	0.00	0.00	0.00	0.00	0.42	0.64	0.00	0.00	0.12	-
-H ₂ O	0.13	0.16	0.31	0.12	0.18	0.08	0.23	0.17	0.27	0.18	-
P ₂ O ₅	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02
total	100.68	99.57	99.39	99.23	99.56	99.90	99.99	97.86	97.96	99.35	
Rb	140		140	205		201	233	275		218	242
Sr	90		145	150		203	220	144		186	43
Y	105		100	118		122	90	108		129	90
Nb	37		45	43		32	37	34		46	19
Zr	208		287	302		253	310	297		276	170
Ce	54		66	61		78	75	70		67	150

* A-type: average of 8 analyses of A-type granites (Collins *et al.*, 1982).

most studied samples have potassic-sodic characters. Moreover, on the alkalinity variation diagram of Wright (1969) (Fig. 3B), the biotite granites have alkaline nature, while the leucogranites have strong alkaline with minor peralkaline tendency. This result is reflected by the occurrence of normative acmite ($Ac=1.1-3.1$) and Na-metasilicate ($Ns=0.2-2.1$). Additional for the alkaline and the peralkaline affinity of

the present granites comes from the fact that the agpaitic index $(Na_2O+K_2O)/Al_2O_3$ for the examined samples ranges from 0.60-0.74 in the biotite granites (ph-II) and from 0.70-0.95 in the leucogranites (ph-III). These features suggest that the biotite granites and leucogranites were derived from alkali-rich magma.

Fig. 3. Plots show the magma type of the studied granites.

A) K₂O vs. Na₂O variation diagram. B) SiO₂ vs. alkalinity ratio variation diagram (after Wright, 1969).

Fig. 4. Plots show the tectonic setting and petrogenesis of the studied granites. A) $(\text{Na}_2\text{O}+\text{K}_2\text{O})/\text{CaO}$ vs. $\text{Zr}+\text{Nb}+\text{Ce}+\text{Y}$ diagram (Whalen *et al.*, 1987). ORG, unfractionated (normal) I/S-type granites; FG, highly fractionated I- or S-type granite. B) ACF diagram (Chappell and White, 1974). C) Rb vs. Sr (ppm) diagram, numbers in km. refer to crustal thickness (after Condie, 1973). D) Rb vs. Y + Nb diagram (Pearce *et al.*, 1984).

4. Tectonomagmatic Setting and Petrogenesis

The plot of $(\text{Na}_2\text{O}+\text{K}_2\text{O})/\text{CaO}$ versus $\text{Zr}+\text{Nb}+\text{Ce}+\text{Y}$ was adopted by Whalen *et al.* (1987) to distinguish the highly fractionated I/S-type granites, unfractionated I/S-type granites and A-type granites (Fig. 4A). In this figure the biotite granites (ph-II) fall in the highly fractionated felsic I-type or S-type granites field, while the leucogranites (ph-III) lie in the field of A-type granites. Moreover, to differentiate between the I-type and S-type granites, the ACF diagram after Chappell and White (1974) was used (Fig. 4B). In this figure, the biotite granites fall in the S-type granites except two samples fall in the I-type field. These results may suggest that these granites were derived from magma which come from deep crustal source, followed by a strong differentiation. On the Rb-Sr diagram (Condie, 1973) (Fig. 4C), the studied granites fall in the field of 20-30 km and >30 km thickness. This feature indicates that the intrusion level of

the biotite granites and leucogranites is similar relatively.

The discrimination between the different tectonic settings, under which the present granites are emplaced was made by Rb versus Y + Nb diagram of Pearce *et al.* (1984) (Fig. 4D). This discrimination diagram reveals that the studied biotite granites and leucogranites are related to within plate granites (WPG).

Fig. 5 can be adopted to reveal the compositional changes of basaltic liquid during fractionation (Barker *et al.*, 1986). It is clear from that figure, the present granites constitute a fractionated series from the biotite granites (ph-II) to leucogranites (ph-III). Biotite fractionation tends to increase silica and Na, hornblende tends to increase silica and alkali, while plagioclase fractionation tends to decrease the Ca contents of derivative liquids.

V. Discussion

It is clear that the examined biotite granites (ph-II, fluorite non-bearing) have the following characters: a) range from monzo-

Fig. 5. Ab+An-Q-Or diagram shows the end members of mantle (zone 1) and crustal (zone 2) origin, and of fractionation and/or mixing (zone 3). The directions of arrows show the composition of the liquid will be changed if biotite (bi), hornblende (hb) or plagioclase (pl) is removed (after Barker *et al.*, 1986).

granite to syenogranite composition, b) quartz is abundant, c) biotite is common (hornblende is absent), d) muscovite is recorded, e) zircon, titanite, apatite and topaz are accessories, f) peraluminous type (A/CNK : 1.3–1.6), agpaite index: 0.60–0.68, g) $CaO = 0.26$ – 0.81% ; $FeO_t = 0.51$ – 2.75% and $SiO_2 = 72$ – 76.8% , h) contain normative corundum, i) slightly greisenized.

According to the former mineralogical and geochemical characteristics, the biotite granites (ph-II) can be comparable with the S-type granite (Chappell and White, 1974; White and Chappell, 1977; 1983; Hine *et al.* 1978; Ishihara, 1981). This is agreement with the conclusion given by Hussein *et al.* (1982), Kabesh *et al.* (1987) and others on the younger granites from Eastern Desert of Egypt. The present granites may also correspond to the low-Ca granite (Turekian and Wedepohl, 1961) (Table 2). It is evident that the investigated granites represent a primitive magma derived by partial melting of metasedimentary source materials.

On the other hands, the leucogranites (ph-III, fluorite-bearing) can be comparable with

the A-type one (Table 2) as following: a) compositional range from syenogranites to alkali feldspar granite; b) felsic minerals include perthitic orthoclase ($\pm$ microcline); c) mafic minerals represent by interstitial biotite; d) accessory minerals comprise fluorite $\pm$ alkali amphibole, monazite and topaz; e) micrographic intergrowths very common; f) high in SiO_2 (77%), Na_2O (4.2%), K_2O (5%) and low in Al_2O_3 (11.8%), CaO (0.4%), MgO (0.04%); g) agpaite index: 0.97–1.36, Na_2O/K_2O ratio: 0.6–1.0; h) mostly near peralkaline; i) contain normative acmite: 0.7–3%; k) high Thornton and Tuttle DI (91–96); l) commonly associated in space and time with the alkaline biotite granites of phase-II.

On the basis of the foregoing mineralogical and geochemical characteristics, the studied leucogranites are most probably analogous to A-type granite (Loiselle and Wones, 1979; Collins *et al.*, 1982; Jackson *et al.*, 1984; Whalen *et al.*, 1987). This result is in agreement with the observations given by El-Gaby *et al.* (1988) and Noweir *et al.* (1990). Direct partial melting of middle to lower igneous rocks, possibly followed by crystal fractionation in the presence of fluorine rich volatiles to form the more evolved varieties, is perhaps the most likely model for the A-type granites (Collins *et al.*, 1982; Whalen *et al.*, 1987). The presence of fluorine and water together greatly increases element transport and redistribution particularly the alkalis (Pitcher, 1993). The A-type granites of the Arabian-Nubian Shield probably were generated by partial melting, under high temperatures, vapour-absent conditions of a crust from which granodiorite melts had previously been extracted (Drysdall *et al.*, 1984).

Since the studied leucogranites are hypersolvus, strongly alkaline to peralkaline, rich in fluorite, high in silica and alkalis and are indistinguishable from the A-type granites, these

granites have a geochemical indicative of their generation by partial melting of lower crustal materials followed by crystal fractionation of fluorine-rich I-type magma.

It is worth to mention that in the Arabian-Nubian Shield, the peraluminous granites are probably post-collisional suites (Sylvester, 1989). This post-collisional plutonism formed after about 610 Ma and continued until 520 Ma (Stern and Hedge, 1985). K-Ar ages of the present younger granites range between 609–568 Ma (Abdel-Karim and Arva-Sos, 1992).

VI. Conclusion

The field relation, petrographic and geochemical characteristics of the late Precambrian granites of Wadi Baba-Wadi Seih area in the SW-Sinai show that these rocks belong to the Egyptian Younger Granite suites. They intrude all the igneous and metamorphic rock-units. They comprise biotite granites and leucogranites and probably correspond to the phase-II and phase-III of the Egyptian Younger Granites. Phase-II cut by felsic dykes and phase-III. The biotite granites (phase-II) are fluorite non-bearing and range in composition from monzogranite to syenogranite. They are subsolvus to hypersolvus-type, fine to coarse grained, porphyritic varieties are also common. On the other hands, the leucogranites (phase-III) are fluorite-bearing and range from syenogranite and alkali feldspar granites. They are hypersolvus-type, medium to coarse grained; granophyric and porphyritic varieties are common, too.

Chemically, the biotite granites are alkaline, largely analogous to S-type and low-Ca granite. Meanwhile, the leucogranites are strongly alkaline and even peralkaline, mostly similar to the A-type granite. The biotite granites belong to post-collisional suite, meanwhile leucogranites is A-type and is typical Pan-African granites.

Generally these younger granites are peraluminous nature, potassic-sodic characters. They were derived from deep crustal materials by partial melting and most probably emplaced at moderate to shallow depth in an extensional regime. Regional ductile shear mechanism is the much more likely model for the development of the peraluminous magma in the extensional tectonic setting. Tectonomagmatic setting reveals an intraplate environment of the present granites.

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