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Petrogenesis of Granitoid Rocks of Wadi Baba Area; Southern Sinai-Egypt

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ABSTRACT. The granitoid rocks, in the Wadi Baba area have been classified according to the field relations, petrographical, and geochemical studies into syn-orogenic granitoids comprising, monzodiorite, tonalite, and granodiorite varieties and post-orogenic granites including the monzogranite; syanogranite and alkali-feldspar granite varieties. These granitoids intrude the neighbouring dioritic rocks with sharp contacts. Geochemical studies indicate that, the syn- and post-orogenic granitoids are not related to the dioritic rocks, but, are genetically related to each other. Both syn- and post-orogenic granitic intrusions are peraluminous and calc-alkaline, with the post-orogenic granites showing alkaline nature. The syn-orogenic granitoids have most of the features associated with the I-type granites and are formed over a subduction zone through partial melting of a mantle wedge with little crustal melt contribution. The post-orogenic granites have most of the features associated with S-type granites and are formed through partial melting of the crustal rocks with little contribution from the mantle (or by mobilization of older granitoids) under compression in the lower levels of a thickened crust.

Introduction

The granitoid rocks dealt with here occupy the area around Wadi Baba ($\approx 50\ km^2$) in West Southern Sinai, between latitudes 28° 57′, & 29° 0′N and longitudes 33° 15′ & 33° 23′00″E (Fig. 1). The Precambrian igneous and metamorphic rocks are well exposed in Southern Sinai and cover about 20.000 km^2 of this area including gneisses, sedimentary and igneous metamorphic rocks, calc-alkaline granitoid and volcanic rocks and alkaline intrusive and extrusive rocks. About 55% of the area is occupied by granitic rocks, which fall under two main groups of syn-Late-tectonic granites and post-tectonic granites of Egypt (El Ramly 1972). The age reported for some calc-alkaline syn-Late-tectonic granitoids of Southern Sinai evolved roughly at 600±50 Ma ago through the Pan African event (Shimron 1980). The post-tectonic granites are generally referred to as the younger granites (Akaad and Noweir 1980) and comprise several phases of granites. Their ages range between 480 and 640 Ma ago (Ragab *et al.* 1978).

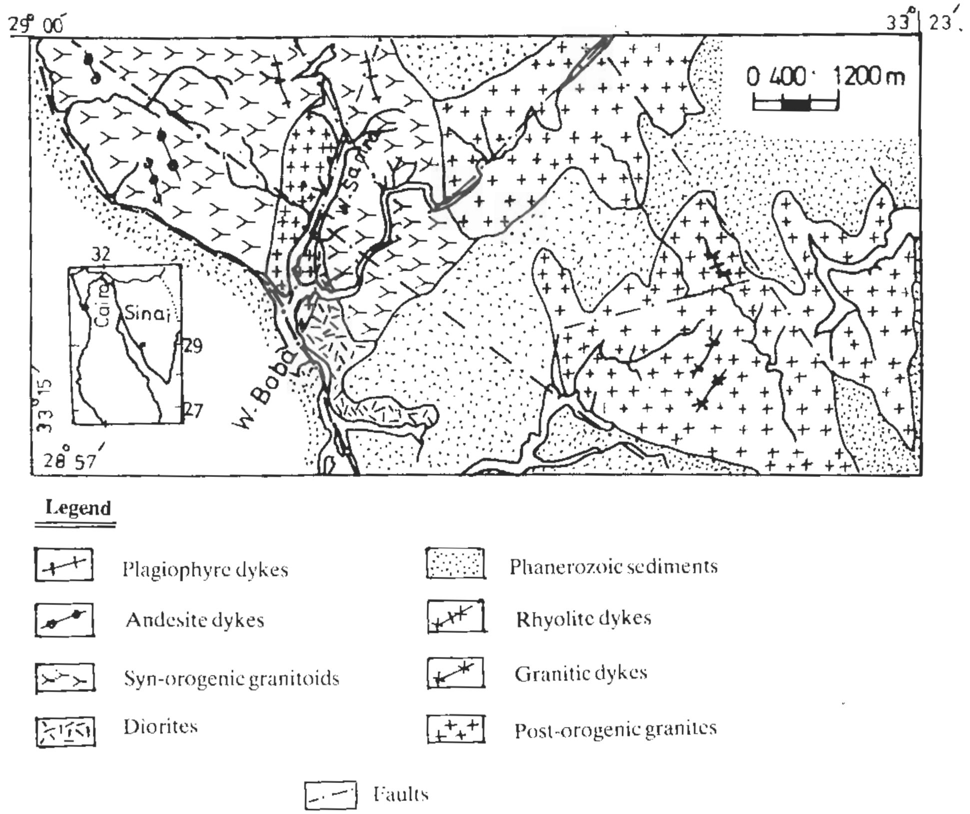

FIG. 1. Geological map of the Wadi Baba area.

The purpose of this paper is to study the petrogenesis of the different granitoid rocks of Wadi Baba area. To achieve this goal, mapping of the area on a scale of 1:40.000; and petrographical studies were done. XRF and Electron microprobe analysis techniques were used to determine the major and some trace elements for the representative granitoid rock varieties. The Data were used to shed light on their petrogenesis and geochemical characteristics.

Geologic Setting

Wadi Baba area is a part of the basement complex of Southern Sinai (Fig. 1). It is occupied by minor outcrops of schist, gneiss, and dioritic rocks intruded by huge masses of Syn-Late-tectonic granitoids which are parts of a large batholith including *monzodiorite*, tonalite, and granodiorite varieties with gradational contacts. Many xenoliths of the surrounding gneiss, and diortic rocks with numerous younger granite apophyses are observed through the endocontact aureole. The skialiths are represented mainly by hornblende and/biotite gneisses, diorites and quartz diorites with size ranging between few cm up to 1.5 m in diameter with sharp and gradational contacts. Some of them are completely assimilated by the host rocks giving rise to dark ghost relics. These rocks encompass the Syn-Late-orogenic calc-alkaline granites of El-Gaby and Habib (1982); Akaad and Noweir (1980); G_1 granites of Hussein *et al.* (1982) and pertain to cordilleran stage in the new classification of El-Gaby *et al.* (1988).

Post-orogenic granites are well developed in the study area forming mountain masses with high Peaks. The contacts of these granites with the neighbouring rocks are always sharp. Variations in the proportions of the ferromagnesian minerals and textures are common in these granites indicative of a multi-phase mode of formation; at least two main phases can be easily distinguished in the field with sharp contacts between them. They may correspond to the second and third phases of the Egyptian younger granites (Akaad and Noweir 1980) and belong to the post-tectonic alkaline and peralkaline granites of El-Gaby and Habib (1982) and to G_2-G_3 granites of Hussein *et al.* (1982). The relatively more basic or the second phase is pale pink to grey in colour and enriched in biotite, while the more acidic or the third phase is pink to red in colour and depleted in ferromagnesian minerals.

NE-SW trending dykes of dolerite, microdiorite, felsite and granite porphyry cut through the mentioned rocks. Few granite and porphyritic dolerite dykes are also observed trending NW-SE. The area is highly sheared and faulted along NW-SE; NE-SW and occasionally N-S directions (Fig. 1), in harmony with the general structure of Sinai peninsula and related to the Gulf of Suez, Gulf of Aqaba and Dead Sea rift systems respectively.

Petrographical Characteristics

The mineralogy was determined by optical microscopy and electron microprobe analysis using a Cambridge Instrument Geoscan fitted with link systems model 290-2KX energy-dispersive spectrometer and ZAF-4/FLS quantitative analysis software system. Modal data for the representative dioritic rocks; syn-orogenic granitoids and post-orogenic granites of Wadi Baba area are given in Table 1 and ploted in Fig. 2. The modes were determined from 1000 points on thin sections. The mineralogical studies and analysis (Tables 2 & 3) were done in the laboratories of the Geology Department, University of Manchester, Manchester, England.

The Dioritic Rocks

These rocks are represented by medium to coarse grained diorites and quartz diorites. Petrographically, they are made up of plagioclase$_{(An\ 30\text{-}45)}$ laths ranging in size from 0.28×0.17 to 1.38×0.35 mm. They are highly altered to kaolinite and sometimes show primary zonation. Biotite forms the main mafic component as tabular crystals and flakes up to 0.8 mm in length and highly altered to chlorite with anomal-

TABLE 1. Modal analyses of the studied granitic rocks.

Sp. No.	Quartz	K-feldspar	Plagio.	Biot. + chlor.	Hornb. + chlor.	Access.
1	13.99	0.40	68.37	7.90	9.33	–
2	13.53	0.60	67.50	8.17	9.50	0.7
3	12.03	0.50	68.00	8.97	8.60	1.1
4	23.65	5.47	60.58	5.65	3.30	1.35
5	24.65	6.55	58.02	4.35	5.00	1.43
6	11.05	19.80	59.79	5.30	2.06	2.00
7	20.80	17.60	56.80	2.40	2.50	0.30
8	25.66	5.54	57.10	5.27	3.90	2.53
9	31.00	13.00	52.00	2.50	1.5	–
10	25.60	20.50	50.10	2.90	0.9	–
11	28.70	48.20	20.50	1.00	0.10	1.50
12	31.00	30.00	35.00	3.00	0.50	0.50
13	36.90	53.50	8.40	0.11	–	0.99
14	31.03	49.47	12.55	5.11	0.46	1.38
15	38.05	30.11	28.00	3.31	–	0.53
16	41.60	48.58	7.56	1.70	–	0.56
17	44.50	50.46	3.50	0.34	–	1.20
18	37.80	54.40	7.40	1.10	0.10	0.90
19	35.2	56.30	6.50	1.30	–	0.70

Samples 1-3 diorites; 4-10 syn-orogenic granitoids; 11-19 post-orogenic granites.

ous grey and blue interference colours and liberation of iron oxides along cleavage planes. Hornblende occurs as subhedral green crystals, highly altered to biotite and chlorite indicating a low grade metamorphism. Quartz diorites exhibit hypidiomorphic, equigranular to porphyritic textures with interstitial quartz grains.

Syn-Orogenic Granitoids

Petrographically and mineralogically, these rocks can be classified according to Streckeisen (1976) (Fig. 2) into monzodiorite, tonalite and granodiorite varieties. Some of them show gneissose structure resulting in the strong foliation indicated by the parallel orientation of mica and hornblende crystals. These varieties are characterized by small variation in mineralogical composition. They are composed of quartz which ranges from 11 to 31 volume %; K-feldspar (perthites) from 5.47 to 20.5%; sodic plagioclase from 50.1 to 60.58% biotite from 2 to 5.6% and hornblende from 1.5 to 5%. All these minerals usually occur in the same rock in various amounts with accessory minerals including epidote, chlorite, apatite, zircon and iron oxides. Undeformed rock varieties show coarse grained, hypidiomorphic, equigranular to inequigranular textures in which plagioclase and perthites form large phenocrysts. Sheared and deformed granitoids reveal fine grained textures.

Quartz is a very abundant mineral in these granitoids and sometimes forms more than 31 volume per cent of the rock. It is present mostly as anhedral crystals with irregular interlocked boundaries. Quartz is characterized by undulose extinction in some sheared rocks. In some granodiorites simultaneous crystallization of quartz and feldspars produced graphic textures.

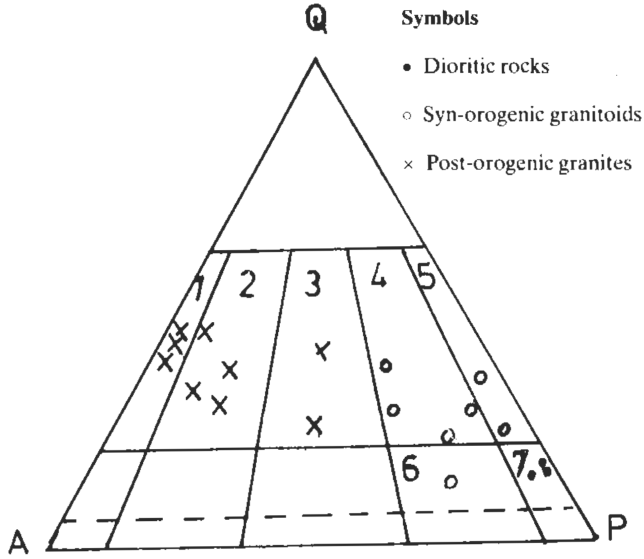

FIG. 2. Modal Q-A-P triangular diagram for the classification of the granitic intrusions in the Wadi Baba area (after Streckeisen 1976). The fields 1 = alkali-feldspar granite; 2 = syenogranite; 3 = Monzogranite; 4 = Granodiorite; 5 = Tonalite; 6 = Monzodiorite; 7 = Quartz diorite-diorite.

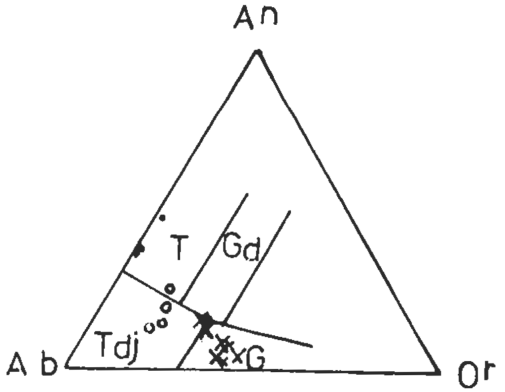

FIG. 3. Normative Ab-An-Or triangular diagram of the Wadi Baba granitic rocks. The fields of rock types are after O'Connor (1965). (Symbols as in Fig. 2).

Sodic plagioclase occurs as a major mineral in both syn- and post-orogenic granitoids. It is more abundant in the syn-orogenic granitoid varieties, ranging in composition from oligoclase to andesine with An contents ranging from 26 to 39 mol% (Table 2). On the other hand the post-orogenic granites contain more sodic plagioclase of albite composition with An contents, ranging from 1 to 5 mol%.

Plagioclase crystals in the syn-orogenic granitoids occur as cloudy subhedral polygonal grains; but due to recrystallization, they form irregular crystals in some var-

TABLE 2. Electron microprobe analyses of plagioclase in the syn-orogenic granitoids and post-orogenic granites.

	Syn-orogenic granitoids			Post-orogenic granites			
	16*			15		14	
	1 +	2	3	1	2	1	2
SiO_2	63.73	58.48	63.16	68.83	70.03	68.47	69.74
Al_2O_3	23.44	25.42	23.09	19.79	20.09	18.85	18.87
CaO	5.58	8.04	5.27	1.05	0.54	0.04	0.01
Na_2O	8.31	6.75	8.06	10.62	11.26	10.68	10.16
K_2O	0.31	0.30	0.38	0.28	0.20	0.00	0.05
	101.13	99.00	99.95	100.58	102.13	98.04	98.83
	0 = 8						
Si	2.776	2.632	2.786	2.983	2.989	3.023	3.053
Al	1.204	1.349	1.200	1.011	1.011	0.981	0.974
Ca	0.261	0.388	0.249	0.049	0.025	0.002	0.000
Na	0.702	0.589	0.689	0.893	0.931	0.914	0.862
K	0.017	0.017	0.021	0.015	0.011	0.000	0.003
	4.960	4.975	4.945	4.951	4.967	4.920	4.892
Ca	26.630	39.000	25.960	5.120	2.585	0.220	0.000
Na	71.630	59.100	71.850	93.320	96.277	99.780	99.650
K	1.700	1.700	2.200	1.570	1.138	0.000	0.350

* = Sample No. + = Analysis No.

ieties. Inclusions of apatite and iron oxides with smaller plagioclase crystals are common in the plagioclase megacrysts, especially at their core. Unzoned plagioclase megacrysts are commonly fresh and occasionally occur in more than one generation with different orientations, sometimes replacing each other.

Alkali feldspars are present as essential minerals in the studied granitoid rocks and they are much more common in the post-orogenic granites but less common or scarce in the syn-orogenic granitoids. They are represented by perthites. The perthites in the syn-orogenic granitoids reveal lower potassium content (Or 45.6-88.2 mol%) than that in post-orogenic granites (Or 94.9-96.5 mol%) (Table 3).

The perthite veinlets are not equally distributed throughout the K-feldspar crystals, suggesting a replacement origin for these perthites. Sometimes they partly or completely enclose and corrode the early formed crystals.

Biotite and hornblende are the only ferromagnesian minerals in these rocks. Sometimes biotite shows strong pleochroic haloes especially in the granodiorites. The biotite with hornblende often show preferred orientation which results in gneissose texture. Moreover the biotites are commonly altered into green pleochroic chlorite. Alteration usually takes place along the cleavage of crystals.

Post-orogenic Granites

Petrographically and mineralogically these rocks can be classified according to

TABLE 3. Electron microprobe analyses of potash feldspars in the syn-orogenic granitoids and post-orogenic granites.

Sample No.	Syn-orogenic granitoids			Post-orogenic granites	
	1	2	3	4	5
SiO_2	67.80	66.73	66.57	65.02	66.59
Al_2O_3	18.13	18.19	18.51	18.15	18.34
CaO	0.05	0.00	0.00	0.01	0.01
Na_2O	6.15	2.00	1.31	0.46	0.38
K_2O	7.88	13.02	14.99	13.24	16.19
	100.00	99.95	101.38	96.85	101.51
O	22	8	8	24	8
Si	8.333	3.030	3.000	9.090	3.014
Al	2.627	0.974	0.983	2.990	0.978
Ca	0.007	0.000	0.000	0.001	0.001
Na	1.466	0.176	0.115	0.124	0.033
K	1.236	0.756	0.862	2.362	0.934
	13.669	4.936	4.96	14.567	4.96
Ca	0.258	0.00	0.00	0.04	0.11
Na	54.115	18.88	11.77	4.99	3.41
K	45.626	81.12	88.22	94.97	96.49

Streckeisen (1976) (Fig. 2) to monzogranites, syenogranites and alkali feldspar granites. These rock varieties are coarse grained, equigranular to inequigranular textures in which perthite crystals form the large phenocrysts. They show small variation in their mineralogical composition including, quartz, which ranges from 31 to 44 volume % K-feldspars from 30 to 56.3% ; sodic plagioclase from 3.5 to 35% ; biotite from 0.11 to 5.11% of the granitic rock. Pegmatitic varieties are also observed in some zoned granites and are composed of quartz and feldspar minerals. Sheared and tectonized varieties are also recorded. Alkali feldspar granites are made up mainly of subhedral to anhedral crystals of flame and patch perthites; while the syenogranites have more K-feldspars and less sodic plagioclase than those recorded in the monzogranites.

Perthites in the granitic varieties form large phenocrysts set in a coarse matrix of quartz, perthite, sodic plagioclase together with flakes of biotite resulting in porphyritic texture. The perthite phenocrysts often include numerous small stringers and grains of rounded to irregular quartz crystals, small euhedral laths of plagioclase, small flakes of biotite and minute prismatic apatite crystals resulting in poikilitic texture. Very often curved and vermicular quartz inclusions are intergrown with the plagioclase crystals resulting in myrmekitic texture. These usually penetrate the perthite megacrysts in some granitic rocks. The plagioclase in these rocks are strongly zoned.

Deformation of the Granitic Rocks

Occasionally the granitic rocks, either the syn-orogenic or post-orogenic types

TABLE 5. Trace element values (ppm) of plutonic rocks of Wadi Baba area.

S. No. Element	Dioritic rocks			Average	Syn-orogenic granitoids				Average	El-Gaby (1976)
	1	2	3		2	17	4	18		
Nb	0.0	21.0	3.0	8.0	8.0	4.0	9.0	12.0	8.3	2
Zr	77.0	502.0	166.0	248.3	220.0	193.0	178.0	502.0	273.3	155
Y	13.0	76.0	27.0	38.7	34.0	25.0	38.0	29.0	31.5	22
Sr	1551.0	53.0	1015.0	873.0	299.0	585.0	300.0	311.0	373.8	287
Rb	32.0	17.0	28.0	25.7	103.0	73.0	93.0	58.0	81.8	51
Zn	98.0	14.0	83.0	65.0	100.0	75.0	84.0	103.0	90.5	n.d.
Cu	0.0	5.0	1.0	2.0	0.0	4.0	5.0	2.0	2.8	15.2
Ni	103.0	11.0	41.0	51.7	71.0	44.0	55.0	15.0	46.3	9.4
Cr	155.0	3.0	73.0	77.0	114.0	139.0	93.0	28.0	93.5	26.9
Ce	34.0	235.0	68.0	112.3	79.0	78.0	83.0	195.0	108.8	n.d.
Nd	0.0	59.0	14.0	24.3	12.0	38.0	5.0	183.0	59.5	n.d.
V	269.0	19.0	167.0	151.7	142.0	98.0	113.0	86.0	109.8	69.3
La	67.0	96.0	66.0	76.3	79.0	78.0	80.0	141.0	94.5	12.4
Ti	5157.0	998.0	5133.0	3762.0	4555.0	3291.0	3594.0	3928.0	3842.0	n.d.
Ba	342.0	61.0		256.7	556.0	624.0	542.0	885.0	651.8	568
Sc	24.0	0.0		89.3	301.0	5.0	14.0	8.0	82.0	8.4

TABLE 5. (continued)

S. No. Element	Post-orogenic granites									Average	El-Gaby (1975)
	16	5	6	8	10	11	13	14	15		
Nb	9.0	0	25	22	25	16	18	8	9	14.7	4.4
Zr	241.0	69	173	116	103	224	95	261	182	162.7	226
Y	26.0	10	149	101	103	69	98	35	36	69.7	48
Sr	383.0	588	16	19	11	74	18	87	56	96.6	111
Rb	89	77	428	410	378	233	330	152	150	249.7	115
Zn	78	12	25	22	34	57	31	38	38	37.2	n.d.
Cu	0	0	0	1	0	0	0	0	0	0.1	8.5
Ni	18	9	32	22	21	12	18	14	13	17.7	4.6
Cr	53	2	6	23	0	6	3	2	0	10.6	10.1
Ce	118	9	108	34	79	126	79	131	130	94.4	n.d.
Nd	0	6	38	27	46	85	34	42	43	35.7	n.d.
V	45	16	1	10	10	20	7	36	23	18.7	8.1
La	92	77	92	76	82	135	92	77	97	91.1	36.7
Ti	2201	205	301	218	223	1214	255	1056	589	706.9	n.d.
Ba	651	813	159	59	85	297	106	618	279	340.8	528
Sc	11	0	0	0	0	0	2	2	0	1.7	2.8

diagram (Fig. 3); where their rock samples plot in the field of granites.

Both syn- and post-orogenic granitoids are per-aluminous with $Al_2O_3 > CaO + Na_2O + K_2O$ (Shand 1951), have a calc-alkaline trend on the AFM diagram (Fig. 9) and the plots are nearly perpendicular to the F-M side line of the diagram; similar in these to the granitic rocks formed under environment of compression as defined by Petro *et al.* (1979).

Figure 4 is a plot of the granitic rocks of the Wadi Baba area on the Wright's (1969) alkalinity diagram. This figure illustrates the calc-alkaline character of the dioritic rocks and syn-orogenic granitoids, while the post-orogenic granites show an alkaline character. This is in agreement with observations reported for the older and younger granites in the Arabian Nubian Shield (Gass 1977, Nassif and Gass 1980, Hussein *et al.* 1982, Hassan 1987). Further information may be drawn from the K-Na-Ca triangle (Fig. 5) leading to distinction between the classic calc-alkaline differentiation series and the trondhjemitic series (Barker and Arth 1976). On this figure, the studied granitic rocks follow a classic calc-alkaline trend and show no affinity to the trondhjemitic differentiation mode.

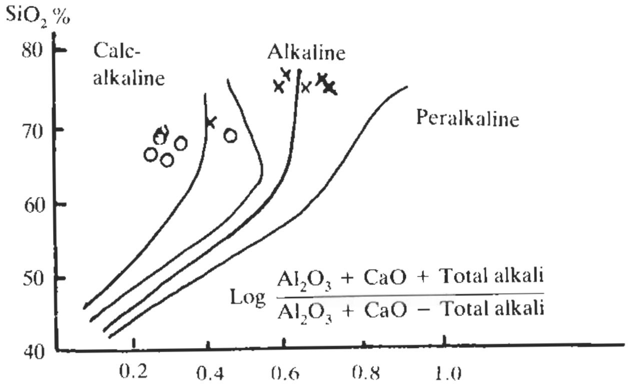

FIG. 4. Alkalinity variation diagram of Wright (1969) for the Wadi Baba granitic rocks. (Symbols as in Fig. 2).

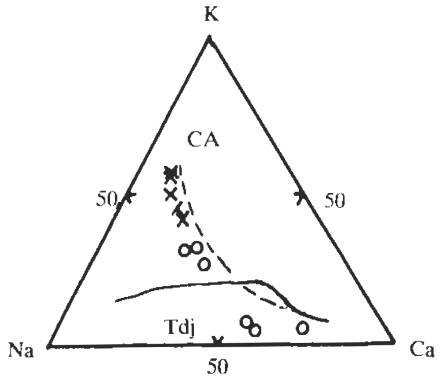

FIG. 5. Diagram (Barker and Arth 1976) showing the trondhjemitic and calc-alkaline character of the studied granitoids. Tdj = trendhjemitic trend, and CA = classic calc-alkaline trend (Symbols as in Fig. 2).

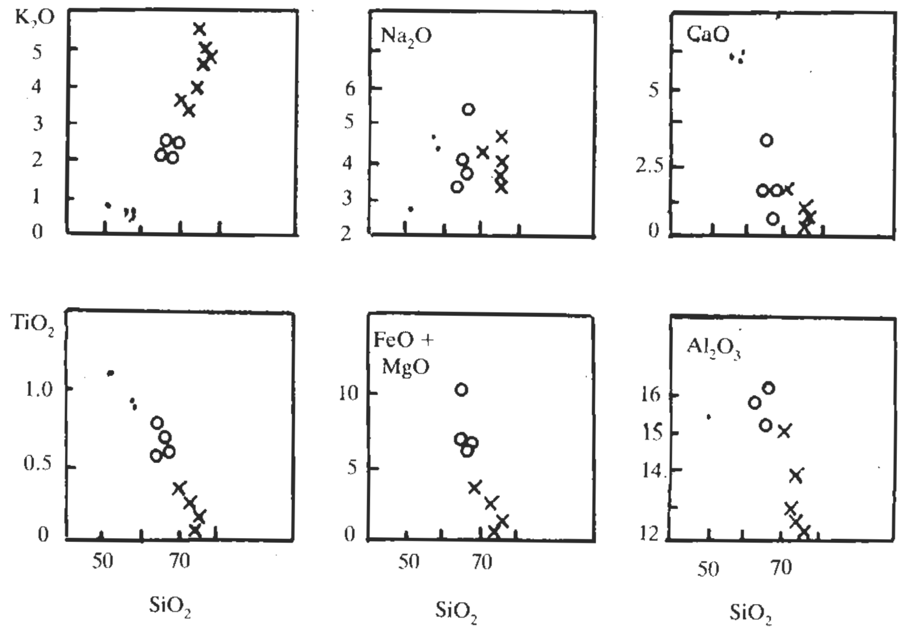

FIG. 6. SiO_2 versus Major oxides diagram for the Wadi Baba intrusion rocks. (Symbols as in Fig. 2).

Figure 6 shows a Harker plot. The dioritic rocks exhibit a limited range of differentiation trend ($52.6 \leq SiO_2 \geq 58.6$) and have formed a separate field, but the granitoid series show differentiation trends of wide ranges ($64.6 \leq SiO_2 \geq 77.65$) and form a continuous separate field. The oxide contents decrease when SiO_2 increases except that of K_2O points which are positively correlated with SiO_2, while Na_2O plots show a scatter manner. Through the syn- and post-orogenic granitoids formation, the magmatic differentiation operates according to a single general mechanism. The fact that, the point distribution may be statistically described by a single straight line indicates that the fractionated mineral assemblage remained constant in composition through the process of differentiation.

Figure 7 is a plot of the Rb, Sr and Ba proportions of Wadi Baba granitoids in a ternary diagram with two fields indicating the positions of both older and younger granitic rocks of Egypt after El-Gaby (1975). The syn-orogenic granitoids of Baba area fall in the field of older granites of Egypt, and the post-orogenic granites studied fall in the both fields of younger and older granitoids of Egypt and are very rich in Rb, whereas some of them lie near to the Rb corner, indicative of the heterogeneous nature of the post-orogenic granites under consideration. This may be supported by Figure 8; where the syn-orogenic granitoids plot in the field of subduction related or the calc-alkaline batholiths and the post-orogenic granites plot in the field of crustal-related or alkali granites as defined by Rogers ad Greenberg (1981).

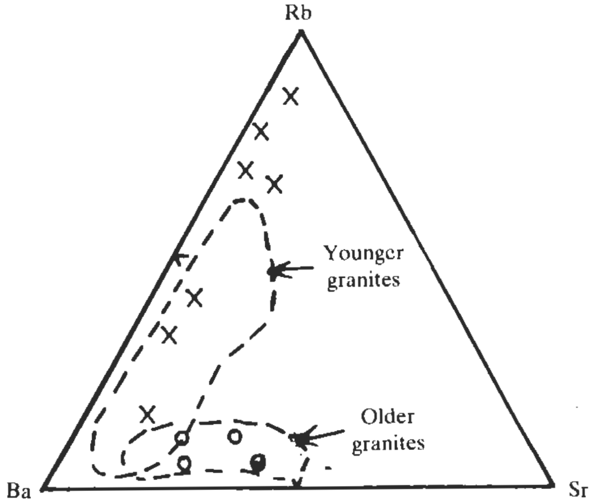

FIG. 7. Rb-Ba-Sr proportions for the investigated granitic rocks. The fields are after El-Gaby (1975). (Symbols as in Fig. 2).

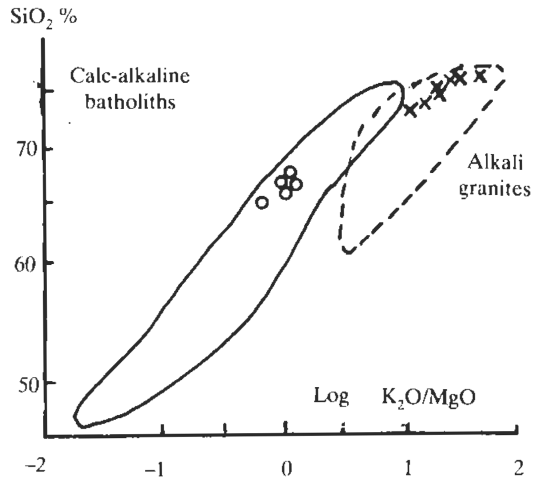

FIG. 8. SiO_2 versus log K_2O/MgO plot of the studied granitic rocks. The fields are after Rogers and Greenberg (1981). (Symbols as in Fig. 2).

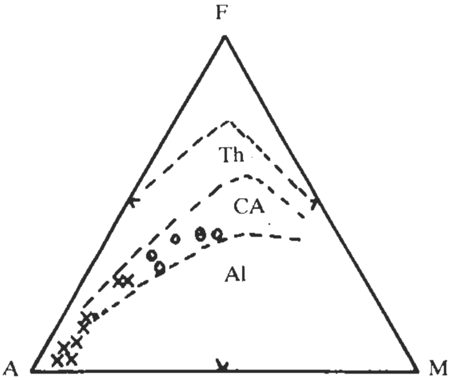

FIG. 9. AFM (Kuno 1968) diagram shows the referred rocks belong to a calc-alkaline trend. Th = tholeiitic field, CA = calc-alkaline field and Al = alkaline field. (Symbols as in Fig. 2).

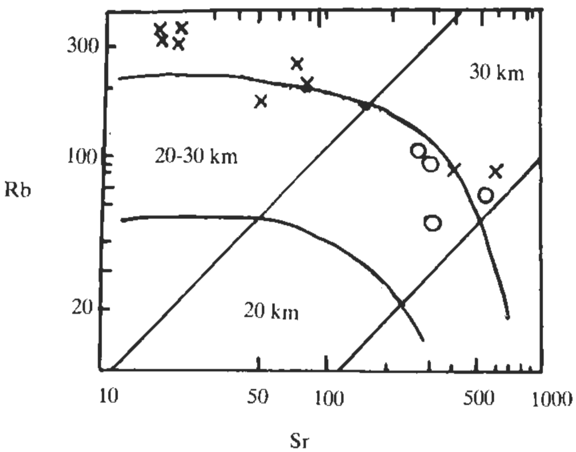

FIG. 10. Rb versus Sr diagram of the studied rocks. The fields are after Condie (1973). (Symbols as in Fig. 2).

The conclusions reached from the foregoing discussion become clear, however, when plotting Rb versus Sr of the studied granitoids in Fig. (10), with the different field boundaries after Condie (1973). Both syn- and post-orogenic granites fall in the field of 20-30 km and 30 km thicknesses of the crust, indicating that they were formed at the lower levels of the earth's crust. The diagram of Pearce *et al.* (1984) (Fig. 11) for the granitic classification according to the tectonic setting was adopted for the granitoids under consideration. This discrimination diagram reveals that, the syn- and post-orogenic granitic rocks fall within or near to the central Chile field (continental/calc-alkaline environment) and within plate granite field.

Figure 12 shows that, the K/Rb ratios of the Baba granitoids are widely dispersed between 100 and 500 with tendency to group around 250. In spite of this they plot around the "main trend" defined by Shaw (1968) for continental igneous rocks.

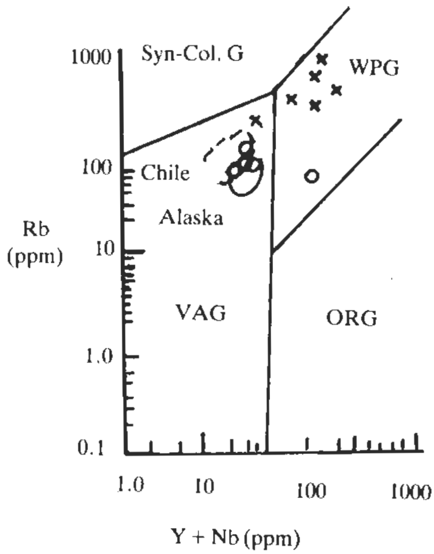

FIG. 11. Rb-(Y + Nb) discrimination diagram for syncollision granites (syn-COLG); volcanic arc granites (VAG); within plate granites (WPG), and Ocean ridge granites (ORG), after Pearce *et al.* 1984. (Symbols as in Fig. 2).

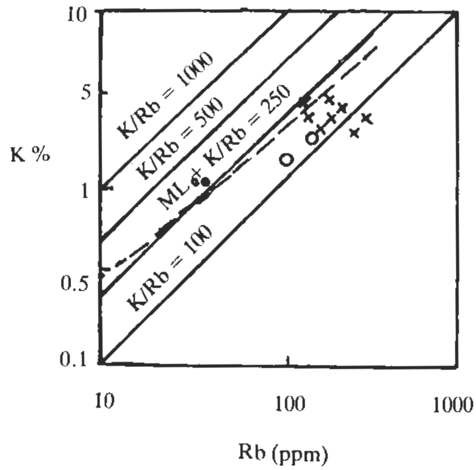

FIG. 12. K versus Rb variation diagram for the studied granitoid rocks. MT = main trend defined by Shaw (1968) for continental igneous rocks. (Symbols as in Fig. 2).

The syn-orogenic granitoids studied have most of the features associated with I-type granites as quoted by Hussein *et al.* (1982) as they:

1) Form a large intrusion.
2) Range in composition from monzodiorites to granodiorites.
3) Hornblende is the main ferromagnesian mineral in the mafic phases (monzodiorites) and the more felsic phases contain biotite and hornblende muscovite is absent.
4) Sphene, zircon, iron oxide and apatite are common accessory minerals.
5) SiO_2 ranges from 64.64% to 67.93%.
6) Mol. $Al_2O_3 / Na_2O + K_2O + CaO$ ranges from 1.7 to 2.06.
7) Na_2O ranges from 3.74% to 5.40%.
8) Rb/Sr ratio ranges from 0.12 to 0.34.

These rocks have low Rb/Sr ratios in comparison with the younger granites. Gast (1965) and Heier (1973) have shown that low Rb/Sr ratio is a characteristic feature for rocks from the lower crust or upper mantle. Based on these characteristics the syn-orogenic granitoids of Baba area are considered to have been formed over a subduction zone through partial melting of parental mantle-derived materials with little crustal melt contribution.

The post-orogenic granites studied are similar to the S-type granites of Chappell and White (1974), as quoted by Hussein *et al.* 1982, as they:

1) Exhibit a limited range of composition (monzogranites, syeno-granites and alkali feldspar granites).
2) SiO_2 ranges from 70.38% to 77.79%.
3) Mol. $Al_2O_3 / Na_2O + K_2O + CaO$ ranges from 1.32 to 1.58.
4) Biotite is the main ferromagnesian mineral.
5) Iron oxide, sphene, apatite and zircon are the main accessory minerals.
6) Rb/Sr ratios are highly moderate (2.58) in comparison with the syn-orogenic type.

Accordingly, these post-orogenic granites are considered to have been formed through partial melting of crustal rocks with little contribution from the mantle.

Figure 13 shows the normative composition of the studied rocks in the system Q-Ab-Or (Tuttle and Bowen 1958), the samples of syn- and post-orogenic granites plot around the minimum melting curve with some overlap between them. Both granitic types plot close to low and moderate water vapour pressure curve, suggesting that they were formed at moderate levels in the crust, and that in agreement with the ideas of El-Gaby (1975) and Zaghloul *et al.* (1976). According to them, these granites are intruded as palingenic magma and the early phases of these magmas were formed at higher water-vapour pressures. Accordingly the Baba post-orogenic granites are considered as one of the moderate level phases of the Egyptian younger granites.

Conclusion

The granitoid rocks of Wadi Baba area are represented by the syn-orogenic granitoids and post-orogenic granites which form the main plutonic rocks accom-

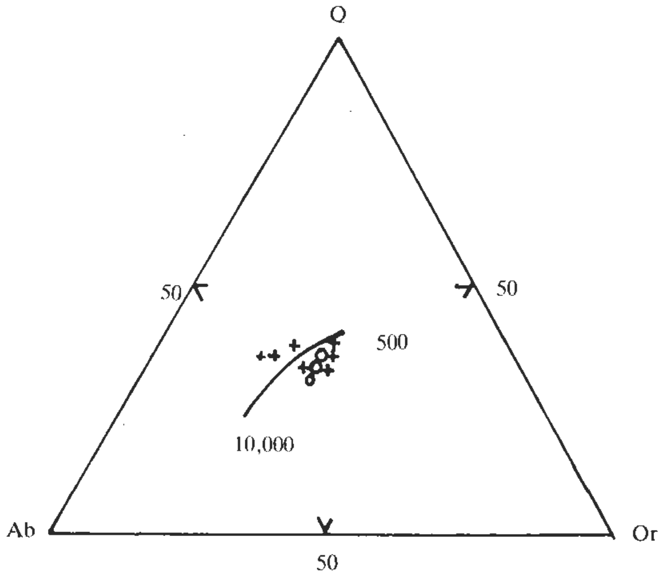

FIG. 13. Normative Q-Or-Ab proportions for the investigated granitic rocks. The solid line represents the variation in position of the minimum melting points in the granite system at water vapour pressures from 500 to 10,000 bars (after Tuttle and Bowen 1958). (Symbols as in Fig. 2).

panying some dioritic rocks in the studied area. The syn- and post-orogenic granitoids are not related to the dioritic rocks, and that is in harmony with the idea of El-Aref *et al.* (1988), but they are genetically related to each other. The dioritic rocks have calc-alkaline character, enriched in ferromagnesian elements and Al_2O_3 and are relatively high in CaO relative to Na_2O + K_2O due to their higher content of hornblende indicating that they were formed from basic magmas having relatively high water content (> 3-2 wt.%) in the melt (Holloway and Sykes 1979). The syn-orogenic granitoids plot in the monzodiorite, tonalite and granodiorite fields of Streckeisen diagram, and have biotite and hornblende as their ferromagnesian minerals. They are enriched in Al_2O_3, Fe_2O_3, MgO, TiO_2, MnO, P_2O_5, Nb, Zr, Ni, Cr, V. La Ba and Sc, and depleted in SiO_2, CaO and Cu relative to the syn-orogenic granitoids of the Eastern Desert of Egypt reported by El-Gaby (1975), and they show most of the features of the I-type granites of Chappell and White (1974). The post-orogenic granites plot in the monzogranite, syenogranite and alkali-feldspar granite fields of Streckeisen diagram and have biotite as their ferromagnesian mineral. They are enriched in Fe_2O_3, MnO, Nb, Y, Rb, Ni, V and La, and depleted in Na_2O and TiO_2 relative to the post-orogenic granites of the Eastern Desert of Egypt of El-Gaby (1975); and they are related to the S-type granites of Chappell and White (1974). Both syn- and post-orogenic granitoids are peraluminous and clac-alkaline, with the post-orogenic granites showing alkaline nature. The syn-orogenic granitoids were formed over a subduction zone, through partial melting of parental mantle-derived materials with little crustal rocks. The post-orogenic granites are formed through partial melting of crustal rocks with little contribution from the mantle (or by re-mobilization of the older granitoids) under environment of compression, probably through collision (suturing) at plate boundaries. This is in agreement with the conclusions presented by Hussein *et al.* (1982).

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نشـــأة الصخـــور الجرانيتيـــة بمنطقـــة وادي بعـــبع بجنوب سيناء ، مصـــر

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المستخلص . يختص هذا البحث بنشـأة الصخـور الجـرانيتية بمنـطقـة وادي بعبـع وخصائصها الحقلية والجيوكيميائية . تم تقسيم تلك الصخور بناء على العلاقات الحقلية والدراسات الصخرية والجيوكيميائية إلى الصخور الجرانيتية المصاحبة للحركة البانية للجبال وتشتمـل على المونزوديوريت والتوناليت والجرانوديوريت . والصخور الجرانيتية اللاحقة للحـركـة البـانية للجبـال وتشتمـل على المونزوجرانيت والسيانوجرانيت والألكلي فلسبار جرانيت . وهذه الجرانيتات وجد أنها متداخلة في صخور الديوريت المجاورة . وقد أظهرت الدراسات الجيوكيميائية أن كلاً من الصخور الجرانيتية المصاحبة واللاحقة للحركات البانية للجبال بالمنطقة ذات علاقة وثيقة ببعضها وينتمى إلى الجرانيتات الغنية بالألومنيوم والكلسى - قلوية في حين أن الجـرانيـت الـلاحق يظهـر الخصائص القلوية . الصخور الجرانيتية المصاحبة للحركات البانية لها معظم الخصائص الموجودة بنوع الجرانيت ذو الأصل الناري (I-type) ، وقـد تكـونت فوق النـطاق الهابط خلال الانصهار الجزئي لصخور الستار العلوي وقليلاً من صخـور القشرة الأرضية ، والصخـور الجـرانيتية الـلاحقة لها معظم خصائص الجرانيت ذو الأصل الرسوبي (S-type) وقد تكون من الانصهار الجزئي لصخور القشرة الأرضية مع قليل من صهير الستار العلوي أو تكون من انصهار الصخور الجرانيتية الأقدم وذلك تحت ضغط متوسط في أعماق بعيدة من القشرة الأرضية .