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FLUORITE GRANITES FROM SOUTHWESTERN SINAI, EGYPT WITH PARTICULAR REFERENCE TO THE A-TYPE

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ABSTRACT

The petrographical and geochemical characteristics of some fluorite granites form Wadi bábá area in the southwestern Sinai of Egypt are presented and compared with the A-type suites. The studied granites belong to the phase-III of Egyptian Younger Granites and are associated, in space and time, with a comagnetic phase-II.

Petrochemically, the fluorite granites possess a peralkaline and sodic-potassic character, with high silica, alkalies and normative acmite. They are magmatic origin, typically A-type granites and are formed through partial melting of the upper mantle to lower crustal materials followed by crystal fractionation of a fluorine-rich extracted magma in a probable extensional environment. They are, moreover, crystallized under moderate temperature and pressure (1-6 Kb.) and are enplaced as moderate to shallow intrusives in the continental crust.

INTRODUCTION

Granite rocks may be subdivided into those generated during evolution of fold belts (orogenic) and those associated with uplift and major strike-slipe faulting (anorogenic). Anorogenic A-type granites, first definited by LOISELLE and WONES (1979) and COLLINS *et al.* (1982) and discussed by HARRIS and MARRINER (1980) and WHALEN *et al.* (1987). However, A-type suites may represent the final plutonic event in both orogenic belts and rift-related anorogenic magmatism or shield areas, emplacing in a wide range age from Proterozoic to Recent (WHALEN *et al.* 1987). A-type granites are, moreover, derived from recycled, dehydrated continental crust which extracted from igneous protoliths (I-type) or formed from highly contrasting mafic-sialic association of two mixing magmas (WHALEN and CURRIE 1984).

A-Type granites have been discussed in the Arabian Shield by JACKSON *et al.* (1984) and other. In the Egyptian Shield, these granites have been treated by several authors. A-type granites are considerated as latest phase intrusives in the main younger granites (RAGAB 1987) or as post-kinematic shallow cauldron complexes corresponding to G-3 granites (EL-GABY *et al.* 1988). These granite plutons, in Sinai, are grouped together with alkaline monzonite and rhyolite as Katherina Province (BENTOR 1985). In the southwestern district of Sinai, under study, the younger granites were emplaced during late Pan-African event between 609 and 568 Ma and are chemically corresponded the phase II and III (ABDEL-KARIM and ÁRVA-SÓS in press) of the Egyptian Younger Granites. EL-AREF *et al.* (1988) described some plutons of the younger granites of the SW-Sinai as G-2 granite. Moreover, a good relationship between fluorine and latest pulses of the

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Egyptian younger granites have been recently discussed by BENTOR (1986), and RAGAB (1987).

GEOLOGIC SETTING

Younger granites of Wadi Bábá area (including fluorite granites) consist of several large irregular shape complexes of batholithic dimensions, dissected by Wadies: Samra, Bábá, Lahian, Sahu, Budra, Shellal, Igna, Sidri and Atima (*Fig. 1*). The plutons exhibit extremely sharp contact with country rocks including schists, gneisses, migmatites, metagabbro-diorite and mafic dyke-swarms and, in places, by post Cambrian sediments. The granite plutons are collectively composed of dominant monzo- and syenogranite and minor alkali feldspar granite and quartz syenite. The granite rocks are medium to coarse grained, occasionally porphyritic and granophyric and show grayish pink to red colour. Field relation and chemistry indicate that these plutons are corresponded to the phase II and III of the Egyptian Younger Granites. Phase-II is usually crosscut by a number of felsic dykes compared with phase-III. The fluorite granites most probably equivalent to phase-III which merge imperceptibly into a comagmatic phase-II (ABDEL-KARIM in press) with rather indefinite contacts.

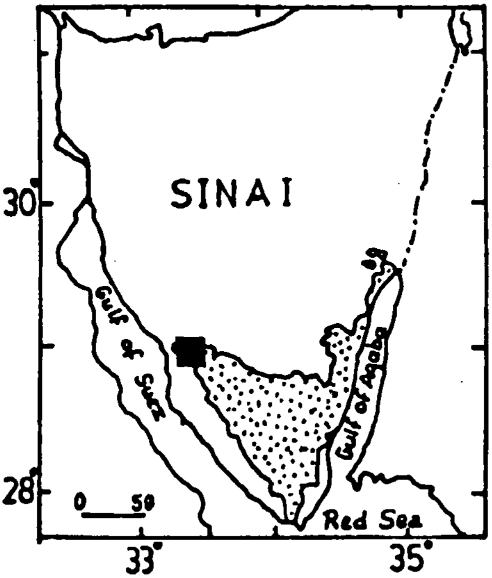

Fig. 1. Location map of the examined fluorite granites.

PETROGRAPHY

The modal analyses of seven samples, collected from examined plutons are shown in Table 1 and plotted in the classification diagram of STRECKELSEN (1978). It is evident that most of the studied rocks are alkali feldspar granite composition.

TABLE 1.

Modal analyses of fluorite granites from Wadi Bábá area, SW-Sinai.

Rock-type	Sample No.	Alk. feld.	Q.	Plag.	Biot.	Amph.	Fluo.	Acc.
Medium to coarse grained granites	1	52.7	32.5	14.3	0.5	—	0.5	0.3
	2	48.8	42.0	6.5	0.1	1.6	—	1.0
	3	50.5	41.1	4.3	1.5	0.4	0.8	0.5
Porphyritic granites	4	42.2	43.3	10.6	2.5	—	1.5	1.2
	5	45.3	38.7	11.0	1.3	1.5	0.7	2.1
Granophyric granites	6	41.3	41.6	14.4	2.7	0.6	0.2	1.7
	7	44	38.3	12.8	1.5	0.5	0.6	1.3

Petrographically, the examined rocks are mostly perthite granites (hypersolvus). They are medium to coarse grained hypodiomorphic-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 phase.

The alkali feldspar represents patchy, flamy and stringly shaped orthoclase perthite with minor microline perthite. Biotite occurs as brown interstitial flakes. Alkali amphibole forms bluish green anhedral crystal relics. Fluorite occurs as yellowish, highly relief and isotropic crystal aggregates, mostly associated with biotite. In the porphyritic varieties, megacrysts of perthitic alkali feldspar (25.5—26.6 %), quartz (8.5—9.4 %) and plagioclase (4.5—4.8 %) are embedded in a micrograntic groundmass consisting of quartz (30.2—33.8 %), alkali feldspar (16.6—18.7 %), plagioclase (5.8—6.5 %), biotite (2.5—1.3 %), alkali amphibole (0.5—0.8 %), fluorite (1.1—1.4 %) and iron oxide. Granophyric granites consist of small amount of megacrysts (10—13.6 %) of alkali feldspar, quartz and plagioclase embedded in a fine-grained graphic and granophyric groundmass (85.5—90 %) composed of the same minerals of porphyritic one.

PETROCHEMISTRY

The results of 9 newly analyzed samples from fluorite granites of the SW-Sinai are compared with the average values of the A-type granites of COLLINS *et al.* (1982) (Table 2). The analyses of major elements were carried out in the laboratories of the Hungarian Geological Survey and Eötvös University in Budapest, using standard wet chemical techniques.

Major elements: The studied granite rocks contain, on average, 76 % SiO_2, 11 % Al_2O_3, 1.2 % FeO_t, 0.1 % MgO and 0.9% CaO (Table 2). Consequently, the average chemical analyses of the plutons are well comparable with that of the A-type granites of COLLINS *et al.* (1982), with slightly higher CaO, MgO and Na_2O contents. The compositional ranges of the main normative minerals are: Q (29—37 %), Or (26—35 %), Ab (18—36 %) with minor Ac (0.7—3 %) and Ns (0.2—2 %). THORNTON and TUTTLE DI of the rocks ranges from 88 to 96.

The examined granites are plotted on the alkalinity variation diagram of WRIGHT (1966) (*Fig.* 2). It is clear that the present granit rocks exhibit a strong alkaline to peralkaline nature which is reflected by the occurrence of normative acmite and Na-metasilicate. Morover, plot of these rocks in the Ca + Mg + Fe_t -

Na + K - Al diagram after BOWDEN and TURNER, (1974) (*Fig. 3*) suggests again the peralkaline nature of these granites. However, the chemical analyses (Table 2) confirm the slightly peraluminous to metaluminous affinity of the studied granites (A/CNK ratio: 0.91—1.23).

TABLE 2.

Major element compositions of fluorite granites from Wadi Bábá area, SW-Sinai

Oxides	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_2O_3	11.00	11.43	10.13	10.75	12.10	11.70	11.90	10.75	10.38	11.13	11.79
Fe_2O_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_2O	3.96	4.40	3.56	3.82	4.67	4.45	4.85	3.84	4.10	4.18	3.08
K_2O	5.33	4.37	6.03	5.62	4.72	4.99	4.50	5.52	5.35	5.16	5.00
$+H_2O$	0.00	0.00	0.00	0.00	0.00	0.42	0.64	0.00	0.00	0.12	—
$-H_2O$	0.13	0.16	0.31	0.12	0.18	0.08	0.23	0.17	0.27	0.18	—
P_2O_5	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02
Sum	100.68	99.57	99.39	99.23	99.56	99.90	99.99	97.86	97.96	99.35	
C I P W norms											
Q	37.15	36.28	37.40	35.63	30.93	31.95	29.56	34.09	32.97		
Or	31.50	25.82	35.63	33.21	27.89	29.49	26.59	32.62	31.62		
Ab	26.91	34.46	18.54	24.01	35.96	32.40	36.16	24.56	23.61		
Ac	3.07	0.72	2.26	1.07	2.37	2.75	0.00	2.62	2.55		
Ns	0.73	0.45	2.10	1.65	0.20	0.50	0.00	1.18	1.91		
Wo	0.20	0.55	0.41	0.50	1.07	1.06	2.23	0.94	3.23		
Cpx	0.54	0.77	2.19	2.65	0.54	0.32	1.45	1.18	1.09		
Mt	0.81	0.36	1.13	0.54	0.64	0.58	0.91	1.26	1.28		
Il	0.19	0.19	0.19	0.19	0.19	0.19	0.32	0.19	0.19		
Hm	0.50	0.00	0.00	0.00	0.38	0.55	0.00	0.00	0.00		
Ap	0.02	0.05	0.02	0.02	0.02	0.02	0.05	0.02	0.02		

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

The FAM diagram (*Fig. 4*) for the studied rocks reveals that they are enriched in alkalies and strongly depleted in magnesium and iron, these features probably result from extrems fractionation of the present rocks. Moreover, the parallel distribution of the analyzed samples close to the FA side of the diagram perhaps indicates an extensional regime PETRO *et al.* 1979) for the studied granites.

Classification: *Fig. 5* illustrated the chemical classification of the examined granites which is represented on the basis of their normative An, Ab and Or (BARKER 1979). In this diagram, all the analyzed samples fall within the granites field. Furthermore, the studied plutons lie near the field of alkali granites showing

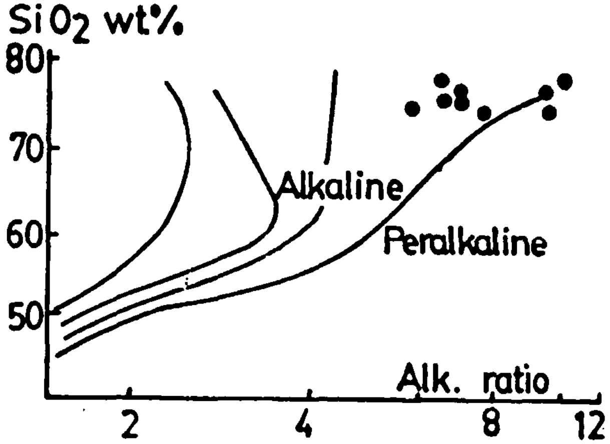

Fig. 2. SiO_2 vs. alkalinity ratio variation diagram (WRIGTH 1969) for the examined fluorite granites.

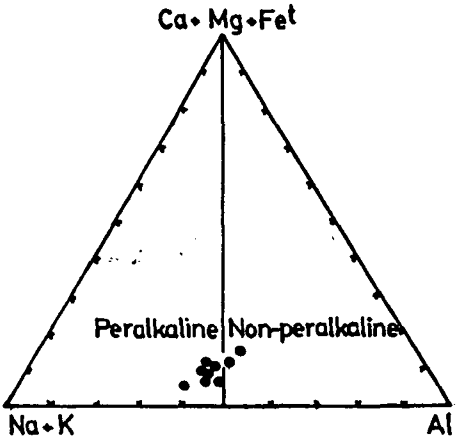

Fig. 3. Na+K - Ca+Mg+Fe_t - Al ternary diagram (BOWDEN and TURNER 1974) for the examined fluorite granites.

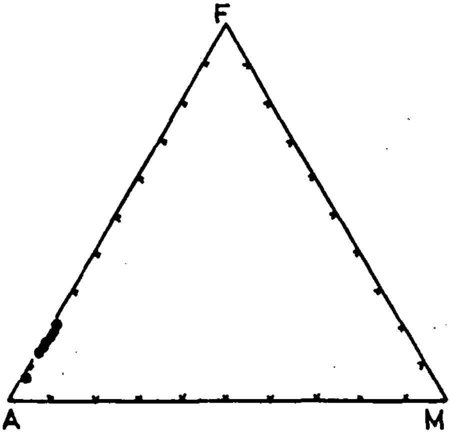

Fig. 4. APM ternary diagram for the examined fluorite granites.

their loss of MgO with increase SiO_2, probably during extreme fractionation. That is appeared on the SiO_2-log10 (K_2O/MgO) diagram proposed by ROGERS and GREENBERG (1981) (*Fig. 6*). Consequently, these rocks are corresponded to the third phase younger granites (HEIKAL *et al.* in press) on the same diagram.

PETROGENESIS

The normative An, Ab and Or proportion of the granitic rocks are plotted in *Fig. 7.* It is clear from the figure that the studied samples plotted on midway along the Ab-Or side indicating their transitional (e.g. sodic-potassic) character. Also, all the samples lie in the orthoclase field mostly near the isobaric univariant curve

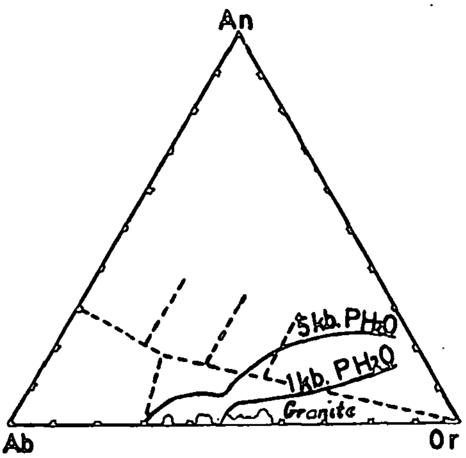

Fig. 5. Ab - An - Or ternary diagram (BARKER 1979) for studied granites

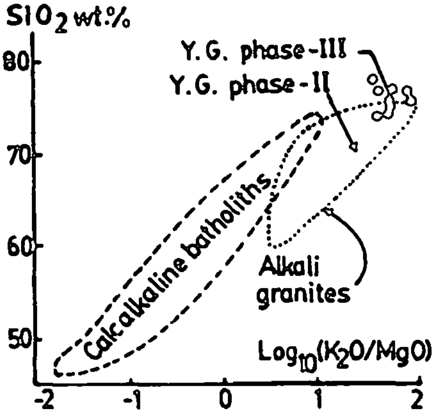

Fig. 6. SiO_2 vs. Log 10 (K_2O/MgO) variation diagram (ROGERS and GREENBERG 1981) for the studied fluorite granites. Trends of Phase II and III Younger Granites after HEIKAL *et al.* (in press)

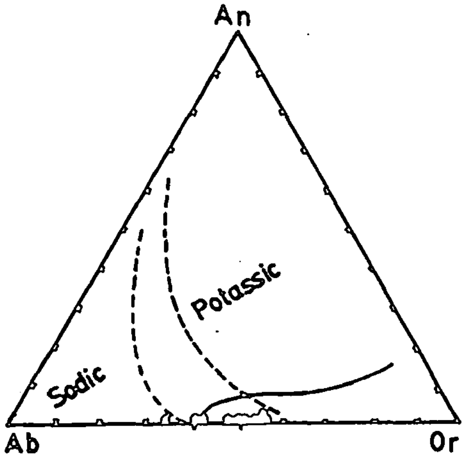

Fig. 7. Ab - An - Or ternary diagram for the studied fluorite granite. Sodic and potassic zones after IRVINE and BARAGER (1971). Solid line represents the two feldspar binary curve for quartz saturated feldspar system at 1 Kb. water-vapour pressure (after JAMES and HAMILTON 1969).

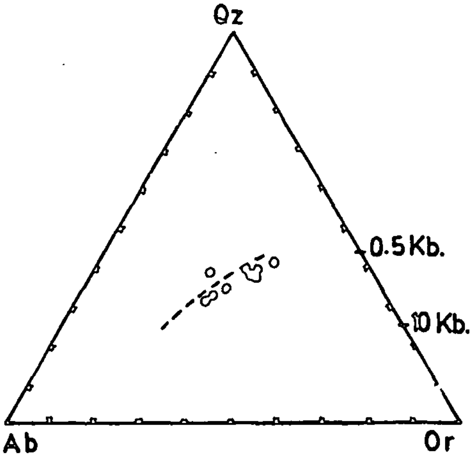

Fig. 8. Ab - Qz - Or ternary diagram for the studied fluorite granites. Dashed line represents the variation in the minimum melting points of the water-vapour pressures from 0.5 to 10 Kb. (after TUTTLE and BOWEN 1958).

indicating that the crystall-liquid equilibrium was the dominant mechanism involved in the genesis of these granites (JAMES and HAMILTON 1969).

The normative Q, Ab and Or proportion of the examined rocks are plotted in *Fig. 8.* and the results are compared with the experimental data of TUTTLE and BOWEN (1958). It is observed from the figure that the composition points of the studied rocks fall near the minimum melting point at low to moderate pressure

(1—6 Kb) in the Ab-Or-Q-H_2O system of TUTTLE and BOVEN (1958). Such a pressure, in turn suggests that these rocks were emplaced at shallow depth in the crust. Furthermore, most samples scatter slightly toward the Or-Q side.

The conclusion of the foregoing discussion becomes clear, when comparing the mineralogical and geochemical characteristics of the investigated fluorite granites (e.g. third phase younger granites) with those for typical A-type granites (LOISELLE and WONES 1979; COLLINS *et al.* 1982; JACKSON *et al.* 1984; WHALEN *et al.* 1987) (Table 3). It is evident that the studied fluorite granites are most probably analogous to A-type granite plutons.

TABLE 3.

Mineralogical and chemical properties of typical A-type granites (LOISELLE and *WONES* 1979; *COLLINS et al.* 1982; *JACKSON et al. 1984; WHALEN et al. 1987) compared with those of some fluorite granite rocks from SW-Sinai, Egypt.*

A-type characteristics	Studied fluorite granites
- Compositional range: from granite to adamellite. - Felsic min.: perthitic alkali feldspar very common. - Mafic min.: biotite late and interstitial. - Acces. min.: fluorite common, +/- arfedsonite, riebeckite. - Micrographic intergrowths very common.	- Alkali feldspar granite. - Perthitic orthoclase (+/- microcline) common. - Interstitial biotite common. - Fluorite common, +/- alkali amphibole, monazite and topaz. - Micrographic intergrowths common
- High SiO_2, Na_2O and K_2O contents. - Low Al_2O_3, CaO and MgO contents. - Agpaitic index: <1 - Na_2O/K_2O: 1 - Mostly near peralkaline. - Contain normative acmite. - High Thornton and Tuttle DI (88-95).	- High SiO_2 (77%), Na_2O (3%), K_2O (5%), - Low Al_2O_3 (11.8%), CaO (0.4%), MgO (0.04%) - Agpaitic index: 0.97—1.36 - Na_2O/K_2O: 0.6—1.0 - Peralkaline. - Normative acmite: 0.7—3% - High DI (88—96)
- Usually associated in space and time with alkaline complexes (biot. granite, peralk. granite and qz. syenite)	- Commonly associated in space and time with the alkaline younger granites phase-II.

Several magmatic processes have been suggested to be involved in the origin of the alkali granites including partial melting, crystal fractionation, metasomatism, liquid immiscibility, halide complexing, and thermo-gravitational diffusion (CLEMENS *et al.* 1986). However, for A-type granites, direct partial melting of middle of lower crustal 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 (COLLINS *et al.* 1982; WHALEN *et al.* 1987).

The A-type granites of the Afro-Arabian 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). The partial melting processes of the deep crust of the Afro-Arabian Shield would be initiated either by the late Precambrian accretion of arc systems which resulted in a thickening of the juvenile crust (GREENBERG 1981) or by a combination of three factors: rising temperatures, dimension pressures and depression of melting points by the presence of the fluorine among the volatiles (BENTOR 1985). Since the studied granites are hypersolvus, peralkaline, rich in fluorite, high in silica and alkalics and are indistinguishable from the A-type granites, these granites have a geochemical indicative of their generation by partial melting of the upper mantle to lower crustal rocks followed by crystal fractionation of fluorine-rich extracted magma. Trace and REE data are needed to test this hypothesis.

CONCLUSION

The mode of occurrence, petrographic and geochemical characteristics of some fluorite granites from Wadi Bábá area in the SW-Sinai have been presented and compared with the A-Type granites (LOISELLE and WONES 1979; COLLINS *et al.* 1982). The examined granites represent the latest pulses of the Egyptian Younger Granites as well as belong to the phase-III which, in the field, merge imperceptibly into a comagmatic phase-II with a rather indefinite contact. These rocks are medium to coarse grained; granophyric and porphyric varieties are common, too. They are hypersolvus-type consisting of perthitic alkali feldspar, quartz and plagioclase with minor biotite, alkali amphibole and fluorite.

Petrochemically, the fluorite granites are sodic-potassic character, enriched in silica, alkalies and normative acmite and Na-metasilicate. They show strong alkaline to peralkaline nature (A/CNK: 0.91—1.23) with an extremely crystal fractionation (DI: 88—96). The studied granites are typically A-type granites, most probably derived by partial melting of upper mantle to lower crustal rocks followed by crystal fractionation of an extacted magma enriched in fluorine. Furthermore, they were crystallized under moderate water vapour pressure 1—6 Kb. (TUTTLE and BOWEN 1958) and were emplaced at relatively moderate to shallow depth in a continental crust of an extentional regime.

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