Arab Gulf J. Scient. Res., **14** (2), pp. 297-326 (1996)

Geochemistry of Umm Anab Granitic Complex – A Precambrian Trondhjemitic Body from the North Eastern Desert, Egypt

A.F. Ahmed, M.M. El-Mahallawi and M.S. Abdel Ghani

Geology Department, Faculty of Science, El Minia University,
El Minia, Egypt

ABSTRACT. Umm Anab granitic pluton has an inhomogeneous composition which varies from quartz-monzodiorite, granodiorite to monzogranite. The former two varieties have strong trondhjemitic affinities. Similar to most trondhjemites, they display high soda, low potash and lime, comparable FeO*, MgO, FeO/MgO and K_2O/Na_2O and are commonly corundum normative. The complete monzodiorite, granodiorite, monzogranite suite exhabits calc-alkaline fractionation trend with some transitional trondhjemitic tendencies. These geochemical aspects characterize the Proterozoic active continental margins, that apparently related to subduction.

The REE geochemical characteristics of Umm Anab granitoids are interpreted to have been produced by partial melting of amphibolite, leaving residues consisting mainly of hornblende.

Many lines of evidence suggest that Umm Anab granitoids are interrelated by crystal fractionation. Albite and antiperthite fractionation can explain some of the scatter in the trondhjemitic varieties which has been noticed within many trondhjemitic suites and was interpreted as a primary magmatic feature.

Umm Anab granitic pluton (24 km^2) consititutes part of the Precambrian basement rocks of El Shayib topographic sheet, north Eastern Desert, Egypt (Fig. 1). It forms bold mountainous relief with a peak of maximum elevation of about 1782 m above sea level (Gebel Umm Anab). The basement rocks of Safaga and El Shayib topographic sheets were mapped by Sabet *et al.* (1972). They were represented mainly by; geosynclinal metasediments associated with metavolcanics which were intruded by older granitoids (7-7.5 x 18^8 years in age; Dixon 1981) and a successive more fractionated younger granitic rocks consist of granodiorite to quartz monzonite (6.2-6.7 x 10^8 years; Stern and Hedge 1985) followed by a flood of LIL-enriched granites (5.7-5.9 x 10^8 years; Fullagar and Greenberg 1978, Hashad *et al.* 1972, Abdel-Monem and Hurley 1978). The older varieties include autochthonous, para-autchthonous and intrusive tonalite and granodiorite, whereas the younger granitoids comprise magmatic porphyritic adamellites, red granites and later alkaline leucogranites. Umm Anab pluton was considered by Sabet *et al.* (1972) as red granite rocks.

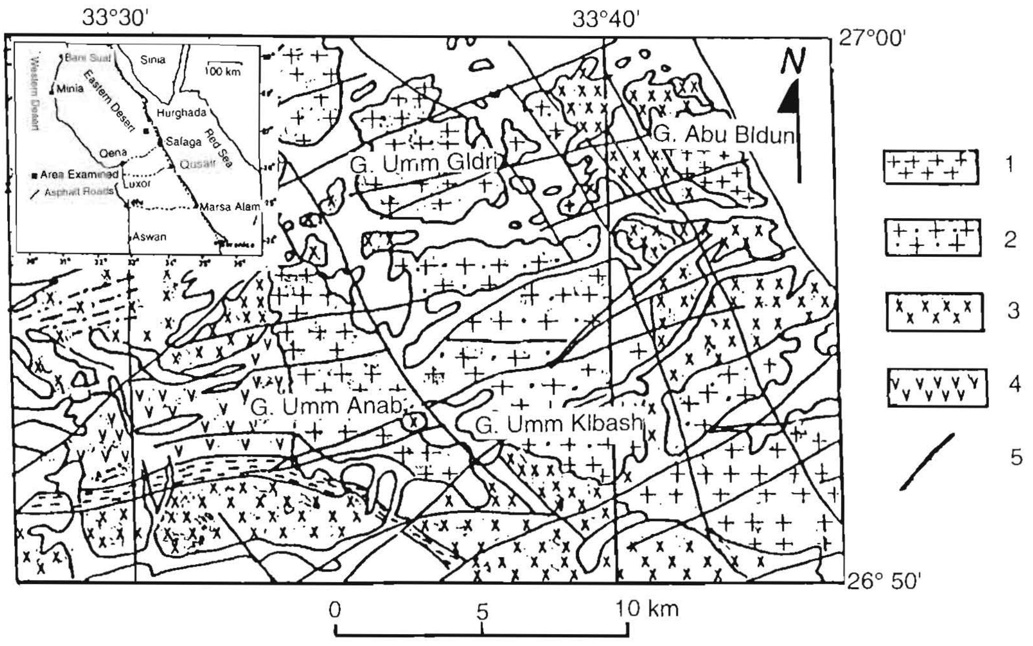


Fig. 1. Geologic map of Gebel Umm Anab area (Sabet *et al.* 1972).
Designation: 1-granites; 2-adamellites; 3-tonalite-granodiorites; 4-metavolcanics; 5-normal faults

The pluton is intruded into the older metavolcanics (mainly metabasalts, metadolerites and andesite metatuffs) to the west and southwest and sends many of shoots cutting them. The marginal parts, however contain abundant angular or elongated metavolcanic xenoliths. They may reach 2 m in length and do not show preferred orientation and display limited interaction with the enclosing granite (Sabet *et al.* 1972). To the south, Umm Anab pluton invades the older gneissic granodiorite complex (the autochthonous variety) and sends many dykes and small masses through them. Moreover, at the NW parts, the pluton shows sharp intrusive contacts with the older tonalite-granodiorite rocks (the intrusive variety). At the east and south east parts, the adamellites of Gebel Umm Kibash are intruded into the gneissic granodiorite complex and faulted against the granitoid rocks of Umm Anab pluton (Fig. 1). Finally, the later is dissected by scores of dykes which have mainly acidic types (felsites, aplites, and granophyres) with subordinate dacites, andesite and andesitic basalt varieties.

Umm Anab pluton is inhomogeneous in composition, where its peripheries attain a whitish grey colour that grades imperceptibly inwards into whitish pink and pinkish tints. Amphibolite xenoliths, up to 15 cm diameter, are found at the northern part of the mass. They are usually scattered and random without any preferred orientation. The pluton and its ridges and summits are aligned in NW-SE direction. According to Sabet *et al.* (1972), this seems due to the fact that its emplacement might have been structurally controlled by pre-existing fractures.

Petrography

The model composition of the studied Umm Anab pluton (Fig. 2) reveals that it comprises rocks extend in the fields of monzogranit, granodiorite and quartz monzodiorite. It is worthy to mention that the latter two varieties contain abundant albite and antiperthite which reflect a trondhjemitic affinity. This fact can be deduced also from the normative An-Ab-Or diagram (Fig. 3) where the samples plot predominantly in the trondhjemite and granite fields of Barker (1979). It should be noted however, that virtually all the samples show a transitional compositional range between the trondhjemite - granodiorite and granite. Moreover, the country grey granite of Umm Anab pluton is comparable with the quartz monzodiorite on the modal AQP triangular diagram and the tonalite - trondhjemite on the normative Ab-An-Or relationship.

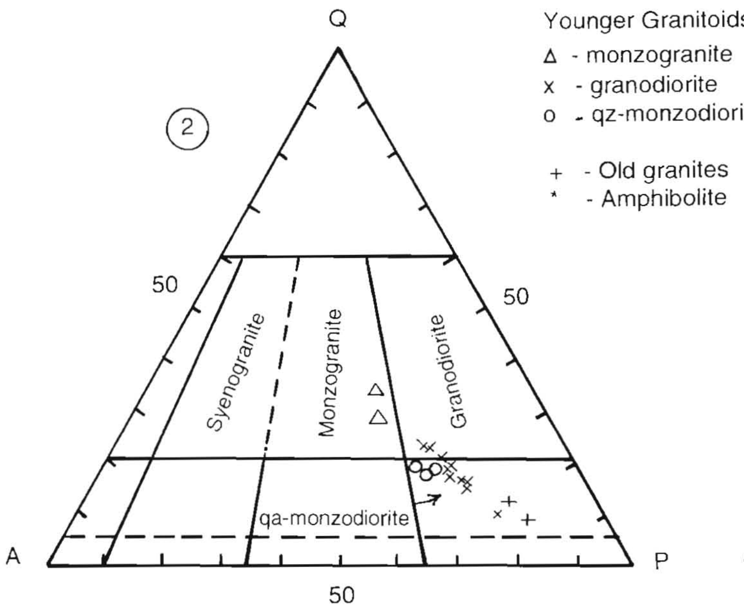


Fig. 2. Q-A-P modal diagram (Streckeisen 1976)

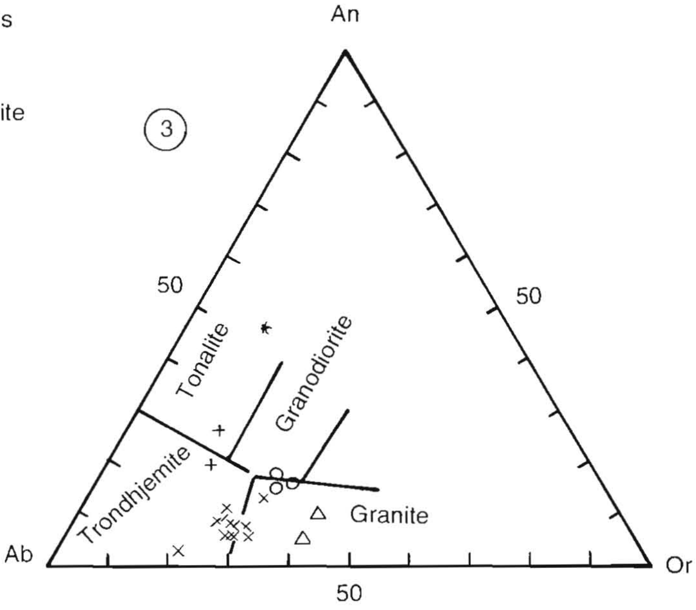


Fig. 3. Normative Ab-An-Or diagram (Barker 1979)

The **older grey granite** is porphyritic mesocratic rock. It is composed essentially of oligoclase, hornblende and biotite with subordinate amounts of quartz and perthite. Oligoclase forms coarse grained subhedral tabular phenocrysts which are sometimes rimed with albite and invaded by perthite. Some crystals are curved and display the wavy extinction. Hornblende and biotite form crystal aggregates associated with accessory magnetite, apatite, sphene and zircon.

Umm Anab pluton comprises three petrographic varieties; including **trondhjemitic granodiorite and quartz - monzodiorite, and monzorgranite**. The former two varieties are the result of variation of the mineralogical composition between K-feldspars, plagioclase and quartz. They are leucocratic porphyritic to equigranular with hypidiomorphic to allotriomorphic granular texture. These rocks show a foliated structure, display many cataclastic deformations and contain some amphibolitic xenoliths. The rocks are composed essentially of antiperthitic albite which grades to perthitic microcline, oligoclase and quartz. The mafic minerals are mainly biotite and uncommonly green hornblende. Whereas, sphene, magnetite, apatite and epidote are the common accessory constituents. The antiperthitic albite occurs as subherdral to anhedral tabular grains and may form coarse grained simply twined phenocrysts. The mineral usually grades outward to perthitic microcline. Oligoclase forms tabular subhedral crystals and may occur as phenocrysts. It commonly surrounded by albite and antiperthite and reaction rims are developed. Perthitic microcline tends to form anhedral coarse-grained phenocrysts and occurs also as anhedral intergranular graines associated with quartz and oligoclase. Quartz either occurs as anhedral intergranular crystals or uncommonly forms coarse-grained phenocrysts.

The **monzogranite** is coarse-grained hypidiomorphic to allotriomorphic, leucocratic with a pinkish white colour. The rock is composed essentially of quartz, perthitic microcline, antiperthic albite and oligoclase. Biotite is the sole mafic mineral often associated with magnetite, sphene, apatite and zircone. The rock may display the porphyroclastic texture due to fracturing of quartz and feldspars.

The **amphibolite** enclaves are composed of green hornblende and andesine with abundant apatite inclusions and intergranular clinozoisite. Hornblende is sometimes replaced by chlorite and rimed by bluish green or greenish brown tints, whereas andesine is intensively replaced by sericite, epidote and kaoleinite with few scapolite and quartz.

Geochemistry of Major Elements

Twenty one chemical analyses of Umm Anab granitic rocks were performed at the Mining Institute, Saint Petersburg, Russian Fedral Republic using the XRF technique (Table 1). The range of major elements chemical analysis of these rocks, especially the granodiorite and quartz monzodiorite conform to the definition of trondhjemitic affinity (Baker 1979). High soda (4.99-7.50%) relatively low potash (2.85-3.30%) and lime (0.94-2.03%), and FeO* (total iron as FeO) and MgO total of (1.35-3.77%) and FeO*/MgO ratio of about 3.54 are well comparable with the suggested limites of trondhjemite. K_2O/Na_2O ratios of these rocks vary between 0.38 and 0.74 with an average of 0.59 which also confirms their trondhjemitic nature.

From Table 1, it is clear that Umm Anab granitic rocks are very similar in composition and in all probability are genetically related. The pluton is more felsic which reflects the greater proportion of fractionated rock types present in it. It is therefore suitable for the study of fractionation trend in a trondhjemitic suite.

Similar to the most trondhjemites and many of the associated tonalites, the studied rocks are commonly corundum normative with values up to 2.29% which is comparable with the high - Al_2O_3 trondhjemites. Moreover, the normative plagioclase of the granodiorites, quartz-monzodiorites varies in composition from Ab_{82} to Ab_{97} and the majority of them fall within the albite range. These rocks, however can be considered as albite - bearing trondhjemitic varieties as suggested by Barker (1979).

As the studied granitoid rocks show a strong trondhjemitic affinity, they are relatively far from the chemical averages of the Egyptian granitoid rocks. Nevertheless, they are rather comparable with G-III younger granitoids given by Greenberg (1981) and show many common characteristics of G-II calc-alkaline younger granites proposed Hussein *et al.* (1982). These calc-alkaline granitoids are widespread throughout the Arabo-Nubian Shield and exhibit common basic features regarding stratigraphy, lithology, age, geochemistry, mineralization, tectonics, *etc.* In spite of these common features, there are differences of local and secondary nature (El Shazly 1980, Jackson *et al.* 1984). Many authors compared them to younger subduction related plutonic assemblage and assumed a similar origin for the batholithic plutons of the Arabo-Nubian Shield (Gass 1977, El Shazly *et al.* 1982, Bentor 1985). Moreover, granitoid rocks with strong trondhjemitic affinity were described at different localities in the central Hijaz region among the older assemblage (*e.g.* Bustan and Salajah intrusions, Jackson *et al.* 1984).

Table 1. Chemical composition and CIPW norms of Gebel Umm Anab granitoids

	Old granite		Younger granites									Younger granites									Amphi- bolite enclaves
			qz-monzodiorite			granodiorite						granodiorite							monzogranite		
	An1	An54	An24	An25	An26	An2	An3	An15	An20	An28	An29	An31	An34	An35	An36	An48	An52	An57	An4	An12	An17
SiO_2	59.43	60.07	67.93	69.37	67.48	68.79	67.08	68.12	69.77	69.65	70.13	68.47	66 48	70.04	70.41	69.61	68.37	69.96	72.26	75.42	49.03
TiO_2	1.05	1.07	0.58	0.45	0.55	0.41	0.54	0.50	0.53	0.46	0.25	0.44	0.66	0.49	0.38	0.45	0.46	0.39	0.20	0.11	1.14
Al_2O_3	18.22	15.00	15.56	15.34	15.72	16.35	16.95	16.56	15 97	15.97	16.74	16.63	16.21	15.60	16.01	15.89	16.76	15.62	15.56	14.43	16.76
Fe_2O_3	2.29	2.97	1 48	1.02	1.12	1.37	1.42	1.85	1 44	1.13	0.82	1 15	2.47	2.09	1 55	0.98	1.31	0.86	0.68	0.25	3.71
FeO	2.53	2.81	1 30	1.30	1.37	0.65	0.94	0.58	0.72	0.72	0 43	0.80	0.29	0.65	0.58	1.15	0.79	1.09	0.65	0.58	5.24
MnO	0.29	0.21	0 00	0.00	0.04	0.08	0.08	0.08	0.08	0.06	0.00	0.08	0.08	0.08	0.06	0.08	0.07	0.05	0.00	0.00	0.13
MgO	2.54	3.94	1 68	1.53	2.02	0.59	0.98	0.67	0.49	0.80	0.18	0.80	1.26	0 42	0.29	0.88	0 70	0.85	0 42	0.17	7.29
CaO	5.21	5 28	2.88	2.48	2.38	1.34	1.91	1.45	1.03	1.28	0 94	1.51	1.11	0 89	0.95	0.96	1.59	2.03	1.33	0.64	9.42
Na_2O	5 32	4.99	4 46	4.14	4.51	6.03	6.09	5.78	5 83	5.54	6.20	6.36	7.50	5.45	6.10	5.95	6.15	4.99	4.07	4.15	2.96
K_2O	2.06	2.02	3.56	3.87	3.67	3 63	3.31	3.39	3.49	3.65	3 80	3.23	2.85	3.79	3.49	3.58	3 31	3 67	4.63	4.34	1.44
P_2O_5	0.50	0 43	0.22	0.20	0.19	0.09	0.16	0.11	0.11	0 13	0.06	0.14	0.14	0.10	0 09	0.13	0.14	0.14	0.00	0.00	0.30
LOI	0.70	1 19	0.60	0.49	1.04	1.01	0.68	0.79	0.68	0 49	0.40	0.54	1.15	0.70	0.47	0.51	0 45	0.70	0.31	0.29	2.22
Total	100.10	99.98	100.30	100.20	100.10	100.30	100.10	99.88	100 10	99.88	99 95	101.20	100.20	100.30	100.30	100.20	100 10	100.30	100 11	100.40	99.64
FeOt	4.59	5.48	2.63	2.22	2.38	1 88	2.22	2.25	2.02	1.74	1.17	1.84	2.51	2.53	1 98	2.03	1.97	1.86	1.26	0.81	8.58
FeOt + MgO	7.13	9.42	4.31	3.75	4.40	2.47	3.20	2.92	2.51	2 54	1.35	2 64	3.77	2.95	2 27	2.91	2.67	2.71	1.68	0.98	15.87
FeOt / MgO	1.80	1 39	1.57	1.45	1 18	3.19	2.26	3.26	4.12	2.18	6.50	2 30	1.99	6.02	6.82	2.31	2.81	2.19	3.81	4.76	1.18
Norms																					
Q	7.31	9.24	20.72	23.46	19.65	16.38	13.98	17 67	19.78	19.87	17.30	15.16	8.86	21.43	19.29	18 07	15.91	21.59	27.03	32.38	0.00
Ab	46 08	42.96	28.25	35.56	38.84	51.13	51.83	48.69	49.04	46.78	52.09	54 04	63.79	45.74	51.38	50.54	52.09	42.69	34.13	34.70	25.07
Or	12 46	12.14	21.32	23.21	22.07	21.49	19 67	19.94	20.50	21.52	22.29	19 16	16.92	22.21	20.52	21.23	19.57	21.92	27.10	25.33	8.51
An	20.22	12.78	12 09	11.16	10.75	6.07	8.48	6.45	4.37	5.49	4.24	6 60	2.16	3 73	4 11	3.93	6.98	9.26	6.54	3.14	28.22
C	0.00	0 00	0.00	0.63	0.93	0.56	0.52	2 01	1.98	1.78	1.71	0.52	0.00	2.29	1.37	1 59	1 01	0.17	2.58	3.45	0.00
Di	2 54	9.71	0 84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 00	1.42	0.00	0 00	0.00	0.00	0.00	0.00	0.00	14.49
Hy	4 06	4.53	2.65	2.85	3.66	0.97	1 62	1.09	0.80	1.31	0.29	1.32	1.70	0.68	0.47	1.72	1.15	1.69	0.80	0.53	4.64
Ol	0 00	0.00	0 00	0.00	0 00	0.00	0 00	0.00	0.00	0 00	0.00	0.00	0.00	0.00	0.00	0 00	0 00	0 00	0.00	0.00	8.26
Mt	3.41	4.39	2 18	1.50	1.66	1.17	1 74	0.68	1.04	1.18	0.66	1.57	0.00	0.93	0.96	1 43	1 45	1 26	0.98	0.36	5.40
Il	2.05	2.07	1.12	0.87	1.07	0.78	1.03	0.95	1 00	0.87	0.47	0.84	0.79	0.93	0.72	0 86	0 83	0.75	0.38	0.21	2.17
Hm	0 00	0.00	0.00	0.00	0.00	0.57	0.23	1.38	0.72	0.31	0.36	0.07	2.49	1.44	0.88	0.00	0.32	0.00	0.00	0.00	0.00
Ap	1.13	0.96	0.49	0.45	0.43	0.20	0.35	0.24	0 24	0.29	0.13	0.31	0 31	0.22	0.20	0.29	0.31	0.31	0.00	0.00	0.66

The analytical data when plotted on the AFM triangular diagram (Fig. 4) indicate that the quartz monzodiorite, granodiorite and monzogranite suite has a calc alkaline composition with a clear trend of alkali enrichment. These calc-alkaline trend is commonly interpreted (*e.g.* Barker *et al.* 1976) to be the result of crystal fractionation. On the normative Q-Ab-Or and Ca-Na-K diagrams (Figs. 5 and 6) the studied rocks show normal calc alkaline trends (Barker and Arth 1976). The latter diagram however, show a distinct sodium enrichment of Umm Anab granodiorite and quartz monzodiorite reflecting their strong trondhjemitic affinity.

Variation diagrams of differentiation index versus major oxides are plotted in (Fig. 7a and b) for the older granitoids and the quartz monzodiorite, granodiorite and monzogranites. The diagrams show a prominent gab between the older granitoids and Umm Anab rocks which accomodates against a fractional crystallization mechanism between them. Within the trondhjemitic suite SiO_2, and K_2O show a positive correltion, whereas Fe_2O_3, FeO, TiO_2, MgO, CaO and P_2O_5 have a negative trend. Some other oxides display no systematic trend including Al_2O_3, Na_2O and total alkalies. Nevertheless Na_2O shows positive correlation within the trondhjemitic quartz monzodiorite and granodiorite.

Geochemistry of Trace Elements

Trace elements and rare earth elements in some representative samples of the studied granitoid rocks as well as one amphibolite enclave are given in Tables 2 and 3. REE, Sc and Y were determined by the Instrumental Neutron Activation Analysis (INAA) at the Institute of Nuclear Physics, Moscow, Russian Fedral Republic. V, Cr, Co, Ni, Zr, Ba, and Sr were determined by the XRF method and the other trace elements by X-ray spectral analysis at the Mining Institute, Saint Petersburg, Russian Fedral Republic.

The contents of Sc, V, Cr, Co, Ni, Sr, Ga, Y, Zr and Ba are plotted versus the differentiation index (Fig. 8a and b). The diagrams stand against a fractional crystallization process between the older granitoids and the younger trondhjemitic monzodiorite, granodiorite, monzogranite suite. However, within the latter rocks; Ni, Cr, Co, V and Ga show a negative correlation, whereas Y has a positive trend. Moreover, Zr and Ba display no systematic trend although they are relatively enriched in the strongly trondhjemitic rocks.

The REE contents of the studied granitic rocks are given in Table 3. The values of elements which were not analysed (Pr, Dy, Ho, Er and Tm) have been calculated by extrapolation of the REE curves (Figs. 9 and 10). The calculated and the analysed

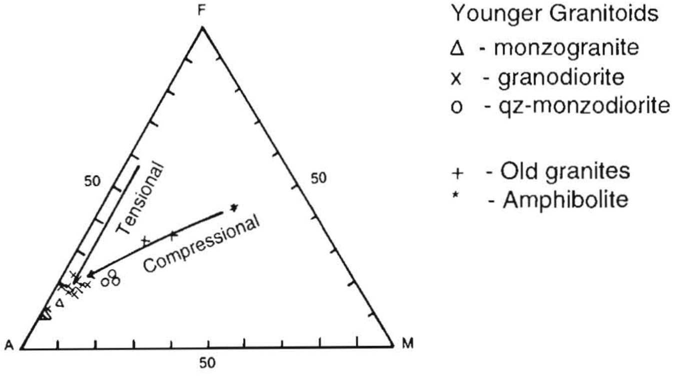
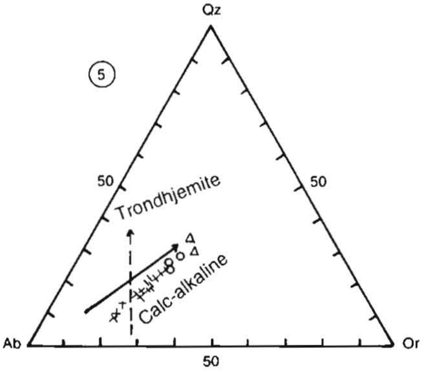


Fig. 4. AFM ternary diagram. Compressional and tensional trends after Petro *et al.* 1979.



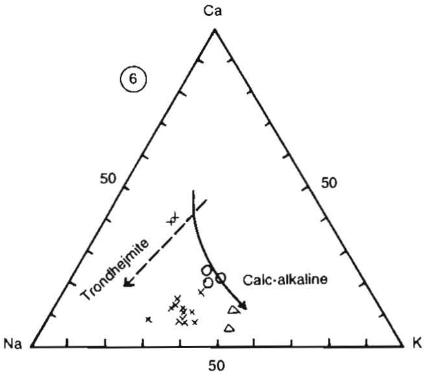


Fig. 5. Normative Qz-Ab-Or ternary diagram.

Fig. 6. Na-Ca-K ternary diagram. The calc-alkaline and trondhjemite trends after Barker and Arth 1976.

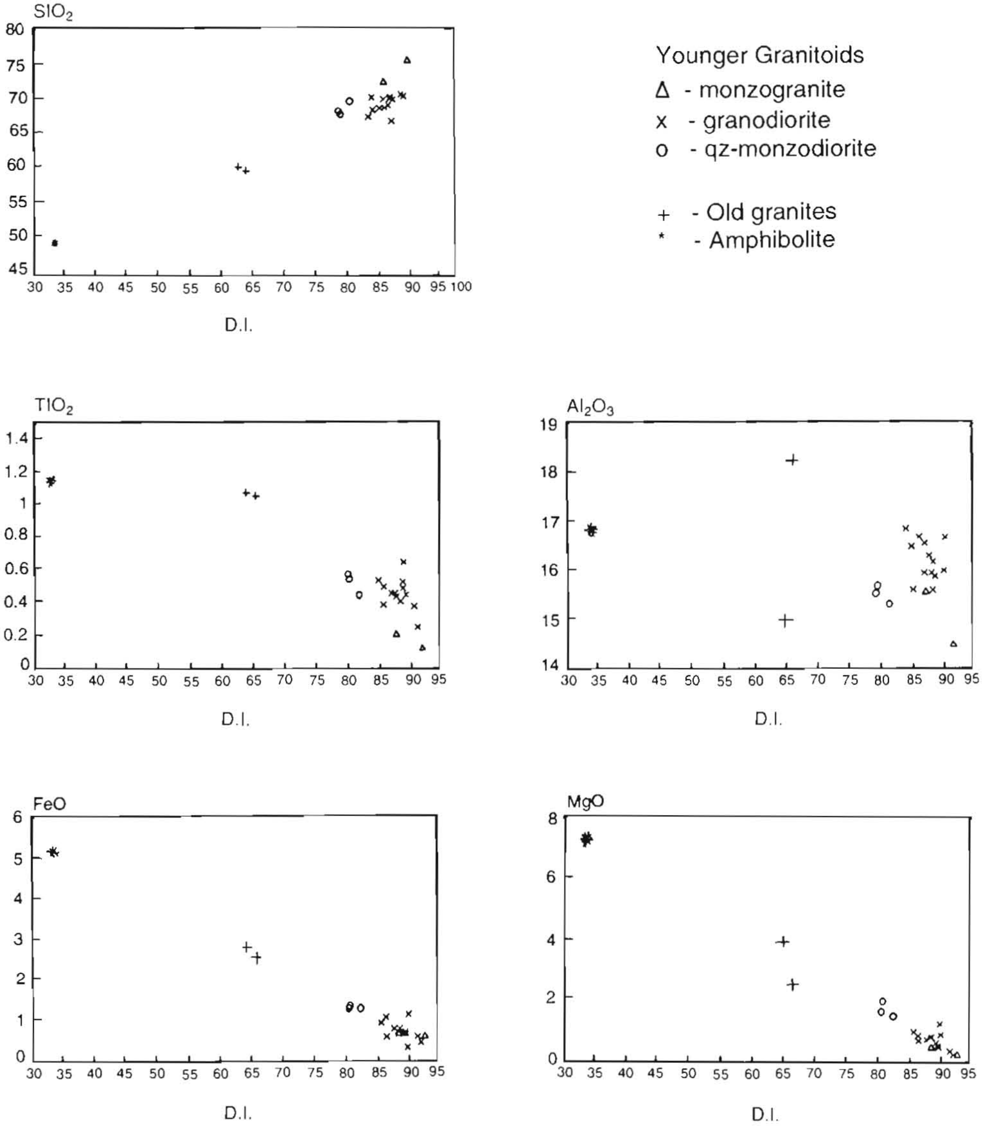


Fig. 7a. Differentiation index (DI) versus major elements.

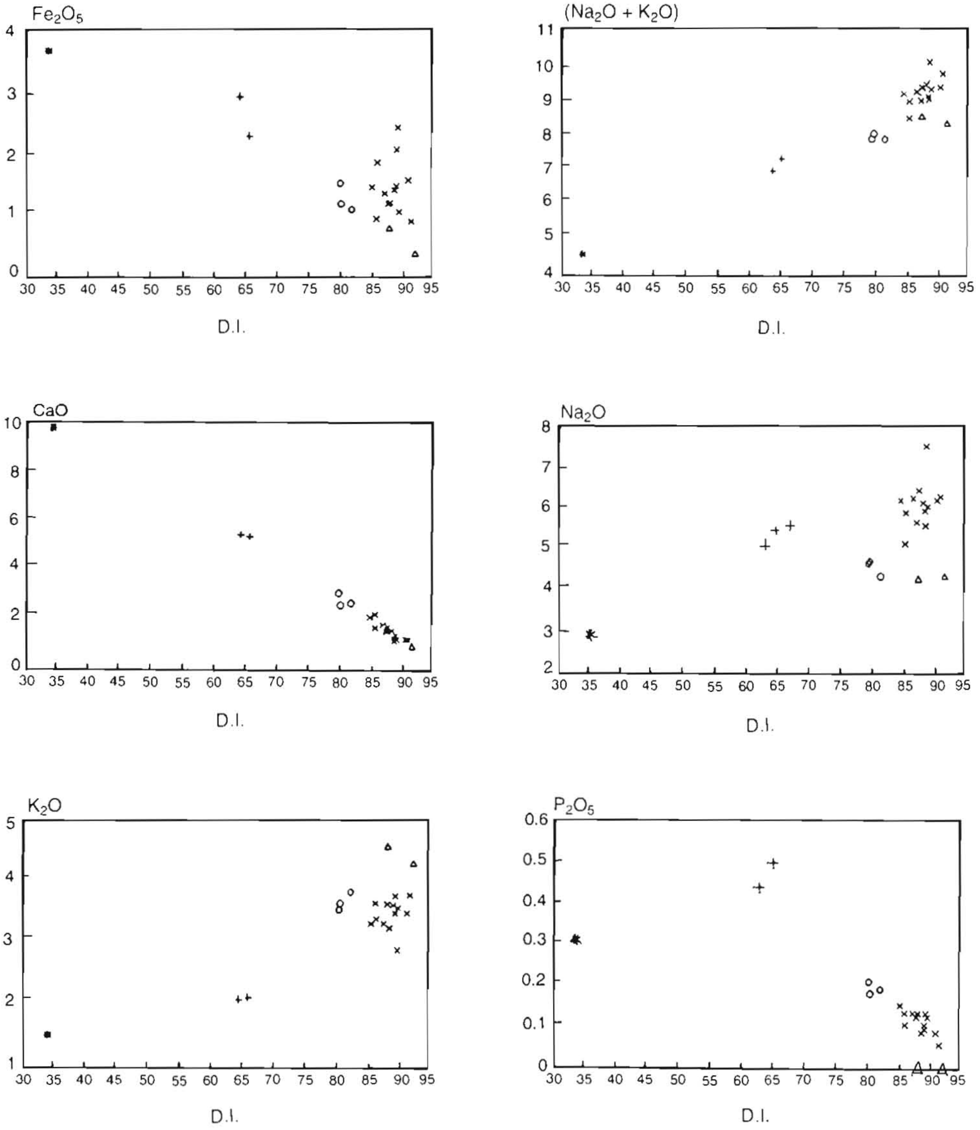


Fig. 7b. Differentiation index (DI) versus major elements.

Table 2. Trace element concentrations of Gebel Umm Anab granitoids

	Old granite		Younger granites								
			qz-monzodiorite			Granodiorite					
	An1	An54	An24	An25	An26	An2	An3	An15	An20	An28	An29
Be	00	2	2	1	2	1	1	2	2	1	1
Sc	12	22	6.1	5	4.1	9	9.6	13	9.6	6.4	2.6
V	91	84	64	74	62	33	35	24	35	17	14
Cr	59	99	53	55	50	28	25	92	23	76	61
Co	32	48	12	10	11	5	3	5	10	3	3
Ni	73	52	65	69	80	22	25	15	27	13	16
Cu	52	71	33	51	35	48	51	30	50	53	12
Zn	51	67	55	53	57	32	47	48	63	72	31
Ga	33	30	29	31	30	28	25	29	27	27	28
Sr	6590	1240	3840	2125	2230	420	870	940	820	430	975
Y	34	46	9.5	11	9.5	17	34	53	59	32	11
Zr	525	246	156	177	172	414	451	458	377	392	230
Mo	3	3	1	1	1	3	5	1	5	3	1
Ba	564	107	609	560	573	1187	1352	1343	1092	940	1325
Pb	7	9	10	10	30	00	00	28	13	32	29

	Younger granites									Amphibolite enclaves
	Granodiorite							Monzogranite		
	An31	An34	An35	An36	An48	An52	An57	An4	An12	An17
Be	1	3	1	1	1	2	2	00	1	2
Sc	9.6	13	8	6.8	8.3	9.1	6.2	2.3	7.9	30
V	24	15	15	16	14	17	19	12	15	244
Cr	69	27	25	28	40	23	35	22	28	138
Co	4	5	3	10	4	3	12	2	4	28
Ni	12	16	24	26	22	20	19	12	10	92
Cu	9	48	35	33	29	48	32	47	34	75
Zn	57	68	49	45	50	30	33	32	29	48
Ga	26	29	28	27	28	25	29	24	25	32
Sr	935	1120	480	750	790	950	985	390	270	1980
Y	35	35	38	40	37	37	25	14	33	17
Zr	466	532	422	210	414	451	274	141	97	126
Mo	1	1	5	1	1	1	1	1	1	1
Ba	1191	689	1146	1050	967	1210	629	439	289	88
Pb	10	12	10	9	7	10	7	52	55	10

Table 3. REE data of Gebel Umm Anab granitic pluton

	Old granite		**Younger granites**								
			qz-monzodiorite			**Granodiorite**					
	An1	**An54**	**An24**	**An25**	**An26**	**An2**	**An3**	**An15**	**An20**	**An28**	**An29**
La	33	35	15	21	29	55	41	49	55	44	27
Ce	81	68	37	50	46	130	110	180	130	86	45
Pr	12	11.1	4.9	6	5.2	17.5	18.20	26	20.8	10.4	6.2
Nd	47	51	19	19	18	67	69	110	93	42	21
Sm	9	14	4.1	3.6	3.9	10	10	20	18	9	4.7
Eu	2.4	2.90	1.1	0.82	0.94	2.9	3.2	4.3	3.7	2.5	2.1
Gd	8.1	10	4	2.9	2.7	9.5	9.6	15	15	8.5	3.4
Tb	1.3	1.60	0.56	0.40	0.39	1.5	1.5	2.2	2.2	1.2	0.46
Dy	8	8.40	2.7	2.5	1.8	8.1	7.5	12	11.7	6	2.4
Ho	1.7	1.8	0.6	0.5	0.4	1.9	1.6	2.4	2.6	1.33	0.6
Er	3.8	4.6	0.32	1.3	1	4.8	4.2	5.9	6.3	3.4	1.3
Tm	0.5	0.6	0.2	0.2	0.1	0.7	0.6	0.8	0.9	0.5	0.2
Yb	2.8	3.3	0.64	0.76	0.73	3.2	3.1	3.9	4.4	2.4	0.9
Lu	0.41	0.41	0.07	0.09	0.1	0.38	0.38	0.51	0.6	0.28	0.11
14REE	211.9	212.7	90.19	109.1	110.3	314.4	279.4	432	364.2	217.5	115.4
(La/Sm)n	2.19	1.64	2.4	3.83	4.88	3.61	2.69	1.61	2.01	3.2	3.8
(Ce/Yb)n	5.79	4.12	11.56	13.16	12.60	8.13	7.1	9.2	5.9	7.17	10
(Tb/Yb)n	1.64	1.71	3.1	1.86	1.88	1.65	1.71	1.99	1.77	1.79	1.8
Eu/Eu*	0.89	0.79	0.92	0.84	0.93	0.97	1.1	0.81	0.75	0.96	1.7
LREE	182.9	179.1	80	99.6	102.1	281.5	248.2	385.0	316.8	191.4	103.9
HREE	26.61	30.71	9.09	8.65	7.22	30.08	28.48	42.71	43.7	23.61	9.37
LREE/HREE	6.87	5.83	8.8	11.51	14.15	9.36	8.71	9.01	7.25	8.11	11.09

	Younger granites									**Amphibolite enclaves**
	Granodiorite							**Monzogranite**		
	An31	**An34**	**An35**	**An36**	**An48**	**An52**	**An57**	**An4**	**An12**	**An17**
La	56	46	46	45	46	48	37	31	44	14
Ce	110	98	100	110	100	110	84	63	97	28
Pr	14.3	13	14	16.3	13	14	10.7	7.15	13	4.2
Nd	50	54	50	57	57	53	42	23	52	18
Sm	9.9	10	12	12	12	10	8.2	3.2	8.8	5.1
Eu	3.1	3	2.7	2.7	3	3.1	1.7	0.74	1.8	1.4
Gd	8.5	8.5	9	10	9	9.3	7.1	3.1	7.1	3.8
Tb	1.4	1.3	1.4	1.7	1.5	1.5	1.2	0.62	1.2	0.68
Dy	8.4	6.6	6.5	8.4	7.8	7.8	6.6	3.3	6.6	5
Ho	1.9	1.4	1.5	3.12	1.6	1.7	1.5	0.75	1.5	1.2
Er	4.6	3.6	3.6	4.6	4.2	4.5	3.6	1.9	4	2.7
Tm	0.6	0.5	0.5	0.6	0.6	0.6	0.5	0.3	0.58	0.4
Yb	2.9	2.6	2.7	3.0	3.0	2.7	2.2	1.3	3.1	2
Lu	0.38	0.37	0.39	0.52	0.45	0.36	0.33	0.17	0.47	0.31
14REE	272	248.9	250.3	275	259.2	266.9	206.6	139.5	241.2	86.79
(La/Sm)n	3.71	3.02	2.52	2.46	2.52	3.15	2.96	6.36	3.28	1.8
(Ce/Yb)n	7.59	7.54	7.41	7.33	6.67	8.15	7.64	9.69	6.26	2.8
(Tb/Yb)n	1.7	1.77	1.83	2	1.76	1.96	1.92	1.68	1.37	1.2
Eu/Eu*	1.12	1.08	0.82	0.82	0.94	1.08	0.74	0.79	0.75	1.04
LREE	240.2	221	222	240.3	228	235.3	181.9	127.4	214.8	69.3
HREE	28.68	24.87	25.59	31.94	28.15	28.46	23.03	11.44	24.55	16.09
LREE/HREE	8.38	8.89	8.68	7.52	8.1	8.27	7.9	11.13	8.75	4.31

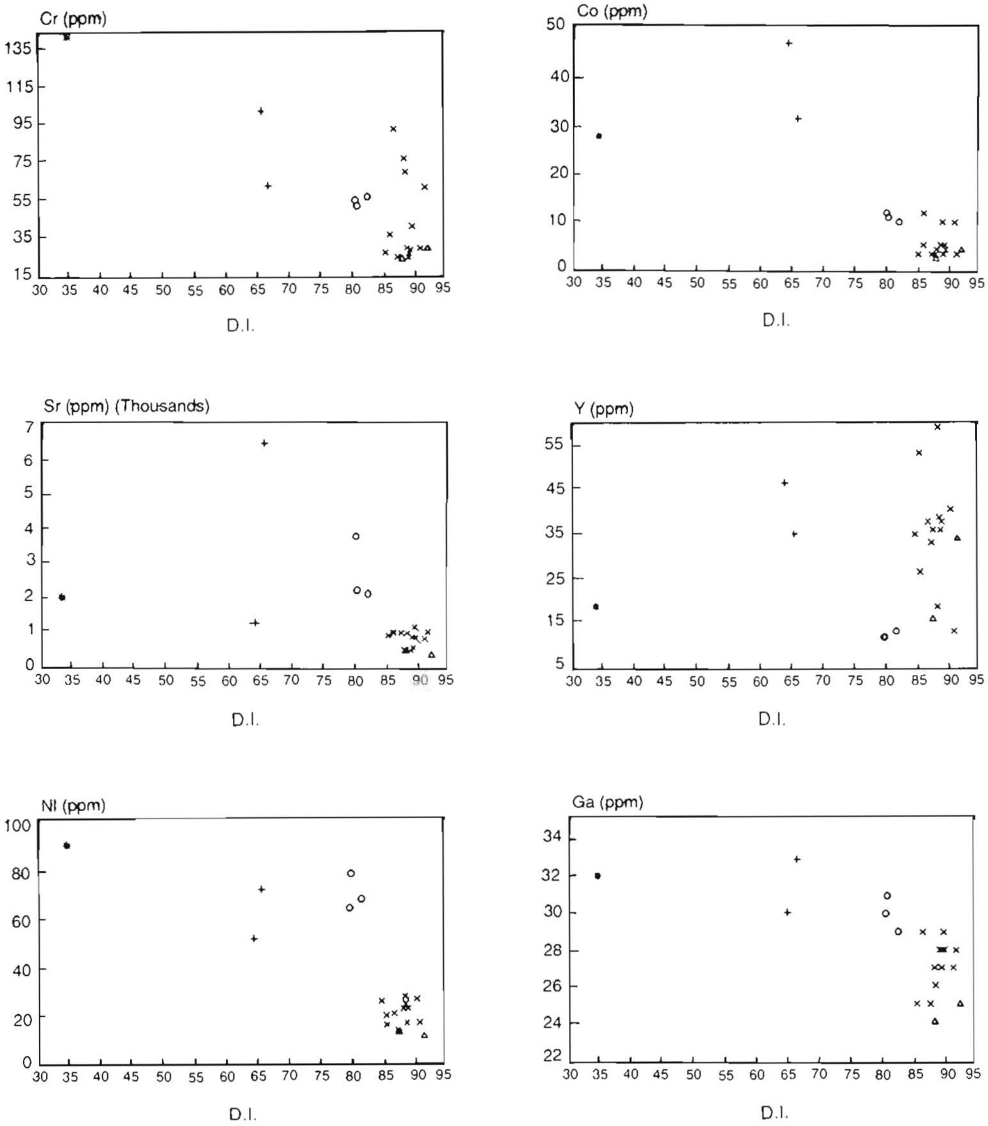


Fig. 8a. Differentiation index (DI) versus trace elements.

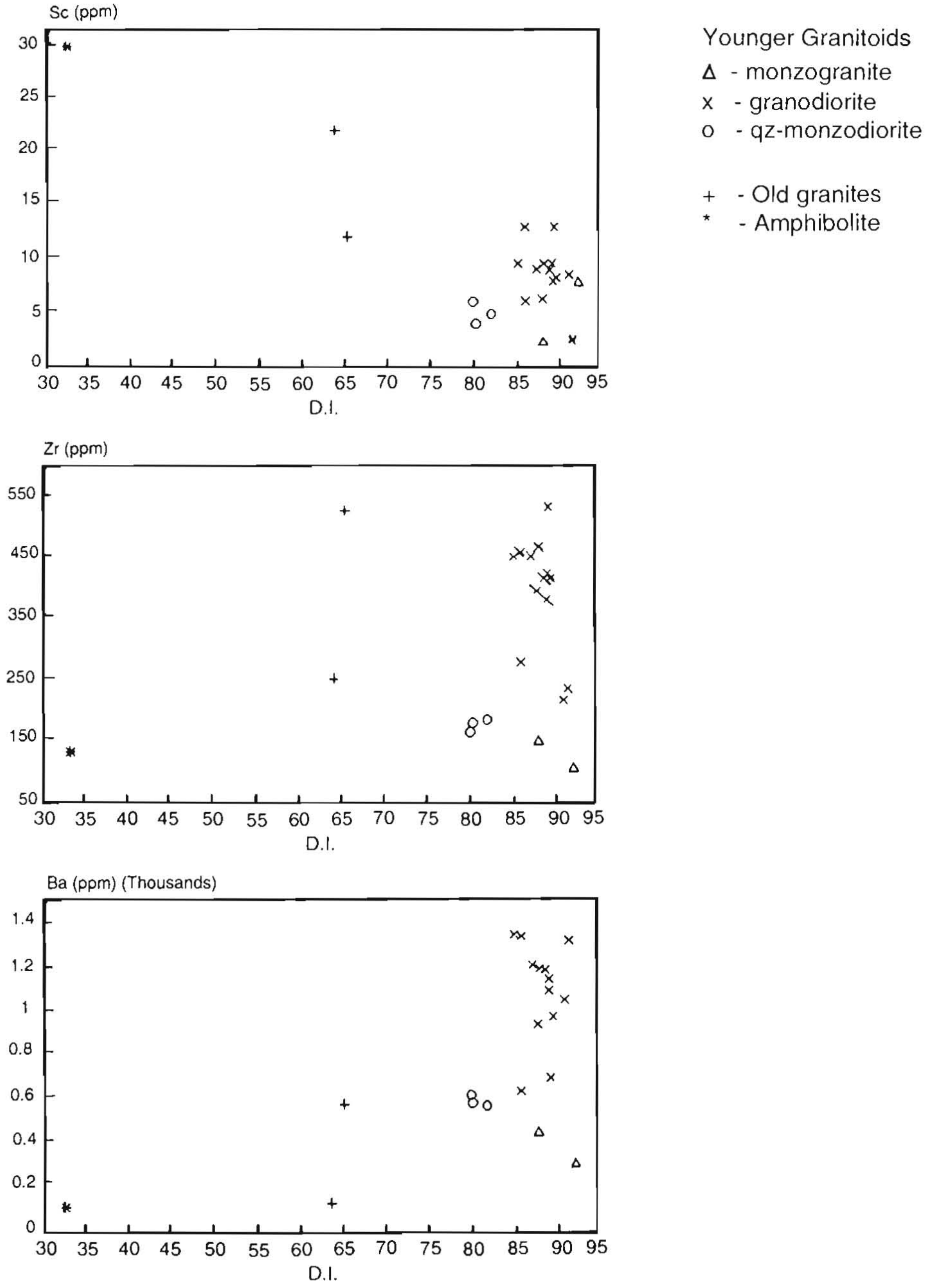


Fig. 8b. Differentiation index (DI) versus trace elements.

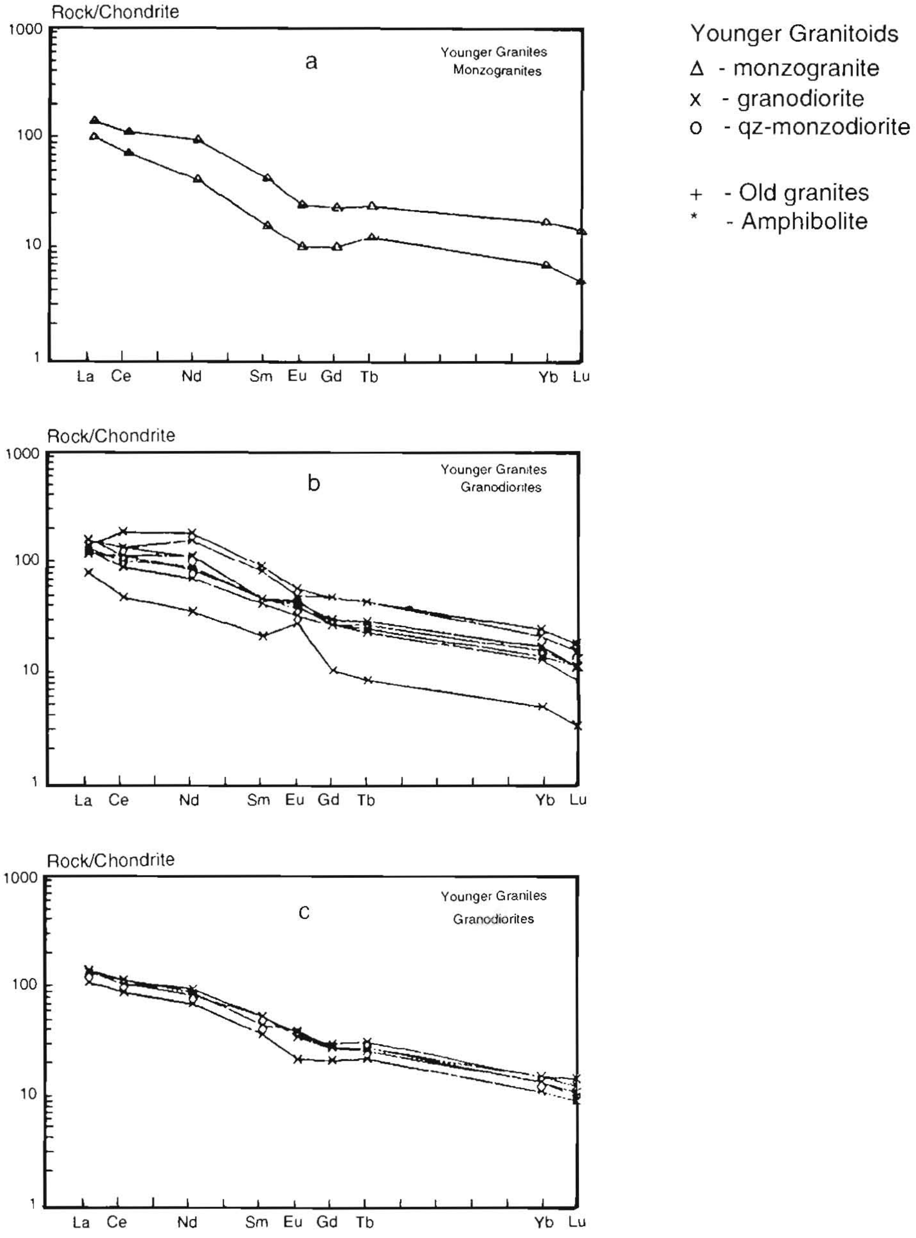


Fig. 9. Chondrite normalized REEs patterns (Schmidt *et al.* 1963) for younger granitoids; a) monzogranites; b&c) granodiorites.

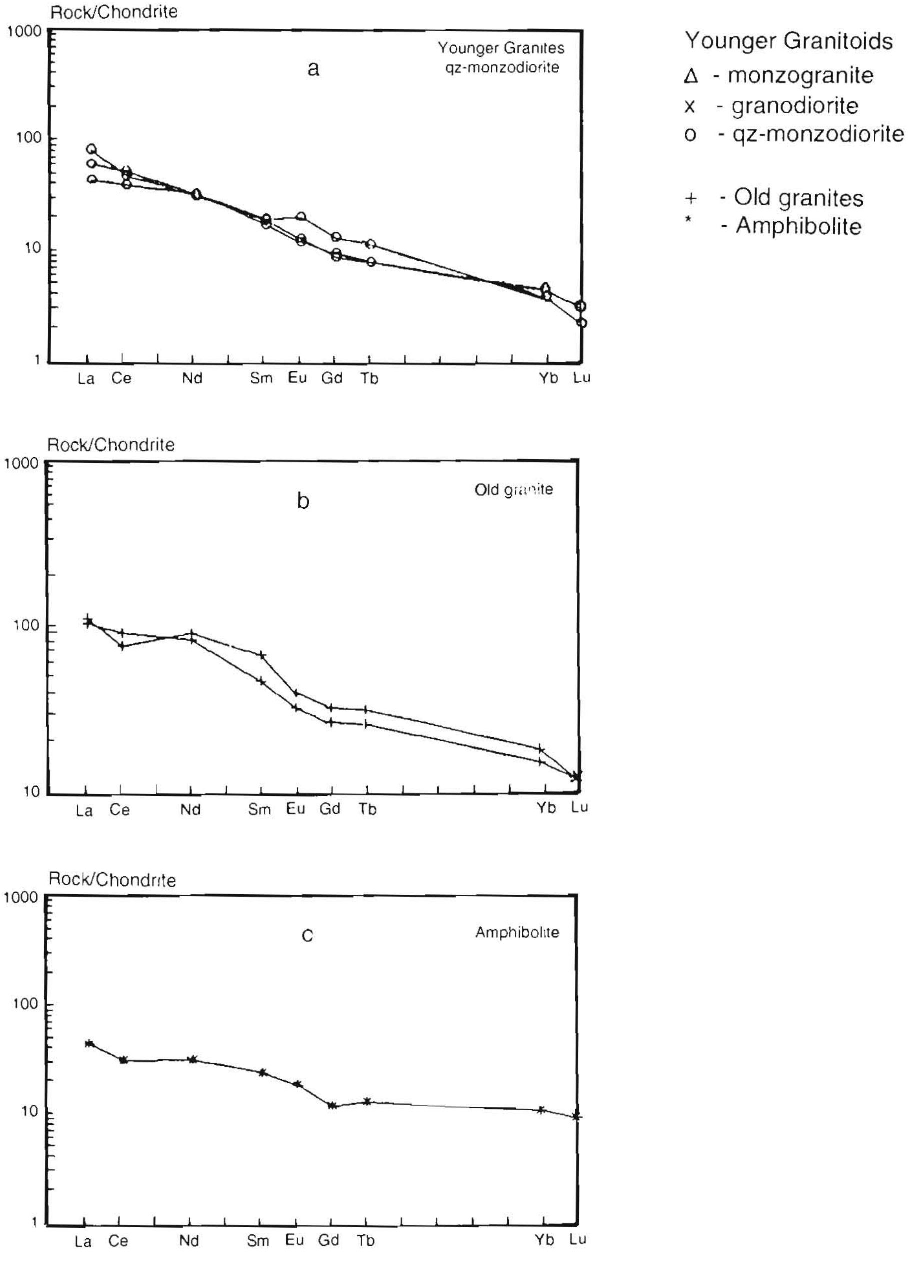


Fig. 10. Chondrite normalized REEs patterns (Schmidt *et al.* 1963) for a) younger granites (monzo-diorite); b) old granites; and c) amphibolite enclave.

values are given as sum of REE (Σ 14 REE), whereas the normalized ratios Ce (n)/Yb(n), La(n)/Sm(n) and Tb(n)/Yb(n) are used as measure of the degree of the fractionation of REE, LREE and HREE respectively. Moreover, the Eu anomaly is estimated as Eu/Eu* (Eu* = Sm(n) + Gd(n)/2).

Two samples of the older granitoids have equal Σ14 REE being about 212 ppm which is lower than the average granitic rocks (250 ppm) given by Hermann (1970). Their REE patterns (Fig. 10-b) show moderately fractionated LREE [La(n)/Sm(n) = 1.64-2.19] and unfractionated HREE [Tb(n)/Yb(n) = 1.64-1.71] as found in many calc-alkaline suites from both island arc and active continental margins (*e.g.* Taylor 1969, Gill 1970, Lopez - Escobar *et al.* 1977). Moreover, the rocks display moderately fractionated REE patterns [Ce(n)/Yb(n) = 4.12-5.79 and LREE/HREE = 5.83-6.87] and have a rather negative Eu anomaly (Eu/Eu* = 0.79-0.89) indicating an appreciable plagioclase fractionation from their melt.

The trondhjemitic quartz monzodiorites have a lower contents of REE (Σ14 REE = 90-110 ppm) as compared with the studied older granitoids and world average (250 ppm). The rock, however, displays a higher degree of REE fractionation where the Ce(n)/Yb(n) ratios varies between 11.5 and 13 and LREE/ HREE = 8.8-14.15. The patterns (Fig. 10-a) have fractionated LREE [La(n)/Sm(n) = 2.4-4.88] and slightly to moderately fractionated HREE [Tb(n)/Yb(n) = 1.8-3.1] and display a negligable negative Eu anomaly (Eu/Eu* = 0.84-0.93).

The trondhjemitic granodiorites have a wide range of 14 REE which varies from 115-432 ppm with an average 253 ppm which is very close to the average of granitic rocks. The patterns (Fig. 9b and c) show a rather fractionated LREE [La(n)/Sm(n) = 1.61-3.80) and slightly fractionated HREE [Tb(n)/Yb(n) = 1.65-2.0]. They also display moderat degree of REE fractionation [Ce(n)/Yb(n) = 5.91-10.0 and LREE/ HREE = 7.25-11.1]. The rocks have a rather negative to positive Eu anomalies, where Eu/Eu* varies between 0.74 to 1.12. One sample An_{29} is exception and displays moderate positive anomaly (Eu/Eu* = 1.7), meanwhile it has the lowest Σ14 REE (115 ppm). it most probably represents an early case of fractionation as it marked by higher positive anomaly and lower REE abundance.

The monzo-granites have wide range of REE content which varies from 140 to 241 ppm and approaching the world average of granitic rocks (250 ppm). The patterns show fractionated LREE [La(n)/Sm(n) = 3.28-6.36] and unfractionated HREE [Tb(n)/Yb(n) = 1.37-1.68] which are characteristic for calc-alkaline rocks (Fig. 9a). They show moderate degree of REE fractionation, where Ce(n)/Yb(n) varies from 6.26 to 9.69 and the LREE/HREE falls within 8.75 and 11.13. Monzogranite has moderate negative Eu anomaly (Eu/Eu* = 0.75-0.79) which implies some fractionation of plagioclase feldspar from the melt.

Discussion

Rare-earth elements have been considered one of the most effective key to granitoid genesis. The partition behaviour of REE has been studied for a variety of mineral phases (*e.g.* Philpotts *et al.* 1972) and the results have frequently been used in petrogenetic models. The available REE and other trace elements data have been used to evaluate a model for the genesis of the trondhjemitic monzodiorite-granodiorite and monzogranite of Umm Anab pluton.

Two theories have been proposed for the origin of trondhjemitic granitoid rock comprising; fractional crystallization from basaltic magmas (*e.g.* Coleman and Peterman 1975, Barker and Arth 1976, Arth *et al.* 1978), or partial melting of eclogite or amphibolite (*e.g.* Hanson and Goldich 1972, Glikson and Lambert 1976, Arth and Barker 1976, O'Nions and Pankhurst 1978).

In view of the low Sr initial ratio; $^{87}Sr/^{86}Sr$ = 0.702-0.704 (Stern and Hedge 1985, Fullagar and Greenberg 1978, Rogers *et al.* 1978), and close similarity in geochemical aspects between the studied trondhjemitic rocks and high-Al_2O_3 trondhjemites in other parts of the world, it is felt that the genesis of the concerned rocks is similar to genesis of like rocks in other regions (*e.g.* Central Hijaz region, Jackson *et al.* 1984, Gill and Stork 1979, Chakradhorpur complex, Sengupta *et al.* 1983, New Mexico, Condie 1978). A study of the chemistry of the amphibolitic enclaves has proved helpful is suggesting probable source rock for the trondhjemitic rocks, providing corroboration for the proposed model. Study of the monzogranite phase help in completing the evolutionary trend of Umm Anab pluton.

The systematics of REE pattern in relation to SiO_2 may be used to distinguish rocks formed by fractionation or partial melting of basaltic liquids (Barker 1979). On the basis of the absence of intermediate members between the studied trondhjemitic rocks and amphibolite argues against the fractional crystallization theory, and propose a partial melting model for the origin of Umm Anab trondhjemitic rocks. The relation between SiO_2 content and REE abundance is explained as being due to an increase of hornblende-liquid partition coefficient for the rare-earth elements as the melt grew more silicic (Arth *et al.* 1978, Sengupta *et al.* 1983). The moderately fractionated REE patterns [Ce(n)/Yb(n) ranging from 5.91-13.0], marked depletion of HREE and the tendency to positive Eu anomaly (Eu/Eu* = 0.74-1.72) within the studied trondhejemitic suite are rather comparable to the typical trondhjemitic rocks (Arth and Hanson 1975, Glikson 1979, O'Nions and Pankhurst 1978) which interpreted to have been produced by partial melting of eclogite or amphibolite, leaving residues consisting mainly of garnet or hornblende. Field observation and geochemical characteristics of Umm Anab trondhjemitic rocks argue against partial melting of eclogite as a mechanism for their genesis and suggest amphibolite instead. These include: 1) the total absence of garnet bearing enclaves and the common amphibolite ones 2) the less extensive depletion of HREE which can be explained assuming hornblende instead of garnet in the residue; 3) liquids produced by equilbirum partial fusion of garnet-bearing assemblage would be systematically more calcic (Tarney *et al.* 1979) in contrast to the normal calc-alkaline magma of Umm Anab rocks. The analysed amphibolite enclave (sample An-17, Fig 10c) shows differentiated REE pattern [Ce(n)/Yb(n) = 2.8]. It is tentatively suggested that it represents the parent material of the Umm Anab trondhjemitic rocks. The hornblende residue from such an already fractionated parent may produce the observed higher [Ce(n)/Yb(n)] ratios in the resulted parent melt.

Many lines of evidences suggest that Umm Anab trondhjemitic monzodiorite-granodiorites and monzogranites are interrelated by crystal fractionation. Firstly, there is a close spatial relationship in the field; the suite forms intrusive bodies into the surrounding rocks and in some instances, a single intrusive body varies in composition along its length from monzodiorite-granodiorites to monzogranites. Moreover, there is a continuum of composition in the Ab-Qz-Or plot (Fig. 5) among these rocks showing the same straight line trend. The latter is suggestive of crystallization along the quartz feldspar cotectic surface towards the thermal minimum. Geochemically, the continuum of rock types from monzodiorite to monzogranite over a range of SiO_2 content from 66.48 to 75.42 wt % and the smooth trends on the A-F-M (Fig. 4) and differentiation index variation diagrams (Figs. 7 and 8) are strongly suggestive a crystal fractionation process. On the [Ce(n)/Yb(n)] versus Yb(n) plot (Fig. 11) the studied rocks show an increasing of REE with depletion in Yb. This trend is consistent with fractional crystallization origin because the distribution coefficients for both Ce and Yb are much less than 1 between plagioclase of granitic and granodioritic liquids (Rollinson and Windley 1980). Ce and Yb will, therefore, remain in the liquid in proportion similar to the parental rock, although the concentration may be enriched slightly. The REE patterns, however as expected show depletion in Eu in monzogranite (Eu/Eu* = 0.75-0.79) relative to the monzodiorite (Eu/Eu* = 0.84-0.93) and granodiorite (Eu/Eu* = 0.74-1.7) this is partly supported by REE determinations by (Tarney *et al.* 1979) on Scourian trondhjemite and granites.

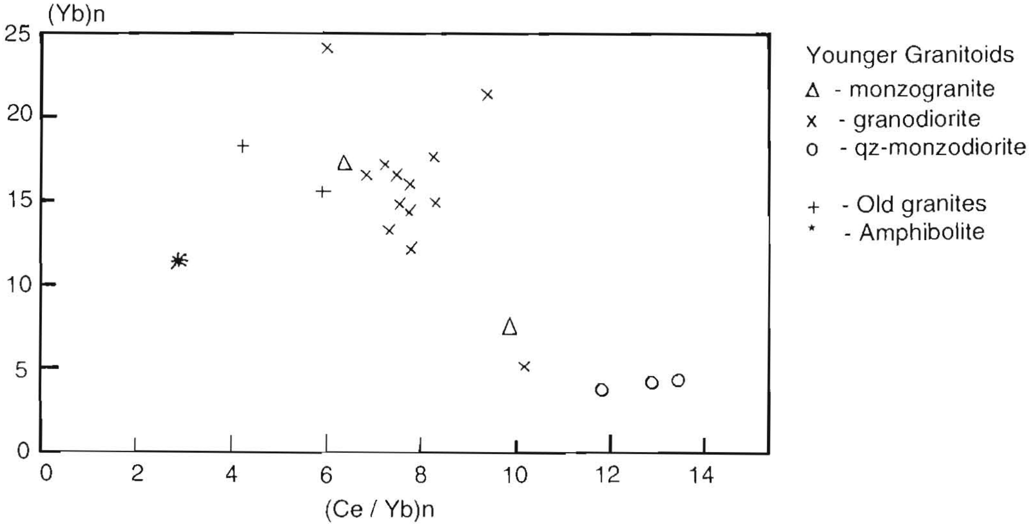


Fig. 11. Variation diagram of normalized values of Yb and Ce/Yb.

In view of large amount of crystal fractionation necessary to produce some of granitic liquids and the difficulty in separating the liquids from the crystal residue it is probable that separation of Umm Anab granitoid rock occured during deformation by means of filter pressure as suggested by Rollinson and Windley (1980).

Albite and antiperthite fractionation can explain some of the scatter in the trondhjemitic rocks of Umm Anab pluton. The pronounced enrichment in Na_2O in these rocks is comparable with the increase in Al_2O_3, Y, Zr, Sc, Ba, LREE and HREE and depltion in K_2O. These two different trends have been noticed within many trondhjemitic granite suites (*e.g.* Wells 1978, Rollinson and Windley 1980) and were interpreted as a primary magmatic feature. An important corollary to the above argument is that granites and granodiorites can be derived by fractional crystallization of Na-plagioclase from trondhjemite. The REE determination of Tarney *et al.* (1979) supports this view. They considered the trondhjemitic rocks which have ΣREE, Ce(n)/Yb(n) and Eu anomalies comparable with the Umm Anab rocks as primary trondhjemitic liquids.

The decrease in TiO_2 with differentiation index within Umm Anab rocks probable reflects sphene and/or ilmenite fractionation, whereas the decrease in Fe_2O_3 and MgO reflect the fractionation of a mafic phase- biotite with or without minor hornblende. The decreasing of Zr and P_2O_5 concentrates reflect minor zircon and apatite fractionation. The rather unsystematic trend of LREE and HREE with increasing differentiation index is not readily explained by classical fractionation schemes which generally show increasing LREE enrichment with fractionation (*e.g.* Haskin *et al.* 1968). Some workers (*e.g.* Tindle and Pearce 1981, Miller and Mittlefehldt 1982) have suggested the observed REE behaviour typical of many felsic rocks as a result of accessory phase fractionation.

It has been argued above that the intrusive grey granites and the younger granitoids of Umm Anab pluton cannot be related by fractional crystallization. The evidence presented from the variation diagrams indicates that the older granites cannot by crystal residues derived from the younger monzodiorite-granodiorite-monzogranite suite. This agrees with the field relationships which indicates that the former are earlier than the younger suite. The REE geochemical characteristics show that there is no direct genetic chemical link between these two granitoid groups. The older granites display high ΣREE (212 ppm) and negative Eu anomaly (Eu/Eu* = 0.79-0.89) where most samples of the younger granitoid suite have lower REE abundance and positive Eu anomaly. The differentiation process might acquire the late differentiates more content of REE, whereas partial melting would leave residue with positive Eu anomaly to characterize Ca-plagioclase accumulation. These characteristics are entirely absent within the concerned two granitoid groups.

Figures 12 and 13, show that the older granites are typically of crustal igneous origin and their REE patterns indicate the probability of their derivation by partial melting of basaltic material with moderate hornblende in the residue to explain the slightly fractionated REE patterns [Ce(n)/Yb(n) = 4.12-5.79]. The slightly negative Eu anomaly implies few plagioclase separation from the melt.

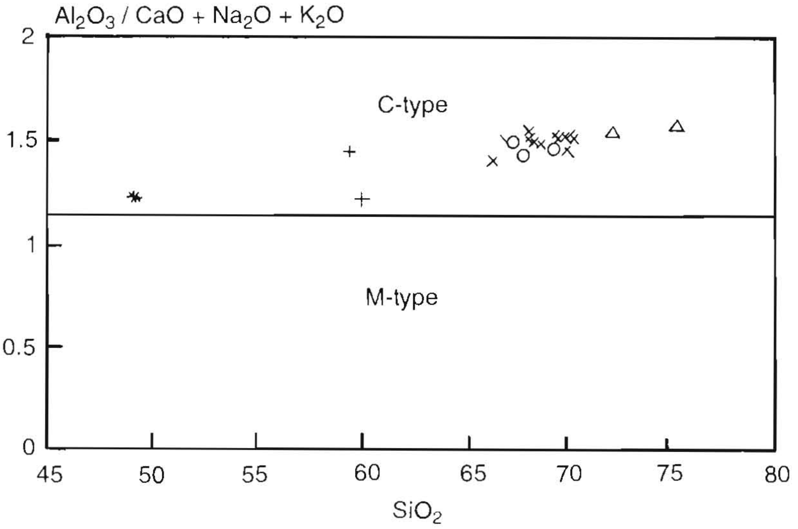


Fig. 12. SiO_2 - Al_2O_3 / CaO + Na_2O + K_2O variation diagram (Didier *et al.* 1982).

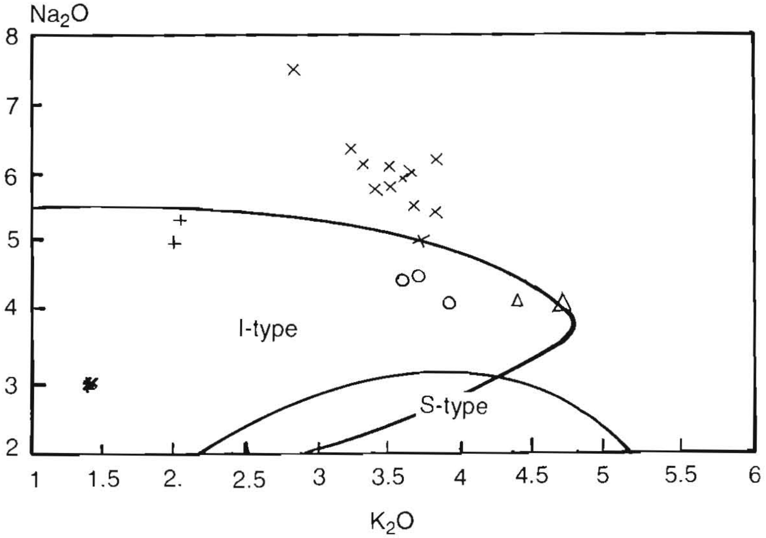


Fig. 13. $K_2O_3 - Na_2O$ variation diagram (S-and I-fields after White and Chappell 1983).

Summary and Conclusions

Umm Anab granitic pluton constitutes part of the Precambrian basement rocks, north Eastern Desert, Egypt. The pluton is intruded into older metavolcanics, older granitoid rocks and faulted against the adamellites of Gebel Umm Kibash. It has an inhomogeneous composition and contains some amphibolitic enclaves. The modal composition varies from quartz monzodiorite-granodiorite to monzogranite. The former two varieties contain abundant albite and antiperthite and show strong trondhjemitic affinities. Simmilar to most trondhjemites they display high soda, low potash and lime, comparable FeO*, MgO, FeO*/MgO and K_2O/Na_2O and are commonly corundum normative. The rocks have normative plagioclase which falls mainly within the albite range to characterize albite-bearing trondhjemitic varieties.

The complete monzodiorite-granodiorite-monzogranite suite of Umm Anab pluton exhibits calc-alkaline fractionation trend with some transitional trondhjemitic tendencies. These geochemical aspects characterize the Proterozoic rocks of the active continental margins that apparently related to subduction.

The moderatly fractionated REE patterns, marked depletion of HREE and the tendency to have more positive Eu anomaly of the studied trondhjemitic suite are interpreted to have been produced by partial melting of amphibolite, leaving residues consisting mainly of hornblende. The analysed amphibolite enclave is tentatively suggested to represent the parent material of Umm Anab pluton. Similar petrogenic model has been given for the Buston trondhjemitic intrusion of the central Hijaz region which might have been produced as a result of partial melting of amphibolite (Jackson *et al.* 1984).

Many lines of evidence suggest that Umm Anab trondhjemitic monzodiorite-granodiorite and monzogranite are interrelated by crystal fraction. Albite and antiperthite fractionation can explain some of the scatter in the trondhjemitic rocks. The enrichment in Na_2O is comparable with increase in Al_2O_3, Fe_2O_3, Y, Zr, Sc, Ba, LREE and HREE and decrease in K_2O. These two different trends have been noticed within many trondhjemitic suites and were interpreted as a primary magmatic feature.

The field observation, major and trace chemical analyses show that there is no direct genetic chemical link between the older granites and Umm Anab granitic rocks. The former are assumed to be derived by partial melting of basaltic material with slight to moderate hornblende in the residue and few plagioclase separation from the melt.

Acknowledgement

The authors wish to thank Prof. Dr. Yury B. Marin, Chief of the chair of Mineralogy, Crystallography, and Petrology of the Mining Institute, Saint Petersburg, Russian Fedral Republic, for the laboratory facilities.

References

Abdel-Monem, A.A. and **Hurley, P.M.** (1978) Age of Aswan monumental granite, Egypt, by U/Pb dating of zircon: *Precambl. Res.*, 6, A4.

Arth, J.G. and **Barker, F.** (1976) Rare-earth partitioning between hornblende and dacite liquid and implications for the genesis of trondhjemitic-tonalitic magmas. *Geology,* **4:** 534-536.

Arth, J.C. and **Hanson, G.N.** (1975) Geochemistry and origin of the early Precambrian crust of northeastern Miinnesota. *Geochim. Cosmochim. Acta,* **39:** 325-362.

Arth, J.G. and **Barker, F., Peterman, Z.E.** and **Friedman, I.** (1978) Geochemistry of the gabbro - diorite - tonalite - trondhjemite suite of southwest Finland and its implications for the origin of tonalitic and trondhjemitic magmas. *J. Petrol.,* **19:** 289-317.

Barker, F. (1979) Trondhjemite: definition, environment and hypothesis of origin. *In:* **Barker F.** (Editor), Trondhjemite, Dacites and Related rocks. Elsevier, Amesterdam, 1-12 pp.

Barker, F. and **Arth, J.C.** (1976) Generation of trondhjemitic-tonalitic liquids and Archean bimodal trondhjemite-basalt suite. *Geology,* **4:** 596-600.

Barker, F. and **Arth, J.C. Peterman, Z.E.** and **Friedman, I.** (1976) The 1.7-1.8 b.y. - old trondhjemites of southwestern Colorado and northern New Mexico: geochemistry and depth of genesis. *Bull. Geol. Soc. Am.* **87:** 189-198.

Bentor, Y.K. (1985) The crustal evolution of the Arabo-Nubian massif with special reference to the Sinai Peninsula. *Precamb. Res.* **28:** 1-74.

Coleman, R.G. and **Peterman, Z.E.** (1975) Oceanic plagiogranite. *J. Geophys. Ros.,* **80:** 1099-1108.

Condie, K.C. (1978) Geochemistry of Proterozoic granitic plutons from New Mexico, U.S.A. *Chem. Geol.* **21:** 131-149.

Didier, J. Duthou, J.C. and **Lameyre, J.** (1982) Mantle and Crustal granites: genetic classification of orogenic granites and nature of their enclaves. *J. Volcanol. and Geotherm. Res.*, **14:** 125-132.

Dixon, T.H. (1981) Age and chemical characteristics of some Pre-Pan African rocks in the Egyptian shield, *Precamb. Res.*, **14**: 119-133.

El Shazly, E.M. (1980) Correlation and evolution of the Precambrian in northeast Africa and south west Asia. *Earth-Sci. Rev.,* **16:** 303-312.

El Shazly, E.M., Dixon, T.H., Engel, A.E.G., Abdel Meguid, A.A. and **Stern, R.J.** (1982) Late Precambrian crustal evolution of Afro-Arabian from ocean-arc to craton. *Egypt. J. Geol.,* **24:** 101-121.

Fullagar, P.D. and **Greenberg, J.K.** (1978) Egyptian younger granites: a single period of plutonism. *Precamb. Res.* **6:** A22.

Gass, I.G. (1977) The evolution of the Pan-African crystalline basement in NE Africa and Arabia. *J. Geol. Sco. London,* **134:** 129-138.

Gill, J.B. (1970) Geochemistry of Viti Levu, Fiji, and its evolution as an island arc. *Contrib. Mineral. Petrol.,* **27:** 179-203.

Gill, J.B. and **Stork, A.L.** (1979) Miocene low K-dacites and trondhjemites of Fiji. *In:* **Barker, F. (ed.)** Trondhjemites, dacites and related rocks: Elsevier, Amsterdam, 629-649 pp.

Glikson, A.Y. (1979) Early Precambrian tonalite-trondhjemite sialic nuclei. *Earth Sci. Rev.,* **15:**

1-73.

Glikson, A.Y. and **Lambert, I.B.** (1976) Vertical zonatin and petrogenesis of the early Precambrian crust in western Australia. *Tectonophysics.* **30:** 55-89.

Greenberg, J.K. (1981) Characteristics and origin of Egyptian Younger Granites: Summary: *Geol. Soc. Am. Bull. I.,* **92:** 224-232.

Hanson, G.N. and **Goldich, S.S.** (1972) Early Precambrian rocks of the Saganaga Lake-Northern Light Lake Area, Minnesota-Ontario: part II: petrogenesis. *Geol. Soc. Am. Mem.,* **135:** 175-192.

Hashad, A.H., Sayyah, T.A., El-Kholy, S.B. and **Youssef, A.** (1972) Rb/Sr isotopic age determination of some basement Egyptian granites. *Egypt. J. Geol.,* **16:** 269-281.

Haskin, L.A. Haskine, M.A., Frey, F.A. and **Wildman, T.R.** (1968) Relative and absolute terrestrial abundances of the rare earth. *In:* **Ahrens, L.H. (ed.)** origin and distribution of the elements. *Intern. Ser. Monograph Earth Sci.,* **30:** 889-912.

Hermann, A.G. (1970) Yttrium and the lanthanides. *In:* **Wedepohl, K.H. (ed.)** Handfook of Geochemistry. *Springer-Verlag, N.Y. , Sec.* 39-57 pp.

Hussein, A. A.A., Ali, M.M. and **El-Ramly, M.F.** (1982) A proposed new classification of the granites of Egypt. J. Volcanol. Geotherm. Res., **14:** 187-198.

Jackson, N.J., Walsh, J.N. and **Pegram, E.** (1984) Geology, geochemistry and petrogenesis of late Precambrian granitoids in the central Hijaz region of the Arabian Shield. *Contrib. Mineral. Petrol.,* **87:** 205-219.

Liew, T., Finger, F. and **Hock, V.** (1989) The Moldanubian granitoid plutons of Austria, Chemical isotopic studies bearing their environmental setting. *Chem. Geol.,* **76:** 41-55.

Lopez-Escobar, L., Frey, F.A. and **Vergara, M.** (1977) Andesites and high alumina basalt from the central south Chile. High Andes: Geochemical evidence bearing on their petrogenesis. *Contrib. Mineral. Petrol.,* **63:** 199-228.

Miller, C.F. and **Mittlefehldt, D.W.** (1982) Depletion of light rare earth elements in felsitic magmas. *Geol.,* **10:** 129-133.

O'Nions, R.K. and **Pankhurst, R.J.** (1978) Early Archean Rocks and geochemical evolution of the earth's crust. *Earth Planet. Sci. Lett.,* **38:** 211-236.

Petro, W.L., Vogel, T.A. and **Wilbrand, J.T.** (1979) Major element chemistry of plutonic rock suites from compressional and extensional plate-boundaries. *Chem. Geol.,* **26:** 217-235.

Philpotts, J.A., Schnetzler, C.C. and **Thomas, H.H.** (1972) Petrogenetic implications of some new geochemical data on eclogite and ultrabasic inclusions. *Geochem. Cosmochim. Acta.,* **36:** 1131-1166.

Rogers, J.J.W., Ghama, M.A., Nagy, R.M., Greenberg, J.K. and **Fullagar, P.D.** (1978) Plutonism in Pan - African belts and the geologic evolution of North Eastern Africa. *Earth Planetary Sci. Lett.,* **39:** 109-117.

Rollinson, H.R. and **Windley, B.F.** (1980) An Archean granulite - grade tonalite - trondhjemite - granite suite from Scouriie, NW Scotland: Geochemistry and Origin. *Contrib. Mineral. Petrol.,* **72:** 265-281.

Sabet, A.H., El-Gaby, S. and **Zalata, A.A.** (1972) Geology of the basement rocks in the northern parts of El-Shayib and safaga sheets, Eastern Desert. *Annals of the Geol. Surv. Egypt.* III. 111-128 pp.

Schmidt, R.A., Smith, R.H., Lash, J.E., Mosen, A.W., Ohely, D.A. and **Vasilevskis, J.** (1963) Abundances of fourteen rare- earth elements, scandium and yttirum in meteoritic and terrestrial matter. *Geochem. Cosmochim. Acta,* **27:** 577-622.

Sengupta, S., Bandyopadhyay, P.K. and **Vanden Hull, H.J.** (1983) Geochemistry of the Chakradharpur granite-gneiss complex - a Precambrian trondhjemite body from west Singhbhum, Eastern India. *Precambrian Research,* **23:** 57-78.

Stern, R.J. and **Hedge, C.E.** (1985) Geochronologic and isotopic constraints on late Precambrian crustal evolution in the Eastern Desert of Egypt. *Amer. J. Sci.,* **285:** 97-127.

Streckeisen, A. (1976) To each plutonic rock its proper name. *Earth Sci. Rev.,* **12:** 1-33.

Tarney, J., Weaver, B.L. and **Drury, S.A.** (1979) *Geochemistry of Archean trondhjemitic and tonalitic gneisses from Scotland and East Greenland. In:* **Barker, F.** (Editor) Trondhjemites, Dacites and Related Rocks. Elsevier, Amesterdam, 175-199 pp.

Taylor, S.R. (1969) Trace element chemistry of andesites and associated calc-alkaline rocks. *In:* **McBirney, A.R. (ed.)** "Proceedings of the Andesite Conference" Oreg. Dept. *Geol. Mineral. Ind., Bull.* **65:** 43-63.

Tindle, A.G. and **Pearce, J.A.** (1981) Petrogenic modelling of in situ fractional rystallization in the zoned Loch Doon pluton, Scottland, *Contrib. Mineral. Petrol.,* **78:** 196-207.

Wells, P. (1978) *The geochemistry of the Patagonian batholith between 45° and 46°S latitude.* M.Sc., Thesis, Univ. Birmingham.

White, A. J.R. and **Chappell, B.W.** (1983) Granitoid types and their distribution in the Lachlan fold belt, southeastern Australia, *Geol. Soc. Am. Mem.* **159:** 21-34.

(Received 20/02/1994;
in revised from 07/10/1995)

جيوكيمياء معقدة أم عناب الجرانيتية – جسم تروندهجيميتي من عصر ما قبل الكامبري بشمال الصحراء الشرقية بمصر

عواد فرغل أحمد و محمود محمد المحلاوي و محمد صابر عبد الغني

قسم الجيولوجيا – كلية العلوم – جامعة المنيا – المنيا – مصر

تكون متداخلة أم عناب جزء من صخور القاعدة لعصر ما قبل الكامبري في شمال الصحراء الشرقية بمصر . وقد تموضعت بداخل صخور البركانيات المتحولة القديمة وصخور الجرانيت القديم وتفلقت بمحاذاة صخر الاداميليت لجبل أم الكباش .

تتميز الكتلة النارية لأم عناب بتركيب غير متجانس يتراوح بين الكوارتز مونزوديوريت والجرانوديوريت إلى المونزوجرانيت . ويظهر النوعين الأولين من هذه الصخور اصالة تروندوهجيميتيه قوية . ويظهر التشابه مع التروندوهجيميت في نسبة الصوديوم العالية مع انخفاض نسبة البوتاسيوم والكالسيوم بمقارنة اكاسيد الحديد والماغنسيوم ونسبة الحديد على الماغنسيوم وتواجد الكورندم في التركيب النموذجي . ويتضح من المجموعة الكاملة لصخور المونزوديوريت والجرانوديوريت والمونزوجرانيت الاتجاه التفاضلي المشابه للصهير الكلس-قلوي مع بعض الصفات الانتقالية للتروندوهجيميت . هذه الخصائص الكيميائية تميز الحواف القارية النشطة للعصر البروتيروزوي وتبدو مرتبطة بالاندساس .

وتفسر الخواص الجيوكيميائية للعناصر الارضية النادرة ان صخورأم عناب الجرانيتية قد نتجت من انصهار جزئي لصخر الامفيبوليت تاركا بقايا صهير مكون اساسا من الهورنبلند . وقد أعطى نموذج ذو أصل صخري متشابه لمتداخلة البستان في منطقة وسط الحجاز والتي ربما نتجت بالإنصهار الجزئي للامفيبوليت .

وتشير الملاحظات الحقلية والتحاليل الكيميائية للعناصر الشائعة والشحيحة على عدم تواجد علاقة مباشرة تربط بين صخور الجرانيت القديم وصخور أم عناب الجرانيتية . والأول يعتقد انه مشتق بالتفارق الصهيري لمادة بازلتية مع تبقي كمية قليلة إلى متوسطة من الهورنبلند وتفارق قليل للبلاجيوكليز من الصهير .

وتشير الدلائل العديدة على أن صخور أم عناب الجرانيتية مرتبطة ذاتياً بالتجزء البلوري . ويمكن توضيح بعض التشتت في النوعيات الترندوهيجيميتية على انه ناتج من انفصال الالبيت والانتيبرثيت كعملية نارية أولية مميزة لمجموعات الترندوهجيميت .