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GEOCHEMISTRY OF SOME YOUNGER GRANITE PLUTONS, CENTRAL EASTERN DESERT, EGYPT AND THEIR TECTONIC SETTING

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ABSTRACT

The chemical characteristics of thirteen younger granite plutons from the central Eastern Desert yield guide variable permitting their division into three distinct groups. Group I are calc-alkaline granodiorites, very similar in composition to the volcanic arc granites (Andinotype marginal continental arc). Group 2 have true granite composition, they are of proper alkaline to strongly alkaline nature and are considered as post-collision granites Group 3 are riebeckite-bearing alkaline granites related to the ring complexes and formed during rifting subsequent to cratonization. The contents of SiO_2, K_2O, Y and Rb gradually increase whereas the contents of CaO, TiO_2, Al_2O_3, MgO, FeO (total iron as FeO), Sr and Ba decrease from Group I through Group 2 to Group 3.*

INTRODUCTION

The Egyptian granites have long been known to pertain to an older and a younger group under various names. Hume (1935) was the first to classify them into an older phase (the grey granite) and a younger suite (Gattarian Granite). This was further emphasized by the Geological Survey in the central Eastern Desert. At that time the "grey granites" were only known to be the older of the two groups of granites; being cut by the "pink granites" as shown in many places such as in Gabal Siwigat El-Arsha and Gabal Abu Diab.

Schurmann (1953) added a new subdivision, namely the "Shaitian" granite after a granite well developed at Wadi Shait, preceding the "Grey Granites". Schurmann's type "Shaitian" granite at the head of Wadi Shait was studied by Akaad and Moustafa (1963) and found to be but a cataclastic-mylonitic gneiss of older "grey granite" origin. An almost identical cataclastic mylonitic gneiss north of Gabal El-Maiyit was also found by Akaad and El-Ramly (1963) to be a part of an older "grey granite" mass and the so called granite of Shaitian type was finally equated with the "grey granites".

The relative stratigraphic position of each of the two major granitic groups was established by El-Ramly and Akaad (1960) only after the study of the Igla Formation by Akaad (1957) and Akaad and El-Ramly (1958). In this sequence, the "Grey Granites" are older than the "Igla Formation" whereas the "Younger Granites" are younger than the latter. These two groups were later referred to by El-Shazly (1964) as synorogenic and late orogenic plutonites. He considered the porphyritic granite of Aswan to form a much younger group of post-orogenic granite.

El-Gaby (1975) divided the Egyptian granites into two groups (a) the synorogenic granitoids (which comprise the grey granite, the Shait granite and the porphyritic Aswan granite) and (b) the younger granite (which comprise the late to post orogenic pink and red granites). He concluded that they constitute one continuous series and that the hypersolvus alkaline granites represent a side-branch developed during the late phases of differentiation, probably under subvolcanic conditions and through gas transfer. Later El-Gaby and Habib (1982) and El-Gaby et al. (1987) classified the Egyptian granites into (a) an older, syn-to late orogenic calc alkaline granite series (including the older grey granite, the porphyritic Aswan granite and the two-feldspar younger granite) and (b) a younger, post-tectonic alkaline to peralkaline granite series.

Greenberg (1978) studied the geochemistry, petrography and tectonic origin of some Egyptian younger granite plutons and recognized three possible clans (groups I, II, & III) which share in the qualities of the post-tectonic epizonal intrusions and appear to be of one generation. Akaad et al. (1979) studied 17 plutons of Younger Granite in the Qift-Qusseir region and showed that these possess three phases in order of decreasing age according to field, petrographic and geo-chemical characteristics. Hussein et al. (1982) proposed a new classification of the Egyptian granites, in which the previously known younger granites, red-pink granites, "late" and "post" orogenic plutonites are classified into two groups [illegible] G-II and G-III granites. G-II granites denote granitic types formed as a result of suturing whereas G-III granites denote intraplate anorogenic granites formed within the plate subsequent to cratonization. El-Shatoury et al. (1984) deduced some relevant statistical parameters based on the major chemistry of the different granitoid rocks of Egypt indicating the existence of a very sharp boundary between the older or synorogenic granitoids (Gr.A) on one hand, and both the younger or post-orogenic granitoids ($Gr.B_1$) and the youngest alkali granites ($Gr.B_2$) on the other hand.

The Younger Granites of Egypt were apparently formed within a narrow time range 570 to 607 Ma (Hashad et al., 1972; Meneisy, 1972; Fullagar and Greenberg, 1978, Hashad, 1980; Meneisy and Lenz, 1982; Stern and Hedge, 1985). Their initial $^{87}Sr/^{86}Sr$ ratios range only from 0.7028 to 0.7037. These values are commonly interpreted as indicative of derivation of the granite from the mantle. Rogers et al. (1978) argued that the alkali granites of northeastern Africa, including the Egyptian Younger Granites; must have been mantle-derived because the area contained virtually no continental crust prior to Pan-African time, when the granites were emplaced.

Akaad (1957), Akaad and El-Ramly (1958) and El-Ramly and Akaad (1960) distinguished and amply described the major unconformity at the base of the Hammamat sediments and overlying the Dokhan Volcanics. Rogers and Greenberg (1983) considered this unconformity as about 600 Ma and that it marks the end of compressive subduction related tectonics. They also believe that the intrusion of the Younger Granites through the unconformity and immediately overlying rocks was the last major tectonic/igneous event in the evolution of the crystalline shield of the eastern Egypt and which formed at the time of (Pan African) stabilization of the continental crust. Stern and Hedge (1985) reported that the igneous activity during 600 to 575 Ma episode involved the emplacement of the pink granites. They also noted that the tectonic activity during this time is generally limited to the development of broad open folds. Stern et al. (1984) argued these features are most consistent with an extensional tectonic setting.

The present paper deals with the geochemistry of granites from thirteen younger granite plutons occurring approximately between latitudes 25o. and 26^{o} These plutons include Gabals El-Fawakhir, Umm Rus, El Shush, El Dabbah, Igl El Ahmer, El Endiya, Kadabora Abu Itella, Sheikh Salem, El Atawi, Hamret Ghannam, El Sibai and Abu El Tiyur (Fig. 1).

The 13 younger granite plutons cut across a wide array of rock units which include the volcano-sedimentary assemblages, serpentinites, metagabbros, young gabbros and

Hammamat sediments. These plutons generally possess circular to oval and elongate outlines. Some of these are rign-like bodies (El Atawi, Hamret Ghannam, El Sibai and Abu El Tiyur). The plutons form bold mountainous landmarks with sharp contacts against the enveloping rock units.

The mineral composition together with the first indications of the geochemical attributes (precceding the complete data presented herein) permits the present Younger Granite plutons to be classified into three different groups:

Group I : includes El Fawakhir, Umm Rus, El Shush and El Dabbah plutons, which are generally granodiorites. They are mostly of the subsolvus variety as classified by Martin and Bonin (1976) and are composed of sodic oligoclase, quartz and less abundant potash feldspar with notable hornblende and biotite.

Group 2 : includes five plutons which are subdivided into two subgroups. Group 2 A includes the Igl El Ahmer and El Endiya plutons which are composed of quartz, alkali feldspar (perthite + albite) and sodic oligoclase together with subordinate biotite. Hornblende is even more scarce. Group 2 B includes the Kadabora, Abu

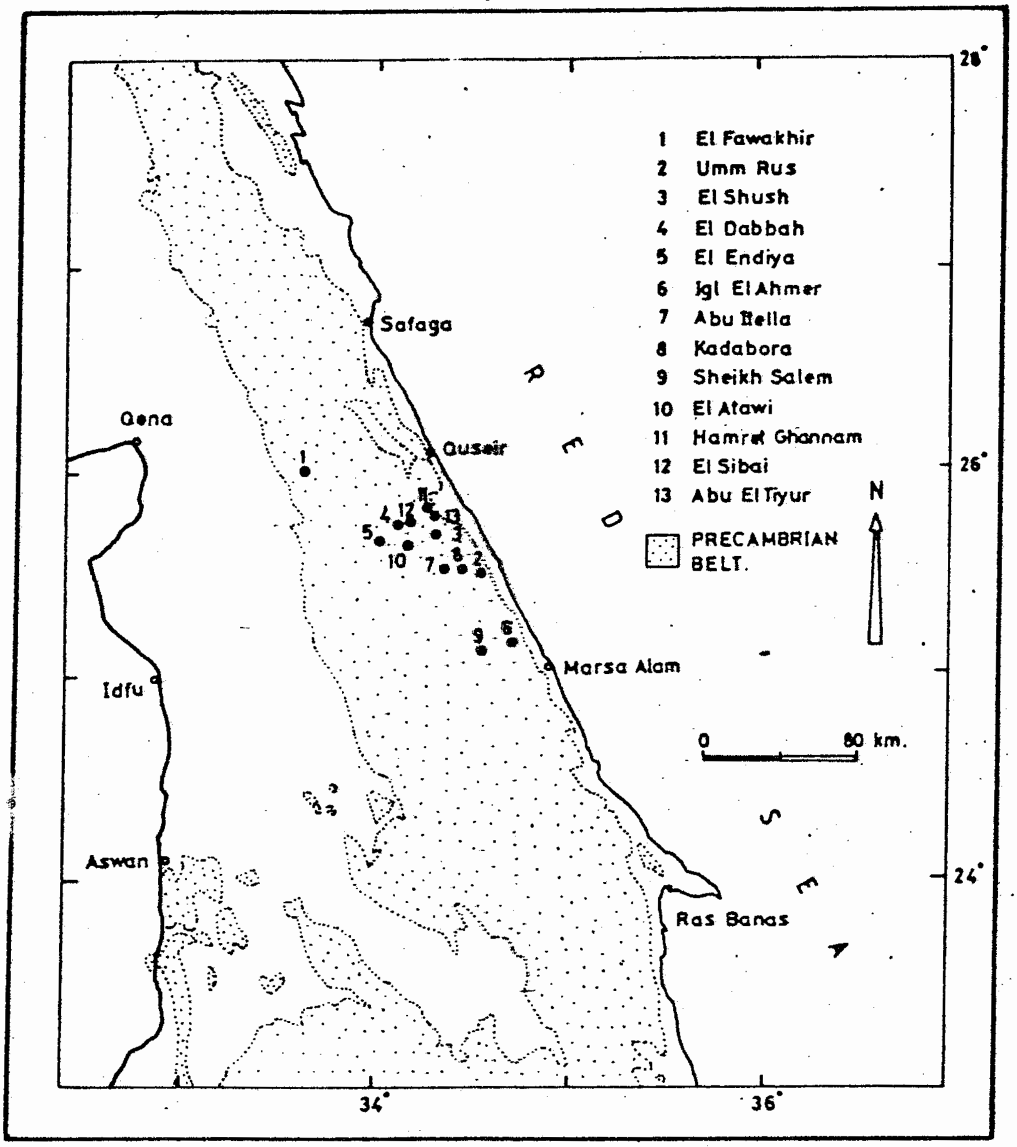

Fig. 1 Location map showing the investigated granite plutons.

Table 1: Major and trace element analyses of some younger granite plutons in the central Eastern Desert of Egypt.

	Group 1											
	El Fawakhir		Umm Rus		El Shush		El Dabbah		El Erediya		Tal El Ahmar	
	90	91	780A	5C	625G	631	573	576	696B	708	291	302
SiO_2(wt%)	66.74	67.12	67.15	67.27	65.85	70.99	70.09	69.51	74.93	73.79	75.49	75.78
Al_2O_3	15.49	15.21	15.62	15.03	17.71	15.92	15.47	16.06	12.79	12.36	12.57	12.34
Fe_2O_3	1.04	1.11	1.02	0.74	1.43	0.94	1.43	1.46	1.10	0.31	0.37	0.75
FeO	2.90	2.79	3.20	3.16	1.64	1.00	1.64	1.52	0.60	1.36	0.96	0.93
MgO	1.06	0.87	1.18	1.11	1.36	0.73	0.98	1.12	0.43	0.56	0.42	0.43
CaO	2.59	2.92	3.75	3.61	5.21	3.38	3.86	4.16	0.45	0.74	0.71	1.09
Na_2O	4.28	4.05	4.45	4.42	4.34	4.76	4.09	3.96	4.94	4.52	4.55	4.62
K_2O	3.68	3.49	2.02	2.20	0.62	1.91	1.76	1.52	3.56	3.63	3.27	3.56
TiO_2	0.72	0.59	0.26	0.25	0.47	0.27	0.48	0.49	0.13	0.37	0.11	0.11
MnO	0.08	0.09	0.08	0.09	0.05	0.06	0.07	0.08	0.03	0.03	0.02	0.03
L.O.I.	0.64	0.83	1.11	0.66	1.34	0.67	0.76	0.52	0.69	1.03	0.60	0.46
Total	99.22	99.07	99.84	98.54	100.22	100.63	100.63	100.40	99.65	99.08	99.07	100.10
Nb (ppm)	11	12	17	10	4	12	7	9	9	14	8	12
Zr	132	118	149	142	85	58	79	82	255	167	168	171
Y	18	20	19	17	2	2	5	11	30	49	29	37
Sr	298	322	255	238	756	604	414	481	68	65	60	70
Rb	62	86	42	46	28	43	50	53	56	88	65	77
Ba	720	692	487	563	204	479	474	433	500	484	463	478
Zn	36	33	28	54	58	42	47	48	7	58	28	30
Cu	23	28	30	28	35	18	22	20	4	16	6	8
Ni	20	18	20	18	14	9	21	18	24	7	25	21
Cr	22	43	8	6	12	40	14	16	8	9	8	3

	Group 2						Group 3								
	Abu Itella		Kadabora		Sheikh Salem		El Atawi		Homrat Ghannam		El Sibai			Abu El Tiyur	
	812	813A	159A	40B	27	28	767	659	235	822B	116A	185E	195E	631	635
SiO_2(wt%)	74.96	75.49	75.49	76.91	75.12	75.42	76.81	75.49	77.19	78.09	76.82	76.62	77.19	76.31	76.02
Al_2O_3	12.17	12.79	12.34	10.78	13.02	13.34	11.73	12.34	11.22	11.00	11.44	11.09	11.67	11.24	11.54
Fe_2O_3	0.10	0.74	0.98	1.02	1.01	0.90	0.57	0.93	0.64	0.91	0.58	0.99	0.81	1.06	1.27
FeO	0.80	0.68	0.96	0.44	0.48	0.28	0.60	0.76	0.52	0.44	0.40	0.28	0.44	0.76	0.88
MgO	0.32	0.27	0.31	0.32	0.29	0.28	0.33	0.30	0.28	0.27	0.27	0.27	0.27	0.29	0.24
CaO	1.35	0.37	0.73	0.38	0.34	0.48	0.35	0.58	E	E	0.32	0.07	0.25	0.42	0.47
Na_2O	3.56	4.13	4.23	3.37	3.96	3.78	4.43	4.50	4.11	3.99	4.57	4.56	4.52	3.96	4.36
K_2O	5.02	5.47	5.09	4.75	5.28	4.93	4.53	4.66	4.78	4.56	4.13	4.23	4.45	4.55	4.63
TiO_2	0.06	0.06	0.08	0.09	0.13	0.12	0.13	0.16	0.12	0.11	0.08	0.08	0.09	0.07	0.07
MnO	0.01	0.02	0.05	0.03	0.04	0.01	0.03	0.03	0.01	R	0.01	0.01	0.03	0.03	0.03
L.O.I.	1.62	0.45	0.48	0.93	0.61	0.63	0.49	0.54	0.38	0.35	0.45	0.57	0.48	0.73	0.56
Total	99.97	100.47	100.74	99.00	100.28	100.17	100.2	100.29	99.25	100.52	98.87	92.57	100.20	99.42	100.07
Nb (ppm)	66	42	32	44	23	22	42	85	34	59	69	82	51	77	61
Zr	212	108	228	249	162	133	81	185	238	334	248	203	180	213	241
Y	119	130	63	93	45	49	79	159	73	74	108	70	98	94	79
Sr	15	10	56	48	33	9	33	24	4	4	2	8	4	5	7
Rb	106	107	93	92	106	108	200	192	77	163	140	162	118	142	161
Ba	124	110	739	448	83	51	146	63	54	7	24	53	113	63	59
Zn	6	73	77	-	-	-	30	121	81	-	133	16	139	140	130
Cu	1	1	4	6	3	6	13	15	2	4	15	14	13	9	12
Ni	30	27	22	29	23	24	2	19	23	28	12	12	14	21	23
Cr	8	5	5	8	6	6	8	13	7	8	10	12	11	9	8

Itella and Sheikh Salem plutons which are composed of perthite, albite, quartz and little amounts of sodic oligoclase and biotite.

Group 3 : includes the El Atawi, Hamret Ghannam, El Sibai and Abu El Tiyur plutons, of alkali feldspar granite composition. They are mostly of the hypersolvus textural type and are composed essentially of alkali feldspar (perthite + minor albite), quartz and very little biotite. Riebeckite is prsent except in El Atawi pluton.

CHEMISTRY

Major and trace element analyses for 27 selected rock specimens representing the thirteen granitic plutons under consideration are represented in Table I. CIPW norm and various geochemical parameters for the analysed samples are given in Table 2.

The analyses were performed by the author at Dokuz Eylul Universitesi, Izmir, Turkey. The contents of the major elements SiO_2, Al_2O_3, total iron (as Fe_2O_3), MgO, CaO, K_2O, Na_2O and MnO were determined by the atomic absorption spectrometry. The total iron (as Fe_2O_3) was determined once

FeO was determined by volumetric titration with $KMnO_4$ standard solution, then Fe_2O_3 was calculated. The concentrations of the trace elements Rb, Sr, Zr, Y, Nb, Ba, Cu, Ni, Ti and Cr were determined by the X-ray fluorescence spectrometry. Calibration curves for major and trace element analyses were constructed from analyses of U.S.G.S. standard rocks AGV-I, GSP-I, G-2, Pcc-I, Sy-2 and Sy-3.

Chemical Classification:

The chemical classification of the studied granitic rocks, based on R_1-R_2 multicationic scheme of De La Roche et al. (1980) is presented in Fig. 2. Group 1 granites fall within the granodiorite field, except for one analysis from Gabal El Shush which falls within the tonalite field. Group 2 A fall within the granite field. Group 2 B and Group 3 fall within the alkali granite field.

Chemical Characteristics:

The alkalinity ratios of the studied granites were calculated (Table 2) and plotted on Wright's (1969) alkalinity ratio variation diagram (Fig. 3) which clearly indicates that: (a) Group I granites have a clac alkaline affinity, (b) Group 2 A are alkaline proper, whereas both Group 2 B and Group 3 are of strongly alkaline character.

The relationship between K_2O and Na_2O is shown in Fig. 4 which indicates that the majority of Group 1 granites have K_2O/Na_2O ratios < 0.5 and consequently have sodic tendencies. Two samples from Group 1 as well as Group 2 A have K_2O/Na_2O ratios between 0.5-I indicating sodic potassic characters. Group 2 B and Group 3 have K_2O/Na_2O ratio between 1-2 indicating a potassic character.

The mafic and felsic indices (Simpson, 1954) for the present rocks (Fig. 5) indicate the majority of the Group 1 granites as intermediate differentiates with only two analyses as acid differentiates. Group 2 and Group 3 granites appear as acid differentiates.

The AFM variation digram (Fig. 6) shows that the analysed granitic samples are progressively richer in alkalies and poorer in Mg and Fe (total iron) from Group 1 through Group 2 to Group 3.

In the K-Na-Ca variation diagram (Fig. 7), the studied granitic rocks show relative variation in composition towards the Na-K sideline. The diagram clearly illustrates that Group 1 granites lie near the Ca-Na sideline, having nearly equal amounts of Na and Ca and low content of K. Group 2 and Group 3 granites, on the other hand, show high values of both K and Na and very low content of Ca.

Some other diagrams have also been used to illustrate the behaviour of some of the major and trace elements (Figs. 8 & 9). In these diagrams, the amount of a given element is plotted against Larsen differentiation index (D.I.). Fig. 8 shows that the SiO_2 and K_2O increase with D.I., wheeas FeO* (total iron), MgO and CaO decrease with D.I.; Na_2O shows stable values. It is also evident that there is a great chemical contrast between Group 1 granites on the one hand and both Group 2 and Group 3 on the other hand. Group 1 granites are richer in FeO*, MgO and CaO and poorer in K_2O and SiO_2 than both Group 2 and Group 3. In Fig. 9, it appears that Group 1 granites are richer in Sr and Cu than Group 2 and Group 3, whereas Nb, Zr, Y and Rb are more concentrated in Group 2 and Group 3 than in Group 1.

The most significant geochemical characteristics of the three granite groups are summarized as follows:

Group 1 granites:

- They have calc-alkaline nature and sodic tendencies.
- SiO2 contents range between 65 and 71 %.
- They have relatively high CaO (2.59-5.21 %). TiO_2 (0.25-0.72 %), AI_2O_3 (15.03-17.71 %), MgO (0.73-1.36%) and FeO* (1.84-4.11) and relatively low K_2O.

- They have relatively low Nb (7-12 ppm), Y (2-20 ppm) and Rb (28-86 ppm) and relatively high Sr (238-756 ppm) and Cu (18-35 ppm).

- The Na_2O content exceeds that of K_2O.

- They have low alkalinity ratio (1.55-2.57) and are both high in solidification index (7.08-14.45) and colour index (4.59-10.86).

Group 2 granites:

- They have characteristics intermediate between Group I and Group 3 since they have intermediate values of CaO (0.34-1.35 %), TiO_2 (0.06-0.37 %), Al_2O_3 (12.17-13.34 %) except for one sample which is 10.78), MgO (0.27-0.56 %), Nb (9-66 ppm), Y (29-130 ppm), Rb (56-108 ppm), and Sr (9-70 ppm).
- They also have intermediate values of alkalinity ratio (3.86-6.39) and solidification index (2.41-5.22).
- Their SiO_2 contents are in the range of 73-77 %.
- The chemical characteristics permit the present Group 2 granites to be subdivided into two subgroups: Group 2 A and Group 2 B. Group 2 A have proper alkaline nature and sodic-potassic characters and are richer in MgO, CaO, TiO_2, Sr, Ba and Cu and poorer in K_2O

Table 2: CIPW norm and various geochemical parameters for the analysed samples

	Group 1								Group 2										Group 3								
	El Fawakhir		Umm Rus		El Shush		El Dabbah		El Radiya		Igl El Ahmar		Abu Itella		Kadabora		Sheikh Salem		El Atawi		Hamrat Ghannam		El Sibai			Abu El Tiyur	
	90	91	780A	5C	625G	631	573	574	696B	708	291	302	812	813A	159A	408	27	28	767	659	235	822B	116A	185E	195E	631	635
C	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.32	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.16	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q	19.26	21.46	22.07	22.57	24.57	27.28	29.26	29.68	31.11	30.87	34.12	32.52	32.04	29.32	29.64	38.60	30.66	33.09	32.91	30.24	35.95	38.01	34.62	33.85	33.68	34.92	32.27
Or	21.77	20.64	11.99	13.23	3.67	11.25	10.36	8.99	21.17	21.71	19.56	21.07	29.76	32.26	29.94	28.43	31.20	29.16	26.79	27.53	28.54	26.88	24.75	25.17	26.32	26.91	27.39
Ab	36.17	34.23	37.67	37.91	36.60	39.98	34.35	33.47	41.90	38.56	38.82	39.01	30.10	34.74	34.76	28.77	33.37	31.89	34.94	37.31	31.23	30.93	36.16	37.66	35.08	32.38	33.47
An	12.14	12.97	16.67	14.86	25.81	16.30	18.50	20.65	2.19	2.65	3.56	2.39	2.36	0.16	0.00	0.22	1.68	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ne	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	0.13	0.00	0.39	0.00	0.23	0.00	0.09	0.00	0.00
Ac	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	0.64	0.00	0.00	0.00	1.64	0.54	1.86	2.31	1.69	0.92	2.33	0.96	2.98
Wo/Di	0.30	0.63	0.82	1.39	0.00	0.16	0.23	0.00	0.02	0.44	0.00	1.26	1.81	0.69	1.50	0.70	0.00	0.00	1.14	1.20	0.00	0.00	0.67	0.15	0.52	0.87	0.97
En/Di	0.13	0.25	0.32	0.51	0.00	0.10	0.14	2.80	0.02	0.19	0.00	0.65	0.70	0.36	0.62	0.60	0.00	0.00	0.53	0.65	0.00	0.00	0.34	0.13	0.25	0.43	0.31
Fs/Di	0.17	0.39	0.31	0.91	0.00	0.04	0.07	0.91	0.00	0.25	0.00	0.58	1.14	0.31	0.88	0.00	0.00	0.00	0.60	0.50	0.00	0.00	0.31	0.00	0.26	0.43	0.70
Fs/Hy	2.52	1.92	4.24	4.10	0.98	0.68	1.09	0.00	0.03	1.65	1.32	0.38	0.16	0.26	0.20	0.00	0.00	0.00	0.34	0.07	0.76	0.54	0.31	0.00	0.45	0.30	0.29
En/Hy	3.25	3.00	2.63	2.31	3.39	1.71	2.29	0.00	1.06	1.23	1.06	0.43	0.10	0.31	0.14	0.20	0.72	0.70	0.30	0.09	0.71	0.67	0.34	0.55	0.43	0.30	0.66
Mt	1.51	1.61	1.48	1.09	2.36	1.35	2.06	2.12	1.60	0.75	0.54	1.09	0.15	1.07	1.09	1.27	1.30	0.59	0.00	1.07	0.00	0.15	0.00	0.71	0.00	1.06	0.35
Il	1.37	1.12	0.49	0.48	0.89	0.51	0.91	0.93	0.25	0.71	0.21	0.21	0.11	0.11	0.15	0.31	0.36	0.72	0.25	0.30	0.23	0.21	0.15	0.34	0.17	0.13	0.13
R_1	1939	2093	2304	2289	2607	2539	2716	2782	2362	2401	2614	2532	2533	2248	2287	2780	2325	2500	2454	2297	2536	2739	2492	2465	2466	2562	2373
R_2	634	654	767	737	974	710	765	817	321	349	344	380	399	304	336	268	306	327	305	319	234	229	272	254	269	280	272
An content	25.13	27.48	30.68	28.16	41.35	28.96	35.01	38.16	4.96	6.44	8.40	5.77	7.27	0.45	0.00	0.77	4.80	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colour index	9.25	8.92	10.62	10.86	8.13	4.59	6.84	6.76	3.00	5.26	3.40	4.01	4.24	3.13	5.26	3.12	2.55	2.92	4.94	4.46	3.95	3.89	4.08	2.81	4.52	4.68	6.39
FeO^*	3.84	3.79	4.11	3.82	3.09	1.84	2.91	2.83	1.58	2.01	1.29	1.60	0.89	1.34	1.83	1.33	1.38	1.08	1.11	1.59	1.09	1.25	0.92	1.16	1.16	1.71	2.02
Mafic index	78.80	81.76	78.02	77.88	69.78	72.21	75.27	72.68	78.91	78.49	75.71	79.10	73.75	83.42	85.86	80.97	83.03	79.58	77.51	84.36	79.53	82.19	77.43	81.26	81.52	86.26	89.96
Felsic index	75.45	72.08	63.31	64.71	48.77	66.37	60.25	56.85	94.97	91.68	91.68	88.24	86.41	96.29	92.74	95.51	96.45	94.78	94.22	94.05	100.00	100.00	96.45	99.21	97.29	95.30	95.03
Alk. ratio	2.57	2.42	2.00	2.10	1.55	2.06	1.87	1.74	4.59	4.31	3.86	4.12	4.47	6.39	5.97	6.34	5.49	4.41	6.40	5.87	8.63	7.98	6.69	6.55	7.08	6.40	6.95
Larsen D.I.	22.28	22.07	19.47	19.90	16.00	21.46	20.28	18.40	27.66	28.93	27.30	27.30	28.34	29.99	29.21	29.69	29.69	29.31	29.25	28.94	30.23	30.59	29.08	29.43	29.66	29.28	29.26
Solidification index	8.18	7.08	10.04	9.61	14.45	7.90	10.06	11.69	4.09	5.22	4.41	4.21	3.27	2.41	2.71	3.28	2.66	2.78	3.17	2.72	2.73	2.68	2.73	-2.64	2.60	2.73	2.11

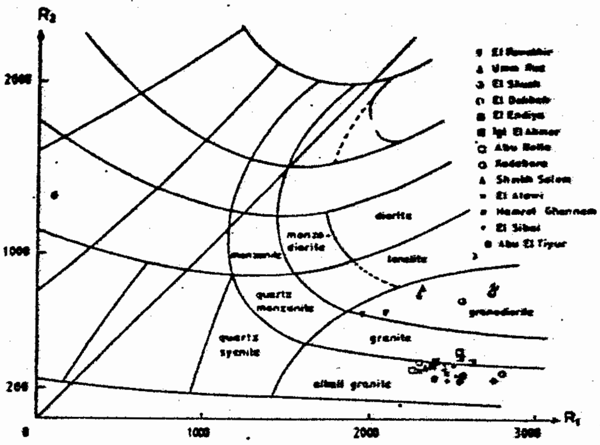

Fig. 2 R_1 R_2 chemical variation diagram.

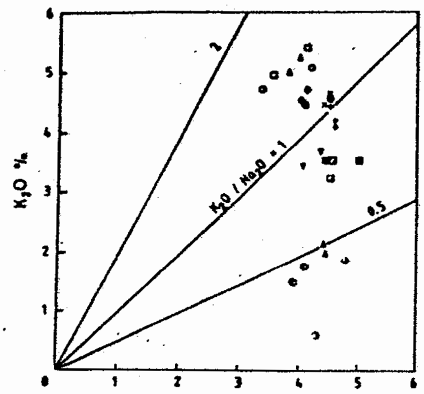

Fig. 4 Variation in alkalies of the studied granitic rocks; symbols as in Fig. 2.

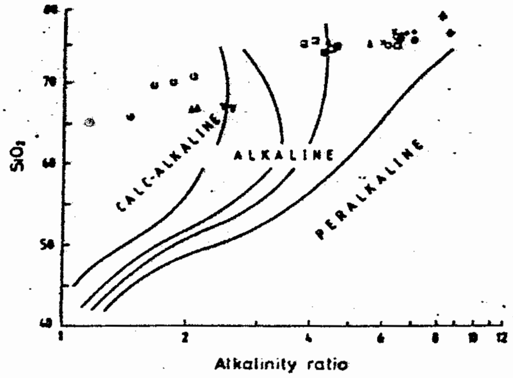

Fig. 3 Alkalinity variation diagram of Wright (1969); Symboles as in Fig. 2

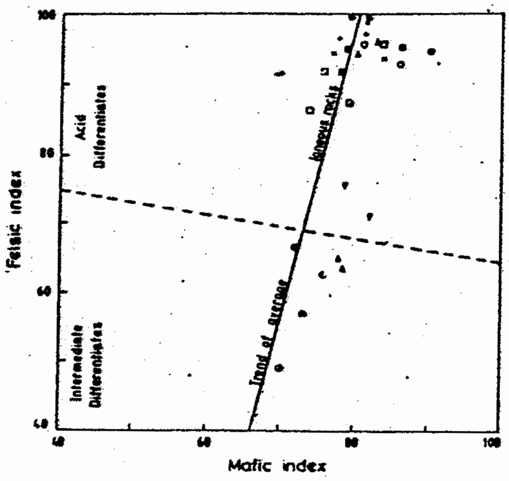

Fig. 5 Mafic index - felsic index relation; symbols as in Fig. 2.

Nb, Y and Rb than Group 2 B. Group 2 B, on the other hand, have strongly alkaline nature and potassic character. In Group 2 A, the Na_2O content exceeds that of K_2O whereas in Group 2 B, the K_2O is always high compared to the Na_2O.

Group 3 granites:

- They are strongly alkaline in composition and have potassic character.

- SiO_2 contents range between 75-79 %.

- They have relatively low CaO (0-0.58 %), TiO_2 (0.07-0.16 %), AI_2O_3 (11.00-11.89 %), MgO (0.24-0.33 %) and FeO* (0.92-2.02) and relatively high K_2O.

- They have relatively high Nb (34-85 ppm), Y (73-159 ppm) and Rb (77- 200 ppm) and low Sr (2-8 ppm except for El Atawi granite).

- The K_2O content exceeds that of Na_2O.

- They have high alkalinity ratio (5.87-8.63) and are both low in solidification index (2.11-3.17) and colour index (2.81-4.94).

The Granitic System:

The normative proportions Qz, Ab and Or are plotted on the Qz-Ab-Or-H_2O system at water-vapour pressures ranging between 0.5 and 10 Kb (Tuttle & Bowen, 1958; Fig. 10). The plots of both Group 2 and Group 3 granites fall at or close to the low temperature minima at low to moderate water-vapour pressures whereas the plots of Group 1 occupy a zone extending from the low temperature minima at modrate water-vapour pressures towards the Qz-Ab side line. The close relationship between the normative composition of the analysed granitic rocks in Washington's (1917) table and the minimum melting point at low water-vapour pressure, lead Tuttle and Bowen (1958) to conclude that the magmatic liquids are involved in the genesis of granitic rocks. El-Gaby (1975) has shown that the field composition of the Egyptian younger granites are close to the low melting point at low water-vapour pressures in the Qz-Ab-Or-H_2O system of Tuttle and Bowen (1958). He considered these granites to be largely intruded as palingenetic magmas.

The plots of Group 1 granites lie deep in the plagioclase field on the ternary diagram of the Ab-An-Or-H_2O system (Fig. 11), whereas both Group 2 and Group 3 granites are situated about the cotectic curve at 1Kb water-vapour pressure (James and Hamilton, 1972) near the low temperature minimum of the Ab-Or binary system. This indicates that the crystal-liquid equilibrium was the dominant mechanism involved in the genesis of these granitic rocks.

Tectonic Classification:

Pearce et al. (1984) has proposed the use of Y, Nb and Rb in discriminant diagrams to determine the tectonic settings of granites. They subdivided the granites according to their intrusive settings into four main groups, viz. ocean ridge granite (ORG), volcanic arc granite (VAG), within plate granite (WPG) and collision granite (COLG).

In Figs. 12a, b, the analyses of Group 1 granites fall within the field of VAG + COLG + ORG, whereas analyses of Group 3 granites fall within the field of WPG + ORG. It can also be seen from these two figures that the analyses of Group 2 A fall within the field of VAG + COLG + ORG (but very close to the field of WPG + ORG) whereas those of Group 2 B fall within the field of WPG + ORG. Rb forms an almost perfect discriminant between ORG and WPG and between VAG and COLG (Pearce et al., 1984). The position of the data points confirms a within plate setting for Group 3 granites (Fig. 12 c) whereas Group 1 granites plot in the field of volcanic arc granites (Fig. 12 b). The analyses of the Group 2 B fall within the field of within plate granites (Fig. 12 c),

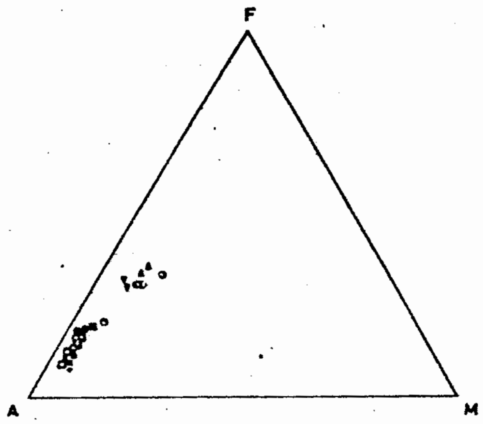

Fig. 6 AFM variation diagram ; symbols as in Fig. 2.

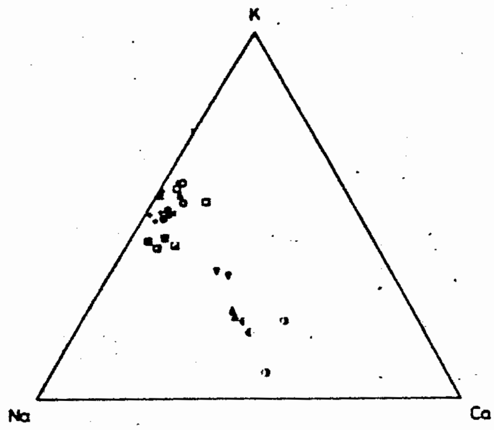

Fig. 7 K – Na – Ca variation diagram ; symbols as in Fig. 2.

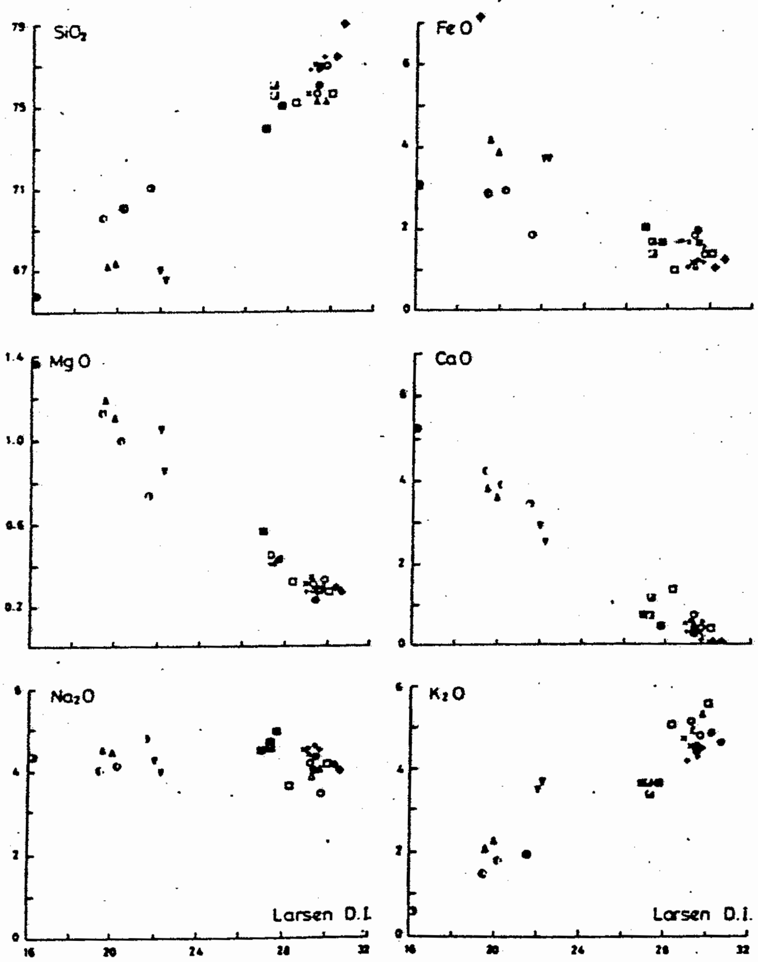

Fig. 8 Plots of the contents of the major elements in the studied granites versus Larsen

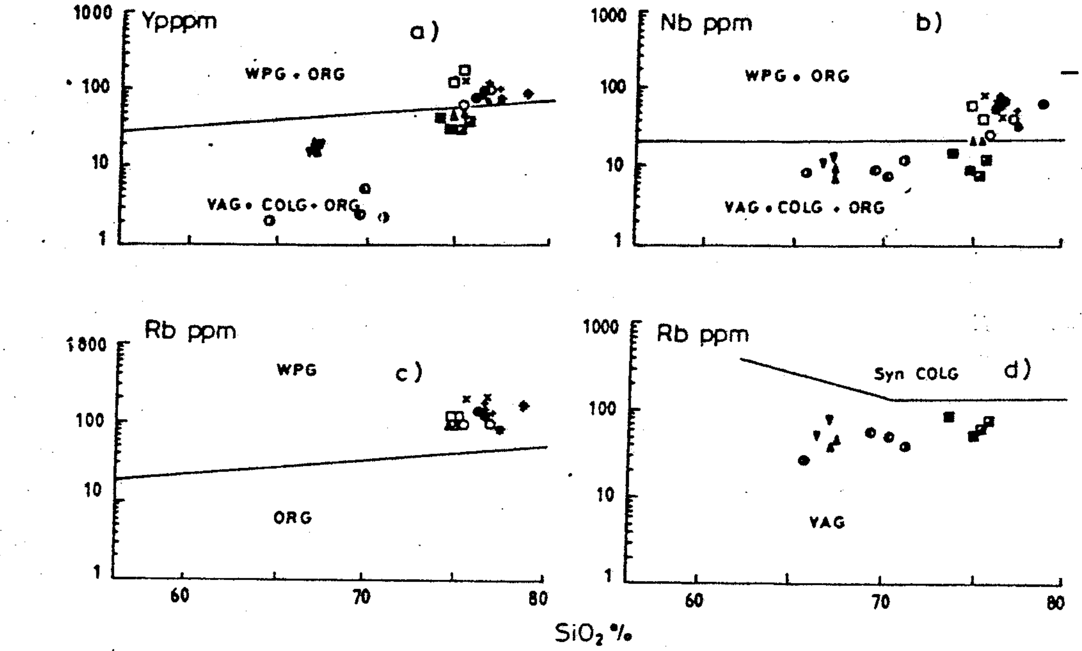

Fig. 12 SiO_2 variation diagrams for Y, Nb and Rb ; symbols as in Fig. 2.

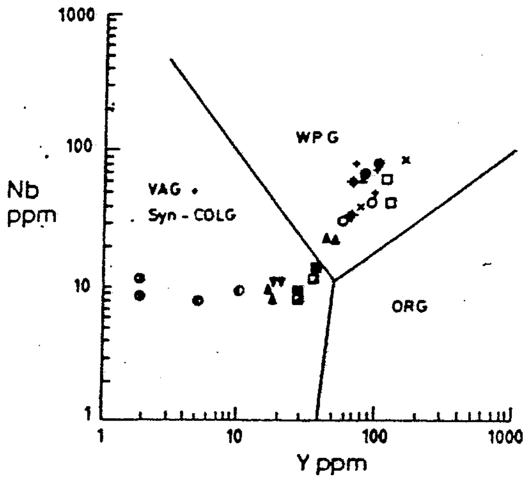

Fig. 13 Nb - Y discriminant diagram ; symbols as in Fig. 2.

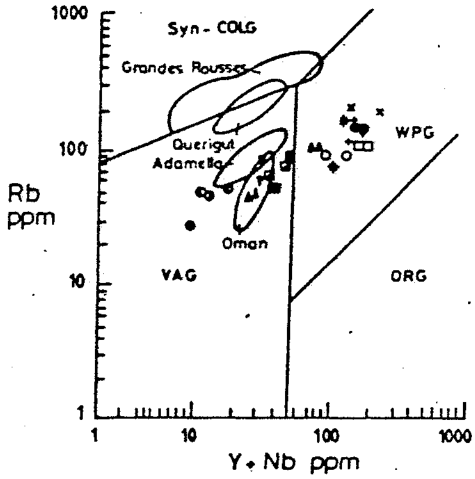

Fig. 14 Rb - (Y + Nb) discriminant diagram; symbols as in Fig. 2.

whereas those of Group 2 A fall within the field of volcanic arc granites (Fig. 12 d).

Discrimination between ORG, VAG, WPG and COLG is obvious from the Y-Nb and Rb-(Y+Nb) diagrams (Figs. 13, 14) where complete separation between these settings is achieved better than in the previous diagrams (Pearce et al., 1984). It is clear from Fig. 13 that Group 1 analyses plot within the field of VAG + COLG whereas Group 3 analyses fall within the field of WPG. It can also be seen that the analyses of Group 2 A plot within the field of VAG + COLG but very close to the field of WPG whereas the analyses of Group 2 B plot within the field of WPG. Pearce et al., (1984) inferred that a graph of Rb against Y+Nb should carry most of the discriminating power of these three elements. The resulting diagram (Fig. 14) reveals virtually no overlap between the designated intrusive settings. In this diagram, Group 1 analyses fall within the field of volcanic arc granite whereas Group 3 analyses fall within the field of within plate granite. It is also clear from Fig. 14 that the analyses of Group 2 A fall within the field of volcanic arc granite whereas those of Group 2 B fall within the field of within plate granite.

The post collision granites represent a major problem in all tectonic-geochemical classifications of granites since their characteristics depend on the thickness and compositon of the lithosphere involved in the collision event and on the precise timing and location of magmatism (Pearce et al., 1984). The Rb and Y+Nb ranges for some typical post-collision granites have been plotted in Fig. 14. They most commonly lie near the top of the VAG field, as exemplified by the zoned Adamello pluton (Dupuy et al., 1982) and the granite of Oman and Masirah Island, and in both the VAG and COLG fields as in the case of the Queigut pluton (Fourcade and Allegre, 1981) as well as in the WPG and COLG fields as in the case of the Hercynian Grandes Rousses granite (Oliver et al., 1983). It is clear from Fig. 14 that the analyses of El Fawakhir and Umm Rus granites fall within the Oman post-colision granite field. It is also observed that the analyses of Group 2 A lie near the top of the VAG field similar to some post-collision granites.

DISCUSSION AND CONCLUSION

The chemical characteristics obtained from 27 analyses of 13 Younger Granite plutons lead to their subdivision into three groups with considerable mineralogical and chemical contrasts between them.

Group 1 includes the granites of El-Fawakhir, Umm Rus, El Shus and El Dabbah. These granites are mainly have calc-alkaline nature and sodic tendencies. They are very similar to the volcanic arc granites as described by Pearce et al. (1984). The Group 1 granites have relatively low SiO_2, K_2O, Nb, Y and Rb and high CaO, TiO_2, Al_2O_3, MgO, FeO*, Sr and Ba, all indicative of the relative abundance of mafic phases and higher An plagioclase. The present granites show the main characteristics of the I-type (Cordilleran) granites according to the shceme of Pitcher (1983) as they: a) commonly form granodiorite, b) have hornblende and biotite as the dominant ferromagnesian minerals, c) muscovite is absent, d) they do not contain cordierite, garnet, andalusite or sillimanite, e) sphene is the common accessory, f) magnetite is the common iron oxide, g) their SiO_2 content is dominantly in the range 65-71 %, h) the Na_2O content is usually higher than 3.2 % i) their molecular Al_2O_3/Na_2O+K_2O+CaO is generally less than 1.1, j) most of them show CIPW normative diopside. The I-type (Cordilleran) granites was considered by Pitcher (1983) as Andinotype marginal continental arc. Pitcher (op. cit.) stated that: "During ocean-continent subduction, as during the Createceous in the Central Andes, this recycling is so continued a process, deep beneath the continental lip, as to lead to the segregation of underplate material of dioritic composition. Episodic wholescale remelting of the latter provides the pulses of I-type (cordilleran) magmas, and these differentiate during their temporary residence in inter-connected chambers, the degree of differentiation depending on the period of residence".

Group 2 includes the granite plutons of IgI El Ahmer, El Endiya, Kadabora, Abu Itella and Sheikh Salem. The granites of these plutons have true granitic composition, proper alkaline to strongly alkaline nature and sodic-potassic characters. In fact, the Group 2 granites have intermediate values of major and trace elements between Group 1 and Group 3. The geochemical characteristics permit the present Group 2 granites to be subdivided into two subgroups,Group 2 A and Group 2 B, although the properties of these two subgroups are somewhat overlapping. Group 2 A generally contains less K_2O,Nb, Y and Rb and higher MgO, CaO, TiO_2, Sr and Ba than Group 2 B. On the trace element discrimination diagrams (Pearce et al., 1984), Group 2 A lie near or within some post-collision granite fields whereas Group 2 B plot within the field of within plate granite. Pearce et al., (1984) mentioned that the post-collision granites can plot in the syn-collision granite, volcanic arc granite or within plate granite fields. The author is inclined to consider the Group 2 granites as post-collision granites. According to pearce et al., (1984), the post-

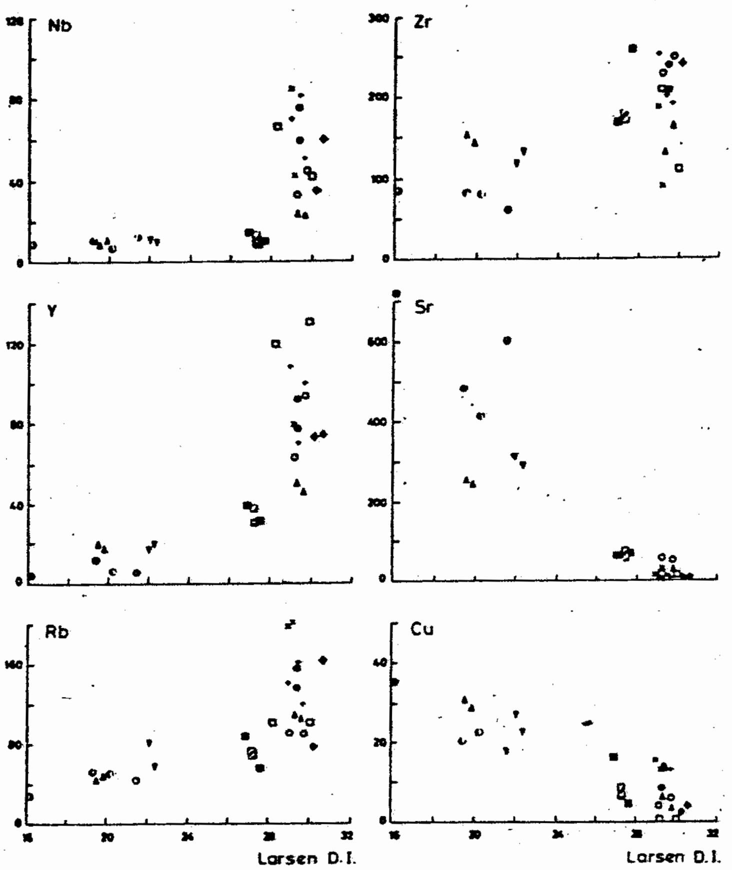

Fig. 9 Plots of the contents of the trace elements versus D.I. ; symbols as in Fig. 2.

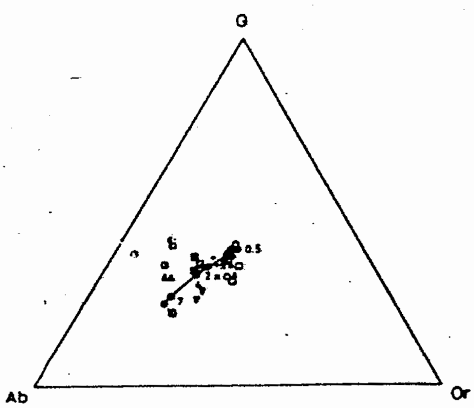

Fig. 10 Normative Q - Or - Ab proportions for the analysed granitic rocks. The solid line represents the trace of the isobaric minima or ternary points of the granite system at water vapour pressures from 500 to 10,000 bars (Tuttle & Bowen, 1958).

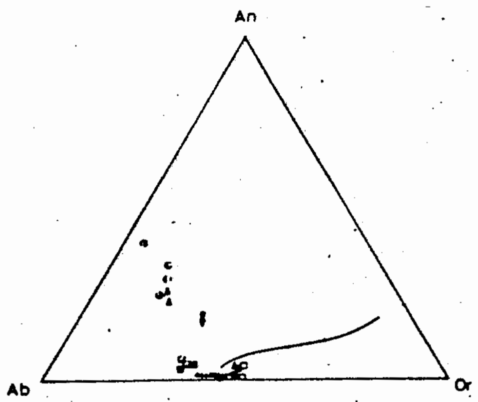

Fig. 11 Normative Ab - An - Or proportions for the analysed granitic rocks; symbols as in Fig. 2. The solid line represents the - feldspar boundary curve for the quartz - saturated ternary feldspar system at 1 Kb water vapour pressure (James & Hamilton, 1972).

collision granites can result both from melting of the lower crust due to thermal relaxation following collision and from melting of the upper mantle (which may be of "within plate" or "arc" composition) due to the adiabatic decompression that accompanies post-collision uplift and erosion.

Group 3 includes the granite plutons of El Atawi, Hamret Ghannam, El Sibai and Abu El Tiyur. The granites of these plutons are riebeckite-bearing alkaline granites which form ring-like granite bodies. These granites were considered by El-Ramly and Hussein (1982), Hussein et al., (1982) and El-Gaby et al., (1987) to be related to the ring complexes of Egypt. Comparing with the two aforementioned granite groups, Group 3 granites have relatively low CaO, TiO_2, Al_2O_3, MgO, FeO*, Sr and Ba and high SiO_2, K_2O, Nb, Y and Rb. The Group 3 granites plot well within the field of within plate granite on the trace element discrimination diagrams proposed by Pearce et al., (1984) and show all the characteristics given by Pitcher (1983) for the A-type granite formed within anorogenic situations since they: a) commonly occur as shallow plutons of ring-like bodies, b) usually of alkalic granite composition, c) riebeckite is frequent and green biotite is present, d) K-feldspars often occur as perthites, e) Their molecular Al_2O_3/Na_2O+K_2O+CaO is more than 1.1, f) associated with caldera-centred alkalic lavas (the caldera alkalic lavas are exemplified by the

Katherina Volcanics which are rare and only described from South Sinai as remanants of a caldera by Shimron, 1980), g) fluorite mineralization is associated. In the light of the foregoing it can be suggested that Group 3 granites are anorogenic granites intruded into the continental cratons that may be undergoing initial stages of rifting.

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