Acta Mineralogica-Petrographica, Szeged, XXIV/2, 245—256, 1980

BEHAVIOUR OF MAJOR ELEMENTS IN THE GRANITIC ROCKS OF KADABORA PLUTON, EASTERN DESERT, EGYPT

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ABSTRACT

The petrochemical features of the granitic rocks of Kadabora pluton, Eastern Desert, Egypt are presented. Results of twenty new chemical analyses are advanced and processed following several petrochemical parameters. The average chemical composition of Kadabora granitic rocks is in harmony with that of low-calcium granite of TUREKIAN and WEDEPOHL [1961]. The granitic rocks possess in general rather pronounced potassic characters with few sodic affinities. Chemical classification of the granitic rocks is attempted. Magmatic origin is suggested for the examined granitic rocks and is based on experimentally studied systems.

INTRODUCTION

The granitic rocks of Kadabora are regarded by EL-RAMLY and AKAAD [1960], and SABET [1961] and EL-RAMLY [1972] as belonging to the younger group of granitoids. Recently the granitic pluton of Kadabora, together with several other granitic plutons have been considered by SABET *et al.* [1976] as belonging to the late Proterozoic-early Paleozoic intrusions. These authors further assigned such granitic plutons

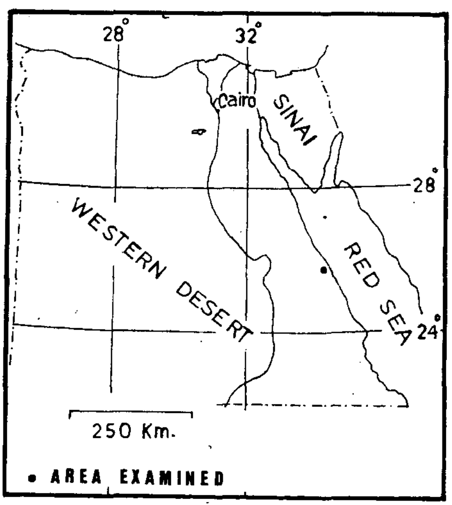

Fig. 1. Location map

to the "Cattarian Group" and to the phase of the coarse-grained biotite granite and the leucocratic granite.

The examined granitic rocks of Kadabora occur in the central Eastern Desert of Egypt *(Fig. 1)*. They are two-feldspar granites in which the feldspars comprise plagioclase, orthoclase and microcline perthite. The chemistry of biotites separated from these granitic rocks proved the magmatic origin of the host granite [SALEM, 1975].

The present study forms part of a continuing program aiming at the petrochemical characterization and classification of the group of younger granitoids of Precambrian age in the Central Eastern Desert of Egypt. [KABESH *et al.*, 1975; KABESH *et al.*, 1976; and KABESH *et al.*, (in press)].

The purpose of the present work is to discuss the petrochemical characteristics of Kadabora granitic stock. A chemical classification of the granitic rocks is advanced based on normative feldspars.

GENERAL GEOLOGIC FEATURES OF KADABORA GRANITIC ROCKS:

The granitic rocks of Gabal Kadabora form a roughly circular mass with rather high relief covering a total area of about 154 sq. km. The granitic rocks show intrusive sharp contacts with medium to low-grade metasediments in the east as well as with dioritic rocks at the West and South, sometimes, showing discordant relations. Kadabora granitic rocks may be classified in the field on the basis of feldspar colour into grey, pink and red. They also comprise porphyritic and even-grained non-porphyritic types *(Fig. 2)*. The boundary between these types is gradational and need not reflect mineralogical changes or important variation in the colour index. There-

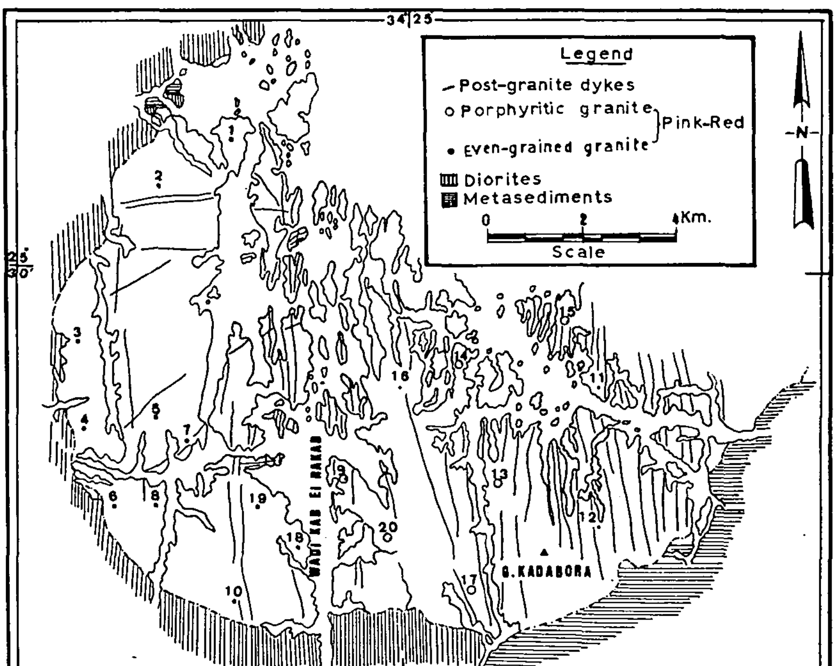

Fig. 2. Generalized geological map of Kadabora Stock showing granitic types and sample location

fore the granitic rocks of Kadabora my be regarded as homcgeneous representing crystallization of the granitic magma in one phase of emplacement. Cuboidal and sheet jointing are well develcped. Bouldery and exfoliaticn types of weathering are recognized. Several postgranitic dykes of acidic intermediate basic and alkaline composition are recorded. Milky quartz veins and lenses are found in several spots.

PETROGRAPHY

Petrographically three main types have been reccgnized namely biotite-granite, biotite-muscovite granite, and leucogranite. These granitic rocks show holocrystalline hypidiomorphic granular texture. They are generally medium-grained either non-porphyritic or porphyritic with megacrysts of microcline-perthite and occassionally quartz. The essential constituents are represented by quartz, microcline, orthoclase, microcline-perthite, albite, and little amount of oligcclase, biotite and muscovite. The accessory minerals are represented by euhedral zircon, apatite, sphene and iron oxides. Perthite intergrowths are of the patchy and the vein types. Microcline usually shows well by cross-hatching. Myrmekitic intergrowths are not uncommon.

Quartz sometimes forms megacrysts and usually forms intersitial aggregates. In rare cases quartz is intergrowth with alkali feldspars as micrographic texture.

Quartz is sometimes deformed and shows strong wavy extinction. Biotite forms irregular stout flakes, sometimes with torn ends and enclose zircon and iron oxides. Brown biotite is the common mafic while green biotite is rarely observed. Biotite is occasionally chloritized muscovite is common sometimes in association with biotite.

PETROCHEMICAL CHARACTERS

The chemical analysis of twenty samples representing the different types of the granitic rocks of Kadabora stock is given in Table 1 and the location of the analyzed sample is given in *Fig. 2*.

TABLE 1

Chemical analysis of the granitic rocks of Kadabora

Sample number	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	MnO	CaO	Na_2O	K_2O	P_2O_5	TiO_2	H_2O^+	H_2O^-	Total
1	73.85	13.89	1.07	0.86	0.11	0.03	0.39	4.26	4.50	—	0.01	0.84	0.08	99.89
2	74.99	13.63	0.59	0.68	0.20	0.03	0.46	4.73	4.00	—	—	0.45	0.08	99.84
3	74.24	14.53	0.81	0.31	0.01	0.03	0.36	4.32	4.00	—	0.01	0.50	0.09	99.21
4	75.14	13.35	0.96	0.68	0.01	0.02	0.56	3.10	5.29	—	0.02	0.45	0.01	99.59
5	73.27	14.59	0.30	0.31	0.02	0.01	0.46	4.36	5.81	—	0.02	0.42	0.26	99.83
6	72.76	14.48	0.85	0.37	0.03	0.03	0.39	4.24	5.36	—	0.02	0.65	0.07	99.25
7	73.55	13.89	0.79	0.37	0.03	0.02	0.32	4.21	5.06	—	0.03	0.68	0.23	99.18
8	73.99	13.90	0.57	0.81	0.20	0.02	0.40	4.69	5.06	—	—	0.40	0.25	100.29
9	74.80	13.04	0.40	1.68	0.02	0.02	0.88	3.15	5.11	0.04	0.05	0.51	0.17	99.87
10	73.18	13.88	0.40	1.24	0.03	0.03	0.37	4.35	5.22	—	0.05	0.75	0.15	99.65
11	73.93	14.04	0.30	0.44	0.14	0.03	0.33	3.94	5.74	—	0.03	0.45	0.08	99.45
12	74.62	14.44	0.22	0.50	0.20	0.02	0.40	3.73	4.14	0.14	0.02	0.75	0.08	99.26
13	71.88	14.96	1.00	1.18	0.22	0.02	0.99	3.88	4.82	0.14	0.06	0.41	—	99.56
14	73.28	14.79	0.67	0.56	0.03	0.02	0.34	4.15	5.59	0.14	0.09	0.32	—	99.98
15	73.79	15.37	0.08	0.44	0.01	0.02	0.36	3.88	4.85	—	0.05	0.85	0.14	99.84
16	73.85	13.40	0.61	1.87	0.02	0.02	0.70	3.50	4.65	—	0.03	0.85	0.27	99.77
17	72.77	13.40	0.81	1.62	0.02	0.02	0.70	4.04	4.82	—	0.03	0.85	0.21	99.29
18	73.88	13.33	0.26	0.47	0.21	0.01	0.33	3.75	5.57	—	0.02	0.85	0.15	98.83
19	73.55	14.50	0.50	1.18	0.14	0.01	0.91	2.39	5.47	—	0,06	0.65	0.14	99.50
20	73.43	14.46	0.69	0.50	0.03	0.01	0.54	3.40	5.52	—	0.05	0.55	0.11	99.29

Fig. 3 shows the variation of the weight percentages Na_2O+K_2O, $FeO+Fe_2O_3$ and MgO of Kadabora granitic rocks. It is evident that these granitic rocks are homogeneous in composition, rich in alkalis and poor in FeO and MgO.

Fig. 4 shows the variation of SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O and K_2O against differentiation index (D. I.) of THORNTON and TUTTLE [1960]. It is clear that

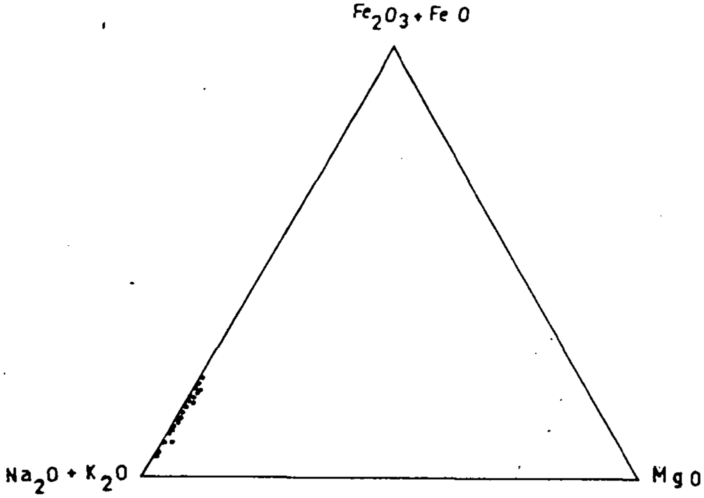

Fig. 3. Relationship between MgO, $(FeO+Fe_2O_3)$ and (Na_2O+K_2O)

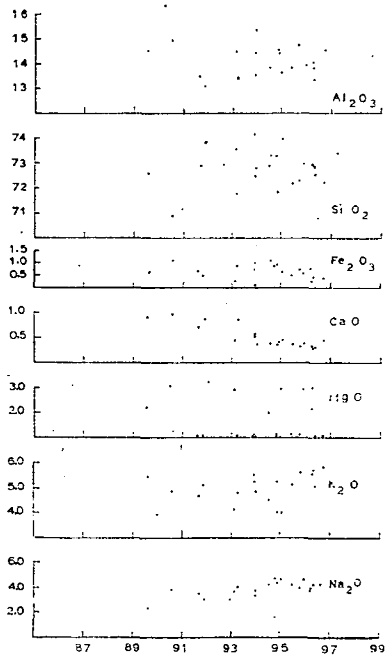

Fig. 4. Plots of percentages of major oxides *versus* THORNTON and TUTTLE'S differentiation index

SiO_2, Na_2O and K_2O increase with D. I., Al_2O_3 and MgO show no definite trend. *Fig. 5* shows the relative molecular ratio of K_2O/Na_2O of the granitic rocks. It is clear from the diagram that all the examined granitic rocks have K_2O/Na_2O ratio >0.6. According to RAGUIN [1965], these granitic rocks possess potassic characters. SEGERSTROM and YOUNG [1972] found a felsic mafic ratio to be very useful in classifying igneous rocks. This ratio is expressed by $SiO_2+K_2O/Fe_2O_3+FeO+MgO+CaO$. Using data by NOCKOLDS [1954] on average chemical composition of igneous rocks,

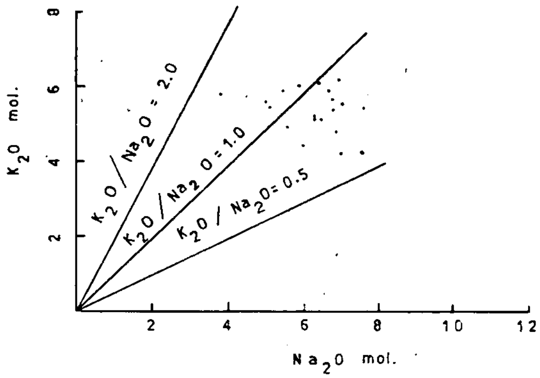

Fig. 5. Variations in alkalies of the granitic rocks

SEGERSTROM and YOUNG (op. cit.) advanced felsic mafic ratios for the various igneous rocks slightly modified by YOUNG, the distribution is as follows:

Rock type	*Felsic-mafic ratio*
Extreme alkali granite	>50
Alkali granite	25—50
Granite	15—25
Qz—monzonite	10—15
Granodiorite	7—10
Qz—diorite	5—7
Monzonite	3—5
Diorite	2.1—3
Gabbro	1.4—2.1
Utramafics	<1.4

In the present work the felsic-mafic ratio of the analysed rocks ranges from 23.77 to 76.55 (Table 2). Thus they pertain to alkali granite and extreme alkali granite.

The calculated NIGGLI values of the examined granitic rocks are given in Table 3. The values of al are plotted against alk values of NIGGLI, *(Fig. 6)*. It is clear that the granitic rocks of Kadabora fall within the relatively alkali rich according to BURRI—NIGGLI [1945]. *Fig. 7* shows the plots of NIGGLI values of the analyzed granitic rocks. The diagram represents a section through the double tetrahedron al-fm-c-alk, as has been outlined by NIGGLI [1954].

From the diagram, it appears that all the examined granitic rocks of Kadabora pertain to the alkali-aluminosilicate magma type (type II in NIGGLI's calssification).

TABLE 2

Felsic-mafic ratio for the examined granites

Sample No.	Felsic-mafic ratio	Sample No.	Felsic-mafic ratio
1	33.99	11	69.10
2	43.38	12	62.49
3	55.41	13	23.77
4	37.80	14	51.89
5	76.55	15	92.72
6	50.22	16	25.62
7	55.58	17	25.91
8	42.29	16	65.51
9	42.87	19	29.82
10	40.56	20	46.79
Average			47.86

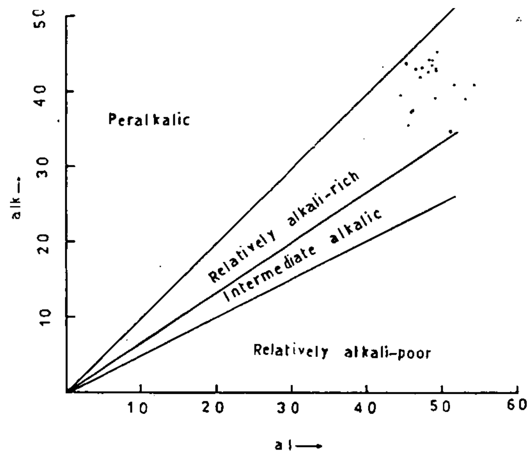

Fig. 6. Relationship of *al* and *alk* in the granitic rocks (after BURRI and NIGGLI, 1945)

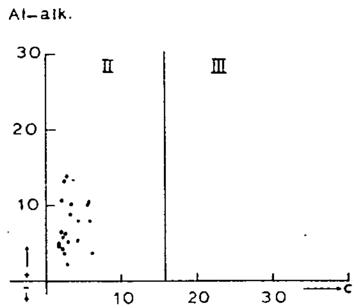

Fig. 7. Plots of granitic rocks on NIGGLI's planar representation

TABLE 3

Niggli values for the the examined granites

Sample number	al	fm	c	alk	mg	k	qz	si
1	47.27	9.90	2.39	40.44	0.09	0.41	+164.86	426.62
2	47.24	7.88	2.90	41.98	0.22	0.36	+173.10	441.02
3	51.61	5.43	2.32	40.64	0.01	0.38	+184.96	447.52
4	48.66	8.18	3.72	39.44	0.01	0.53	+207.15	464.91
5	49.02	2.95	2.81	45.22	0.06	0.47	+136.82	417.70
6	48.90	5.58	2.37	43.15	0.04	0.45	+144.38	416.98
7	48.73	5.72	2.04	43.51	0.04	0.44	+163.92	437.96
8	45.97	7.99	2.39	43.64	0.21	0.41	+140.75	415.31
9	46.04	10.51	5.65	37.80	0.02	0.52	+196.90	448.10
10	46.67	7.99	2.26	43.07	0.03	0.44	+145.38	417.66
11	48.86	4.86	2.09	44.18	0.25	0.49	+159.90	436.62
12	52.89	5.57	2.65	38.89	0.33	0.42	+208.35	463.91
13	45.57	13.54	5.53	35.35	0.12	0.45	+130.24	371.64
14	49.23	5.84	2.07	42.85	0.04	0.47	+142.72	414.12
15	54.05	2.73	2.29	40.92	0.03	0.45	+176.81	440.49
16	46.28	12.12	4.37	37.23	0.01	0.46	+184.01	432.93
17	44.75	11.38	4.22	39.65	0.01	0.44	+153.90	412.50
18	48.19	5.53	2.17	44.10	0.35	0.49	+176.99	453.39
19	51.08	8.37	5.82	34.73	0.15	0.60	+200.77	439.69
20	50.60	5.83	3.41	40.33	0.04	0.52	+173.28	434.60

CHEMICAL CLASSIFICATION

The chemical classification of the granitic rocks of Kadabora is advenced based on their normative feldspars. *Fig. 8* shows the normative classificaticn suggested by HIETANEN [1963]. According to this scheme all the granitic rocks fall within the field of granite.

Fig. 9 shows the normative classification of STRECKEISEN, [1976] for the quartz — feldspar rocks. It is clear that the majority of the granitic rocks of Kadabora fall within the field of alkali-feldspar granite with very few in the field of syeno-granite.

PETROGENESIS

The normative quartz, orthoclase and albite proportions of the granitic rocks (Table 4) are plotted and the results compared with experimental data of TUTTLE and BOWEN [1958] *(Fig. 10)*. It appears from the figure that the majority of the granitic rocks have their composition close to the minimum melting point at low to moderate water-vapour pressures in the $NaAlSi_3O_8$—SiO_2—H_2O system. From the close relationship between the minimum melting point for low water vapour pressures and the normative composition fo the analyzed rocks in WASHINGTON's tables [1917] in which normative Qz+Or+Ab are 80%, TUTTLE and BOWEN [1958] concluded that there can be little doubt that magmatic liquids are involved in the genesis of these granitic rocks.

The plots of normative Qz — Ab and Or of the granitic rocks correlated with the synthetic systems $NaAlSi_3O_8$—$KAlSi_3O_8$—SiO_2—H_2O, [LUTH *et al.*, 1964] are shown in *Fig. 11*. The granitic rocks fall in a region corresponding to the liquidus in the

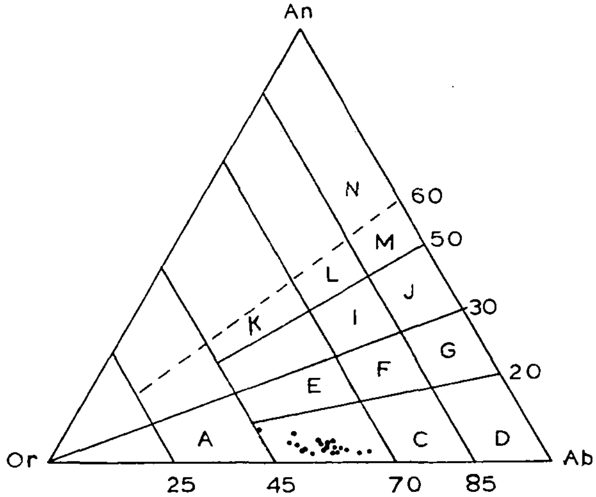

Fig. 8. Triangular diagram for *An*, *Ab* and *Or* normative ratio in the granitic rocks (after HIETANEN, 1963)
A Potassium granite; B Granite; C Granite-Trondhjemite; D Trondhjemite; E Quartz-monzonite; F Monzonite; G Tonalite; H Calci-granite; I Granodiorite; J Quartz diorite; K Calci-monzonite; L Granogabbro; M Gabbro; N Mafic gabbro

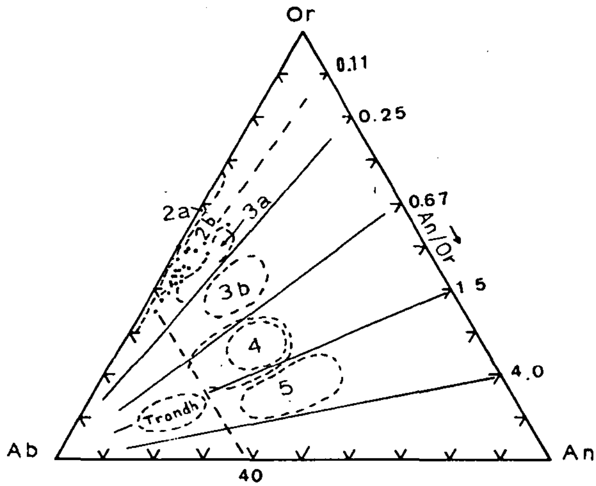

Fig. 9. Quartz-feldspar rocks (after STRECKEISEN, 1976)
2a Alkali granite, Alkali rhyolite; 2b Alkali-feldspar granite, Rhyolite; 3a (Syeno-) Granite, Rhyolite; 3b (Monzo-) Granite, Rhyodacite; 4 Granodiorite, Dacite; 5 Tonalite, Plagidacite, Trondhjemite

minimum system Ab — Or — and Qz — H_2O at relatively low water — vapour pressures.

BOWES [1967] has also concluded that the closeness of the normative Qz, Or and Ab proportions of some of the paraautochthonous and intrusive Lewisian granitic

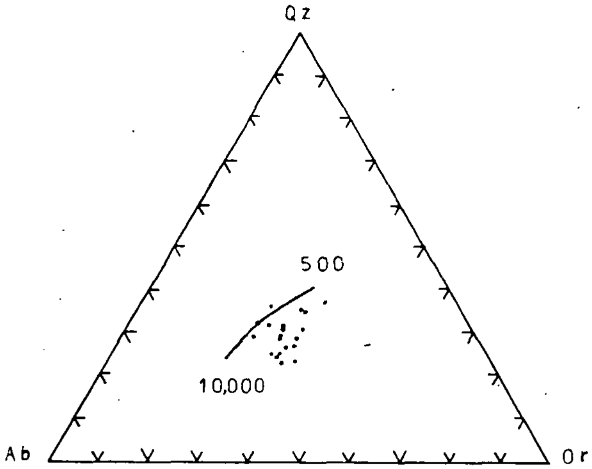

Fig. 10. Normative *Qz*, *Or* and *Ab* proportions for the investigated granite mass. The solid line represent the variation in position of the minimum melting points in the granite system at water vapour pressures from 500 to 10,000 bars (after TUTTLE and BOWEN, 1958)

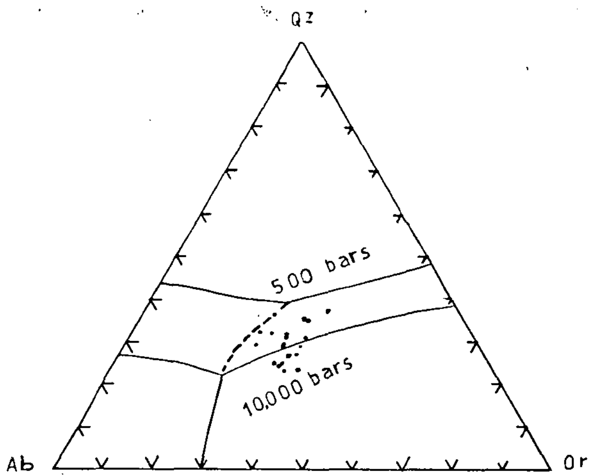

Fig. 11. Normative *Ab*, *Or* and *Qz* of the granitic rocks, plotted in the system $NaAlSi_3O_8$—$KalSi_3O_8$—$SiO_2 \cdot H_2O$. Field boundaries at 500 and 10,000 bars are shown. Dotted line represents the trace of the isobaric minimum or eutectic point at intermediate water pressures (after LUTH et *al.*, 1964)

rocks to the minimum melting point composition at low water-vapour pressure in the system $NaAlSi_3O_8$—$KAlSi_3O_8$—SiO_2—H_2O indicates genesis by selective melting followed by crystallization at low water vapour pressure. The normative Or+Ab and An proportion of the analyzed granitic rocks (Table 4) have been plotted in a ternary diagram *(Fig. 12)*. The majority of the plots fall in the plagioclase field, mostly close to the isobaric univariant curve indicating that crystal equilibrium was the dominant mechanism involved in the genesis of these granites [JAMES and HAMILTON, 1972].

Table 4

Norm values and D. I. for the investigated granites

Sample number	qz	or	ab	an	c	en	fs	mt	il	wo	ap	Total	D. I.
1	28.72	27.00	38.80	1.95	1.45	0.30	0.62	1.14	0.02	—	—	100.00	94.52
2	28.48	23.80	42.80	2.30	0.75	0.56	0.68	0.61	0.02	—	—	100.00	95.08
3	31.19	24.10	39.55	1.80	2.45	0.02	0.08	0.78	0.02	—	—	99.99	94.84
4	33.58	31.95	28.45	2.85	1.69	0.02	0.42	1.02	0.02	—	—	100.00	93.98
5	22.85	34.50	39.35	2.30	0.33	0.06	0.28	0.31	0.02	—	—	100.00	96.70
6	24.08	32.15	38.65	1.95	1.16	0.08	0.08	0.82	0.02	—	—	99.99	94.88
7	27.33	30.50	38.55	1.60	1.01	0.08	0.08	0.81	0.04	—	—	100.00	96.38
8	23.88	29.95	42.15	1.95	—	0.56	0.90	0.60	—	0.01	—	100.00	95.98
9	32.08	30.85	28.90	4.30	0.89	0.06	2.36	0.42	0.06	—	0.06	99.98	91.83
10	24.62	31.25	39.60	1.85	0.46	0.08	1.64	0.42	0.06	—	—	99.93	95.47
11	26.14	34.35	35.80	1.65	0.83	0.40	0.48	0.31	0.04	—	—	100.00	96.29
12	33.92	25.00	34.24	1.45	3.68	0.56	0.66	0.22	0.02	—	0.22	99.98	93.17
13	26.36	28.85	35.30	4.45	1.95	0.60	1.14	1.06	0.06	—	0.22	99.98	90.51
14	25.15	33.20	37.40	1.15	1.64	0.08	0.34	0.70	0.12	—	0.22	100.00	95.75
15	29.65	29.05	35.30	1.80	3.42	0.02	0.60	0.09	0.06	—	—	99.99	94.00
16	31.25	28.15	32.25	3.55	1.51	0.06	2.54	0.64	0.04	—	—	99.99	91.65
17	27.03	28.90	37.30	3.55	0.36	0.06	1.98	0.84	0.04	—	—	100.00	93.23
18	27.98	33.75	34.55	1.70	0.59	0.06	0.54	0.27	0.02	—	—	100.00	96.28
19	34.12	33.30	22.15	4.65	3.38	0.40	1.64	0.28	0.08	—	—	100.00	89.57
20	29.54	33.54	31.30	2.70	2.15	0.08	0.28	0.73	0.06	—	—	100.00	93.99

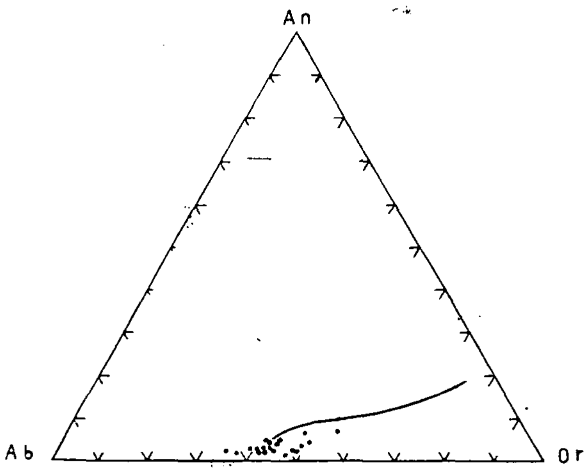

Fig. 12. Normative *Ab*, *An*, *Or* proportions for the investigated granite mass. The solid line represents the two feldspar boundary curve for the quartz saturated ternary feldspar system at 1000 bars water vapour pressure (after James and Hamilton, 1972)

The major normative difference among the granitic rocks of Kadabora lies in the normative An, which ranges between 1.15 and 4.65. Any consideration of experimentally studied systems must therefore take into account the difference in anorthite content. In this regard the normative Ab, An, and Qz proportions of the analyzed samples are plotted and results compared with the experimental data of von Platten [1965] for the system obsidian-anorthite-H_2O having average Ab/An ratio of 17.14 *(Fig. 13)*.

In this diagram there are three areas of crystallization (first for quartz, second for plagioclase and third for alkali feldspar) separated by three cotectic lines which meet in the eutectic point. It is evident that the examined granitic rocks lie in the plagioclase region. The diagram may reveal that the granitic rocks could have been produced by the fusion of a single pre-existing rock type.

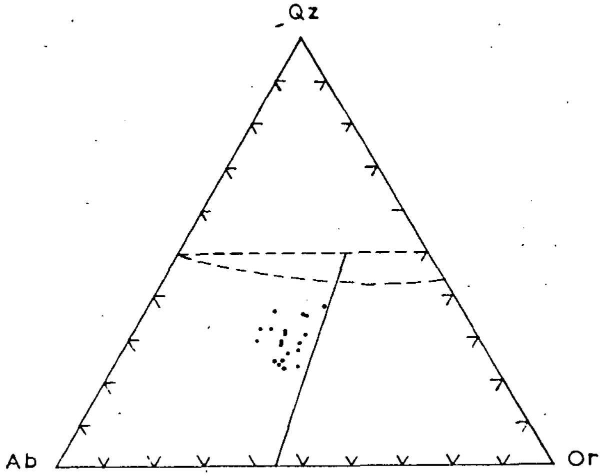

Fig. 13. Plots of normative *Ab*, *Qz*, *Or* of the granitic rocks in relation to cotectic lines and eutectic points valid for obsidian — anorthite — H_2O having an *Ab*/*An* ratio 17.14.

CONCLUSION

The granitic rocks of Gabal Kadabora, from the Precambrian basement of the central Eastern Desert Egypt are petrochemically evaluated. The average chemical composition of the investigated granites compares fairly well with that of low Ca-granite of TUREKIAN and WEDEPOHL [1961]. The granites of Kadabora show potassic characters with scarce sodic tendencies. Petrochemically the examined granitic rocks appear to represent a highly differentiated suite which comprise alkali granite, and syeno-granite. On the basis of experimentally studied systems it is argued that the granitic rocks of Kadabora are of magmatic origin.

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Manuscript received, July 6, 1979.

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