J. Univ. Kuwait (Sci.) **3,** 1976

Geochemistry of some younger granite masses, Southeastern Desert, Egypt

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ABSTRACT

The petrochemical and geochemical characteristics of seventeen granitic masses occurring in the Southeastern Desert of Egypt are presented. The average composition of the granite masses accords reasonably well with that of low calcium granite of Turekian & Wedepohl (1961). The granites have in general pronounced potassic character with some sodic tendencies. Magmatic origin is evident for fifteen granite masses and is based on experimentally studied systems and Ca, Na and K proportions of the analyses.

INTRODUCTION

The present paper deals with the geochemistry of seventeen granitic masses occurring in the Southeastern Desert of Egypt, approximately between latitudes 24° and 25°N. The masses include Gabal El Sukkari, Gabal Nugrus, Gabal Mudargag, Gabal Mueilha, Mueilha tinmine, Urf Abu Hamam, Rod Abu Hamam, Gabal Hamash, Gabal Abu Had, Gabal Homr Akarim, Gabal Ghorab Rayan, Gabal Naslet Marfua, Gabal Metweit, Gabal Homrit Mikbid, Gabal Um Had, Gabal Ghorab Atshan and Gabal El Humr granites (Fig. 1). The geology and the petrography of these granite masses have been recently studied by Soliman (1975). All these granites belong to the well-known group of Younger or Pink granites of Egypt. El-Ramly & Akaad (1960) used the term younger granite for granites and some granodiorites and adamellites younger than the main tectonism that affected the basement complex of Egypt. The term is also equivalent to the late orogenic plutonites (El-Shazly 1964). Hunting Geology and Geophysics (1967) consider the younger granites as characterized by pronounced pink colour, essentially unfoliated, usually forming small masses with isometric outlines and intruding the main batholiths and old geosynclinal sediments of the Southeastern Desert.

Fifty-one samples representing the seventeen younger granite masses in question were chemically analysed by the rapid silicate method described by Shapiro & Brannock (1962) using a spectrophotometer of the Bausch and Lomb 20 type. Silica, Al_2O_3, Fe_2O_3, TiO_2, P_2O_5 and MnO were determined spectrophotometrically. Na_2O and K_2O were determined by flame photometry. CaO and MgO were determined

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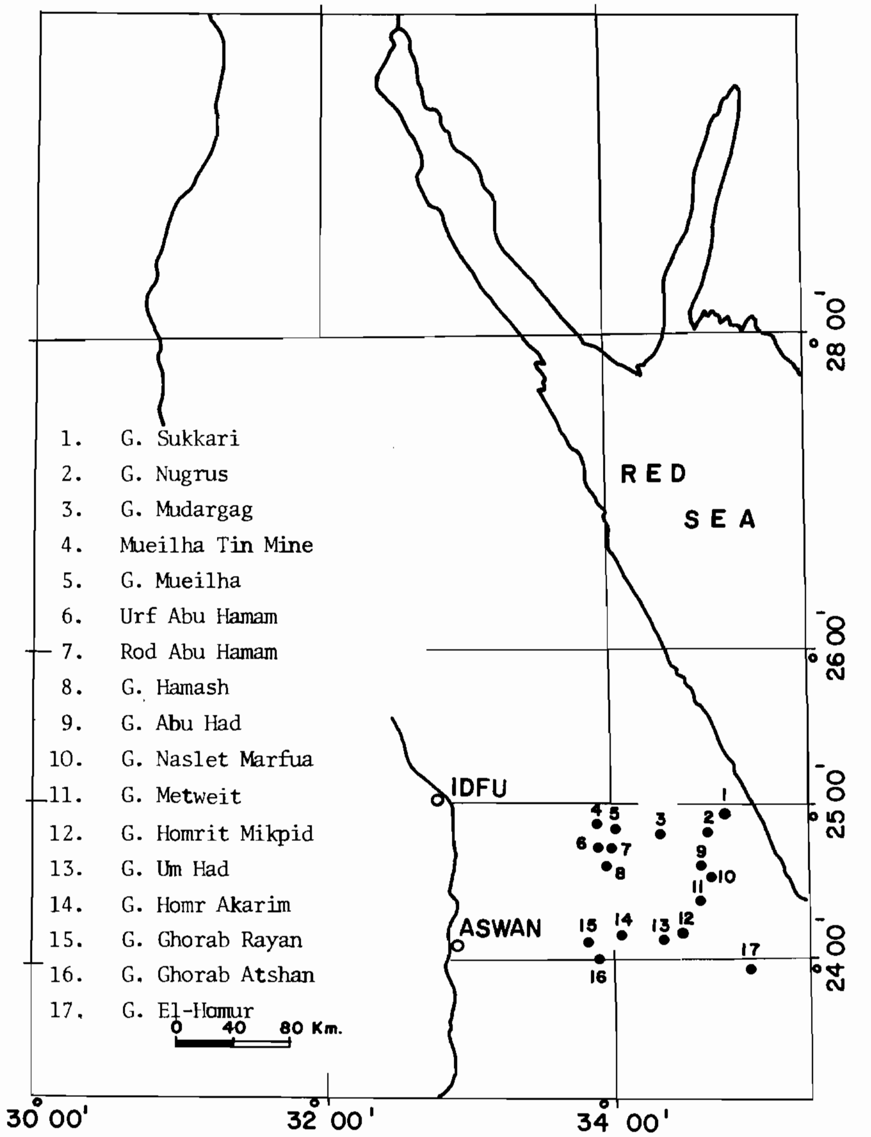

Fig. 1. Location map showing the investigated granite masses.

complexiometrically using EDTA, and FeO was determined volumetrically. The accuracy and precision of the present data were estimated by replicate runs and external standardisation against the USGS standard G-1. An error of $\pm 2\%$ of the present data for SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, MnO, P_2O_5 and TiO_2 and an error of $\pm 3\%$ for Na_2O, K_2O and FeO have been recorded.

The samples were again semiquantitatively analysed for Sn, Nb, Be, Y, Pb, Bi, Mo, W, Cu, Zr, V, Cr, Ni, and Co using a Hilger and Watts large quartz glass emission spectrograph.

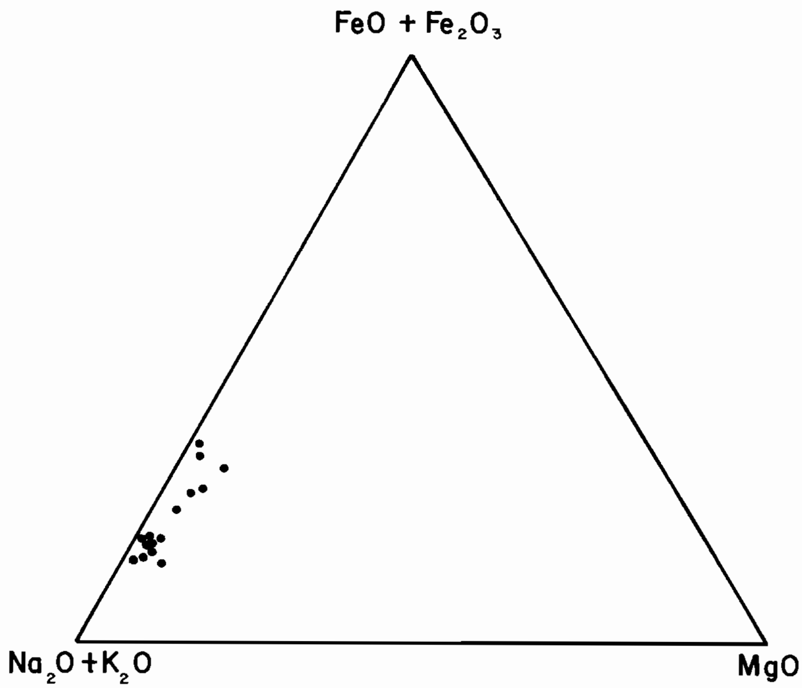

Fig. 2. AFM diagram showing the variation of the relative proportions of (K_2O+Na_2O), (Fe_2O_3+FeO) and MgO of the granite masses.

MAJOR ELEMENTS

The average chemical composition of the seventeen granite masses under consideration compared with that of low calcium granite of Turekian & Wedepohl (1961) are given in Table 1. Average Niggli values and CIPW norms are also given in the same table. It is evident from this table that the composition of the investigated masses compare well with the average low calcium granite. The rocks are relatively enriched in SiO_2 and K_2O with a tendency towards a general depletion in total iron, MgO, CaO, MnO, TiO_2 and P_2O_5.

The composition of the rocks in Table 1 has been recalculated in terms of (K_2O+Na_2O), ($FeO+Fe_2O_3$) and MgO and the results are plotted on an AFM diagram (Fig. 2). The diagram reveals that these granites are enriched in alkalis and impoverished in magnesium and iron. Fig. 3 shows, however, the behaviour of the major elements against the calculated differentiation index (D.I. $= \frac{1}{3}$ Si+K−(Na+Ca)) and from which the close grouping of the granitic masses is evident.

The Fe_2O_3/FeO, MnO/FeO, MnO/MgO, and K_2O/Na_2O ratios of the granite masses have been calculated and listed in Table 1. It is clear that Gabal Sukkari, Gabal Metweit, Mueilha tinmine and Gabal Nugrus granites contain the highest MnO/MgO and MnO/FeO ratios suggesting a slightly higher degree of differentiation (Goldschmidt 1962; Rankama & Sahama 1968). All the granite masses, except those of Gabal Sukkari and Gabal Metweit have $K_2O/Na_2O>0{\cdot}6$. According to Raguin (1965) these granites have potassic character whereas Gabal Sukkari and Gabal Metweit granites show sodic tendencies.

Table 1. Average chemical analyses, Niggli values and norms of some younger granite masses in the Southeastern Desert of Egypt

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	72·44	74·36	74·49	75·85	76·96	76·14	73·66	72·24	75·16	72·12	78·44	76·12	74·54	75·35	71·82	76·62	74·64	74·23
AL_2O_3	14·41	13·66	13·50	13·26	13·22	13·20	14·61	12·64	13·46	13·41	11·37	14·13	13·89	13·98	14·59	13·24	14·23	13·61
Fe_2O_3	3·42	1·25	1·01	1·29	1·05	0·67	0·96	1·10	1·27	1·69	2·09	0·67	1·36	1·06	1·89	1·14	0·93	2·03
FeO	0·35	0·54	0·59	0·29	0·33	0·68	0·33	0·50	1·13	0·60	0·29	0·42	0·56	0·16	0·58	0·29	0·35	
TiO_2	0·33	0·18	0·12	0·06	0·06	0·11	0·22	0·08	0·18	0·37	0·29	0·09	0·05	0·12	0·09	0·17	0·14	0·02
CaO	0·90	1·21	1·79	0·55	1·12	0·83	1·02	1·45	1·10	1·59	0·90	0·74	0·67	1·12	1·06	0·75	1·04	0·71
MgO	0·16	0·14	0·39	0·18	0·31	0·25	0·65	0·16	0·54	0·51	0·21	0·24	0·44	0·14	0·45	0·18	0·37	0·27
Na_2O	5·80	4·29	4·18	4·02	3·13	4·33	4·65	3·91	2·79	4·25	3·79	3·61	3·77	3·67	4·71	3·22	3·86	3·84
K_2O	1·45	3·77	3·89	3·28	3·29	3·37	3·80	3·90	3·51	3·80	1·18	3·08	3·55	3·45	3·84	3·68	3·17	5·06
MnO	0·08	0·04	0·03	0·03	0·03	0·01	0·01	0·03	0·03	0·03	0·04	0·02	0·03	0·01	0·03	0·03	0·02	0·05
P_2O_5	0·07	0·08	0·09	0·04	0·05	0·04	0·09	0·02	0·09	0·14	0·03	0·04	0·05	0·05	0·03	0·07	0·07	
H_2O^-	0·10	0·13	0·16	0·03	0·04	0·13	0·06	0·18	0·19	0·06	0·12	0·05	0·18	0·13	0·16	0·20	0·15	
H_2O^+	1·14	0·70	0·41	0·96	0·37	0·60	0·40	0·46	1·07	1·74	1·71	0·52	0·84	1·11	1·01	0·70	1·08	
Total	100·65	100·35	100·60	99·84	99·96	100·35	100·46	100·67	100·52	100·31	100·47	99·73	99·93	100·35	100·26	100·29	100·05	
Fe_2O_3/FeO	9·76	2·31	1·12	4·44	3·18	0·98	2·90	2·20	1·71	2·80	7·20	1·64	2·24	6·62	3·25	3·93	2·65	
MnO/FeO	0·228	0·074	0·026	0·104	0·091	0·014	0·03	0·06	0·051	0·014	0·134	0·047	0·053	0·062	0·051	0·104	0·06	
MnO/MgO	0·50	0·274	0·055	0·166	0·096	0·04	0·015	0·187	0·088	0·058	0·190	0·083	0·068	0·071	0·066	0·166	0·054	
Na+K/Al	0·709	0·872	0·697	0·811	0·90	0·861	0·853	0·917	0·712	0·888	0·641	0·747	0·782	0·754	0·865	0·778	0·729	
K_2O/Na_2O	0·25	0·878	0·928	0·815	1·05	0·755	0·817	0·997	1·257	0·894	0·311	0·853	0·941	0·940	0·815	1·142	0·812	
D.I.	11·65	13·78	13·49	13·10	13·47	13·92	13·56	13·65	13·35	12·95	13·44	13·60	13·83	13·73	13·59	14·36	13·30	
Niggli values																		
Si	378·3	444·3	449·3	477·4	491·5	462·8	396·7	416	407·8	389	552·8	482·4	433·5	463·4	371·1	496·1	448·2	
al	44·2	45·73	47·34	49·1	49·6	47·2	46·3	40·59	43·56	41·68	47·14	52·67	47·49	50·4	44·4	50·5	50·36	
alk	34·4	37·2	29·4	37·76	32·7	38·5	37·28	34·2	35·74	35·24	31·10	39·6	34·35	35·2	36·33	35·35	33·8	
k	0·13	0·36	0·45	0·35	0·41	0·34	0·35	0·39	0·88	0·59	0·17	0·36	0·38	0·37	0·35	0·43	0·36	
c	5	7·5	7	3·7	7·66	5·47	5·88	8·5	10·5	9·19	6·76	5·06	4·14	7·32	5·87	5·20	4·47	
fm	17	9·55	16·2	9·45	9·96	8·8	10·56	16·71	10·11	13·9	15	7·68	12·56	7	13·35	8·94	9·35	
mg	0·08	0·12	0·30	0·18	0·31	0·25	0·49	0·08	0·32	0·40	0·14	0·30	0·30	0·18	0·25	0·20	0·34	
qz	+141·1	+192·5	+231·68	+226·3	+260·57	+207·76	+147·55	+196·1	+133·6	+148	+328·37	+244	+196	+222·5	+125·78	+254·7	+212·9	

Table 1. (*cont.*)

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CIPW norms																		
Q	29	31	40·7	36·9	41·3	31·8	27·1	33·8	30	27·5	47·4	39·4	35·3	36·1	25	39·9	35	
Or	8·5	22·5	21	20	20	23	22·5	23	23	23	7·5	19	21·5	21	23	22·5	19·5	
Ab	53	38·5	26	36·5	28·5	38·5	41·5	35·5	37	38·5	36	33	34·5	33·5	42·5	29·5	35·5	
An	4	5·5	5	2·5	5·5	4	5	5·5	7	6·8	4·5	3·5	3	6	5·5	3·5	5·5	
C	1·9	0·7	3·8	2·4	2·9	0·6	1·1	—	—	—	2·3	3·6	3·1	2·2	0·8	3·1	2·6	
Fs	—	—	0·6	—	—	0·6	—	—	—	—	—	—	—	—	—	—	—	
En	0·4	0·4	1·4	0·4	0·8	0·8	1·8	0·4	0·8	1·4	0·4	0·6	1·2	0·4	1·2	0·4	1	
Ap	—	—	0·1	—	—	—	0·1	—	0·1	0·2	—	—	—	—	—	—	—	
Il	0·4	0·2	0·2	—	—	0·1	0·2	0·1	0·1	0·4	0·4	0·1	—	0·1	0·1	0·2	0·2	
Mt	0·6	1·2	1·2	0·6	0·6	0·6	0·3	1	1	0·6	1·5	0·6	1·2	0·3	1·2	0·3	0·3	
Hm	2·1	—	—	0·5	0·3	—	0·4	0·1	—	0·8	—	—	0·1	0·4	0·5	0·6	0·4	
Wo	—	—	—	—	—	—	—	0·6	0·8	0·6	—	—	—	—	—	—	—	
Total	99·9	100	100	99·8	99·8	100	100	100	99·8	99·8	100	100	99·9	100	99·8	100	100	
Trace elements (ppm)																		
Sn	—	20	—	381	76	—	—	—	—	—	—	138	—	421	30	15	—	3
Nb	—	21	—	44	45	—	—	—	—	—	—	56	—	66	50	25	27	21
Be	50	—	—	147	81	—	—	—	—	—	—	188	—	671	—	—	—	3
Y	—	28	30	104	36	—	—	30	58	—	120	37	—	87	150	25	130	40
Pb	—	23	—	56	97	—	—	—	—	—	—	38	—	127	35	40	—	19
Bi	—	—	—	20	40	—	—	—	—	—	—	—	—	28	—	—	—	0·01
Mo	—	1	—	6	20	—	—	—	—	—	—	2	—	55	—	—	—	1·3
W	—	10	—	—	—	—	—	—	—	—	—	5	—	20	—	—	—	2
Cu	10	164	4	78	60	47	3	3	9	30	13	16	10	23	10	7	8	10
Zr	50	109	167	60	35	193	100	100	195	100	600	116	100	119	275	10	200	175
V	20	20	5	13	15	33	30	—	22	30	—	26	5	22	15	20	10	44
Cr	—	5	—	—	—	—	—	—	—	—	—	10	—	—	—	—	—	4·1
Ni	—	—	—	—	—	7	5	—	4	—	9	—	—	—	—	2	—	4·5
Co	—	—	—	—	—	7	5	—	4	—	—	—	—	—	—	—	—	—

1, one analysis representing Gabal El Sukkari; 2, average of 5 analyses from Gabal Nugrus; 3, average of 3 analyses from Gabal Naslet Marfua; 4, average of 5 analyses from Mueilha tinmine; 5, average of 5 analyses from Gabal Mueilha; 6, average of 3 analyses from Urf Abu Hamam; 7, one analysis representing Rod Abu Hamam; 8, one analysis representing Gabal Abu Had; 9, average of 4 analyses from Gabal Mudargag; 10, one analysis representing Gabal Hamash; 11, average of 4 analyses from Gabal Metweit; 12, average of 5 analyses from Gabal Homrit Mikbid; 13, one analysis representing Gabal Um Had; 14, average of 5 analyses from Gabal Homr Akarim; 15, average of 2 analyses from Gabal Ghorab Rayan; 16, average of 2 analyses from Gabal Ghorab Atshan; 17, average of 3 analyses from Gabal El Homur; 18, average composition of low Ca-granite of Turekian & Wedepohl (1961).

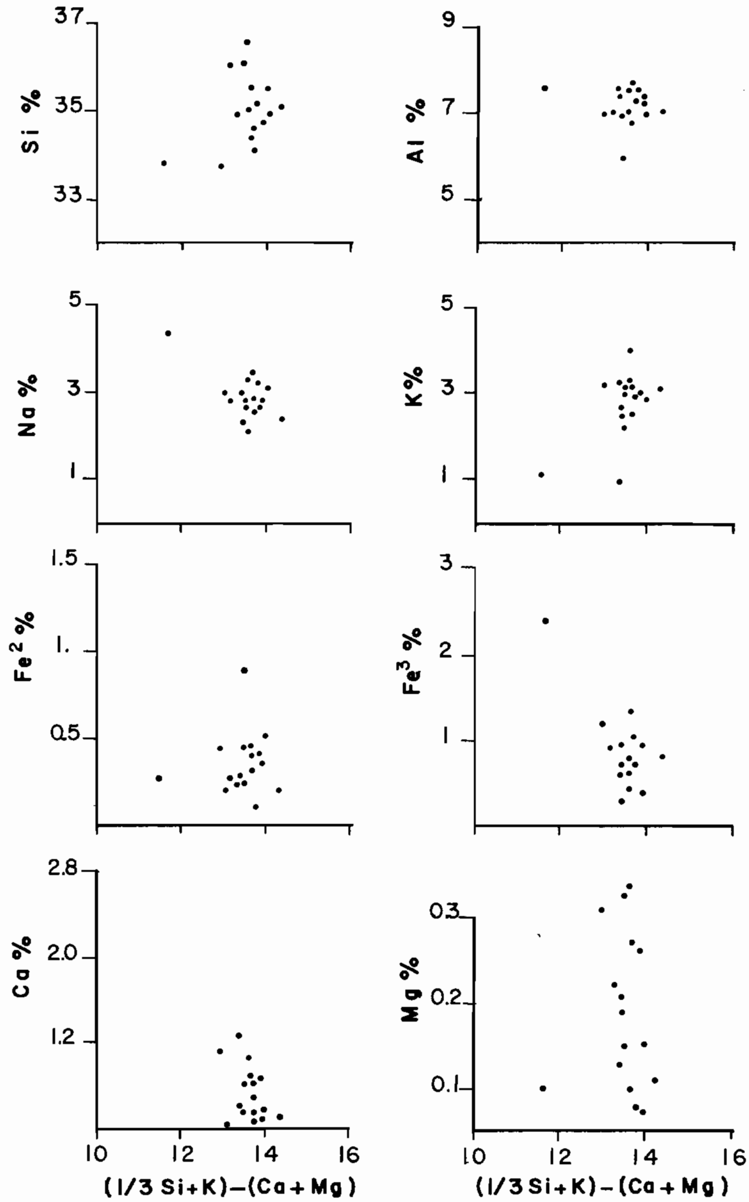

Fig. 3. Plots of the average major element contents of the granite masses versus differentiation index.

DISTRIBUTION OF TRACE ELEMENTS

Fourteen trace elements have been selected for estimation in the present granitic rocks. These include Be, Y, V, Cr, Co, Ni, Zr, Nb, Mo, W, Cu, Sn, Pb, Bi. The average trace element contents of the investigated granite masses compared with that of the reference granite of Turekian & Wedepohl (1961) are also given in Table 1. It is noticeable from this table that the granites under consideration are relatively enriched in Sn, Be, Pb, Y, Bi, Mo, and Cu and depleted in Zr, V, Cr and Ni and contain nearly equal amounts of Nb and W with respect to the reference granite.

Beryllium

This element was only detected in five granitic masses. These are Gabal El Sukkari, Mueilha tinmine, Gabal Mueilha, Gabal Homrit Mikbid and Gabal Homr Akarim granite masses. It ranges from 50 ppm (Gabal El Sukkari) up to 670 ppm (Gabal Homr Akarim).

Yttrium

Yttrium has been detected in granites containing Sn, Nb, Bi, Pb, and W and can be used as an index trace element for these granites. It ranges between 25 ppm (Gabal Ghorab Atshan) and 150 ppm (Gabal Ghorab Rayan).

Vanadium, chromium, cobalt, and nickel

V has been detected in some granite masses with values ranging from 5 ppm (Gabal Naslet Marfua and Gabal Um Had) to 33 ppm (Urf Abu Hamam). It is usually closely associated with accessory magnetite and ilmenite. This is probably due to the similarity of the V^{3+} and Fe^{3+} radii (Goldschmidt 1962). Cr was found in trace amounts (5–10 ppm) in Gabal Nugrus and Gabal Homrit Mikbid granites only. Co is also detected in small amounts (3–7 ppm) in Gabal Mudargag, Rod AbuHamam and Urf Abu Hamam granites. Ni ranges from 1 to 9 ppm and is recorded in Gabal Ghorab Atshan, Gabal Mudargag, Gabal Um Had, Urf Abu Hamam and Gabal Metweit.

Zirconium, niobium and molybdenum

Zr has been detected in all the studied granites with values ranging from 10 ppm (Gabal Ghorab Atshan) to 600 ppm (Gabal Metweit). Nb is recorded in all the Sn-bearing granites ranging from 20 ppm (Gabal Nugrus) to 66 ppm (Gabal Homr Akarim). Mo is recorded also in the Sn-bearing granites ranging in values between 1 ppm (Gabal Nugrus) and 55 ppm (Gabal Homr Akarim).

Wolfram

Wo is detected only in three granite masses including Gabal Homr Akarim granite (20 ppm), Gabal Nugrus granite (10 ppm) and Gabal Homrit Mikbid granite (5 ppm) where it is probably present as wolframite.

Copper

Cu was recorded in all the granite masses. It ranges from 3 ppm (Rod Abu Hamam) up to 164 ppm (Gabal Nugrus).

Tin and lead

Sn is recorded in seven granite masses. These are Gabal Mueilha, Mueilha tinmine, Gabal Homrit Mikbid, Gabal Homr Akarim, Gabal Nugrus, Gabal Ghorab Rayan and Gabal Ghorab Atshan and which are designated herein as the Sn-bearing granites. Their Sn content is much higher than that of the reference granite. Sn ranges between 15 ppm (Gabal Ghorab Atshan) and 421 ppm (Gabal Homr Akarim). Pb is found only in the Sn-bearing granites with values ranging between 33 ppm (Gabal Ghorab Rayan) and 127 ppm (Gabal Homr Akarim).

Bismuth

Bi was detected in three granite masses including Gabal Mueilha (40 ppm), Gabal Homr Akarim (28 ppm) and Mueilha tinmine granites (20 ppm).

PETROGENESIS

The normative Q, Or, Ab proportions of the granitic masses are plotted and the results compared with experimental data of Tuttle & Bowen (1958) (Fig. 4). It is observed from this figure that the majority of the granitic masses have their composition close to the minimum melting point at low to moderate water-vapour pressures in the Na Al Si_3O_8–K Al Si_3O_8–SiO_2–H_2O system. Gabal El Sukkari and Gabal Metweit granites plot, on the other hand, away from the minimum melting-point composition and close to the Q–Ab sideline.

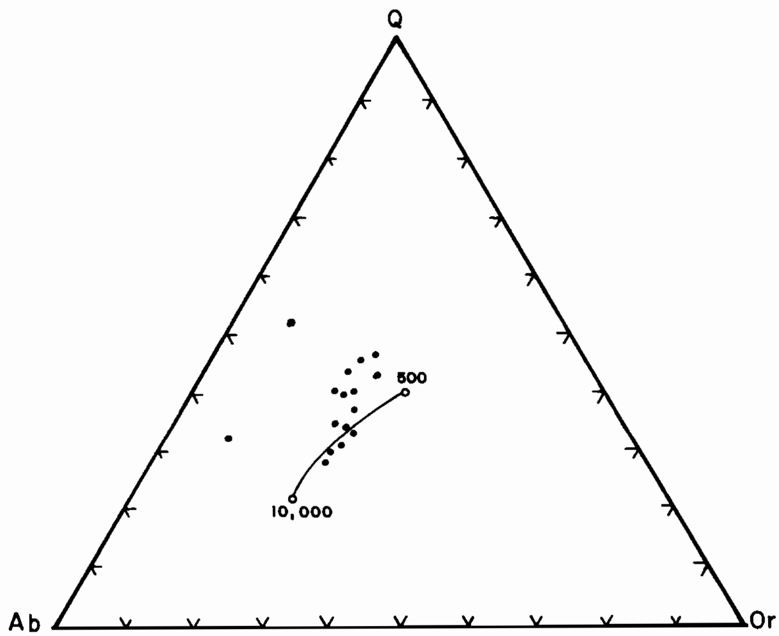

Fig. 4. Normative Q, Or, Ab proportions for the investigated granite masses. The solid line represents the variation in position of the minimum melting points in the granite system at water vapour pressures from 500 to 10,000 bars (after Tuttle & Bowen 1958).

El-Gaby (1975) has shown that the field composition of some of the Egyptian Younger granites is close to the minimum melting point at low to moderate pressures in the Ab–Or–Q–H_2O system of Tuttle & Bowen (1958). According to him, these granites are considered to be largely intruded as palingenetic magmas. The early phases of the palingenetic magma were formed at higher water-vapour pressures while the latter phases were formed under progressively decreasing water-vapour pressures. From the close relationship between the minimum melting point for low water-vapour pressures and the normative composition of the analysed rocks in Washington's tables (1917) in which normative $Q+Or+Ab> 80\%$, Tuttle & Bowen (1958) concluded that there can be little doubt that magmatic liquids are involved in the genesis of granitic rocks. Bowes (1964) has also concluded that the closeness of the normative Q, Or, Ab proportions of some of the para-autochthonous and intrusive Lewisian granitic rocks to the minimum melting-point compositions at low water-vapour pressures in the system Ab–Or–Q–H_2O indicates genesis by selective melting, followed by crystallization at low water–vapour pressures.

The normative Or–Ab–An proportions of the present granitic masses have been plotted in a ternary diagram (Fig. 5). All the plots are shown to fall in the plagioclase field, mostly close to the isobaric univariant curve, indicating that crystal–liquid equilibrium was the dominant mechanism involved in the genesis of these granites (James & Hamilton 1969).

The conclusion which could be reached from the foregoing discussion becomes clear, however, when plotting the ionic weight percentages of Ca, Na, and K of the granite masses in a trilinear diagram including the suggested field for magmatic rocks (Raju & Rao 1974) (Fig. 6). All the granite masses, except those of Gabal El Sukkari and Gabal Metweit, are shown to have their plots inside the field representing granitic rocks of magmatic origin.

CONCLUSION

The average chemical composition of the investigated granite masses compares well with that of low calcium granite of Turekian & Wedepohl (1961). The granites, in general, are hyperacidic in character, enriched in K_2O and depleted in total iron, MgO, CaO, MnO, TiO_2 and P_2O_5. Their petrochemical characteristics reveal the close grouping and the formation of most of these granites under identical physicochemical conditions. Most of the investigated granites show pronounced potassic character and only few of them (Gabal El Sukkari and Gabal Metweit granites) have sodic tendencies.

On the basis of experimentally studied systems, as well as ionic weight percentage proportions of Ca, Na and K of the analyses, all the investigated granites, except those of Gabal El Sukkari and Gabal Metweit, are certainly magmatic in origin. Sodium metasomatism appears, on the other hand, to have been involved in the genesis of Gabal El Sukkari and Gabal Metweit granites.

Of the trace elements, Cu and Zr were recorded in all the investigated granite masses and V occurs in most of these masses. Some of the granites are distinguished, however, by their content of Sn, Nb, Y, Pb. These include the granite masses of Gabal Mueilha, Mueilha tinmine, Gabal Homrit Mikbid, Gabal Homr Akarim, Gabal Nugrus, Gabal Ghorab Rayan and Gabal Ghorab Atshan. These granites might also carry Be, Bi, Mo, W and Cr. Other granite masses are characterised, on the other

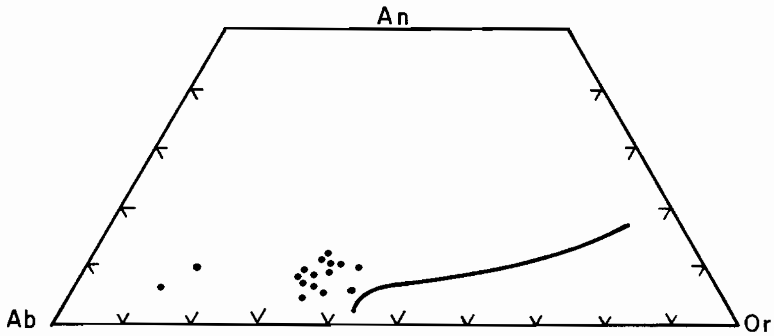

Fig. 5. Normative Or–Ab–An proportions for the investigated granite masses. The solid line represents the two feldspar boundary curve for the quartz saturated ternary feldspar system at 1000 bars water vapour pressure (James & Hamilton 1969).

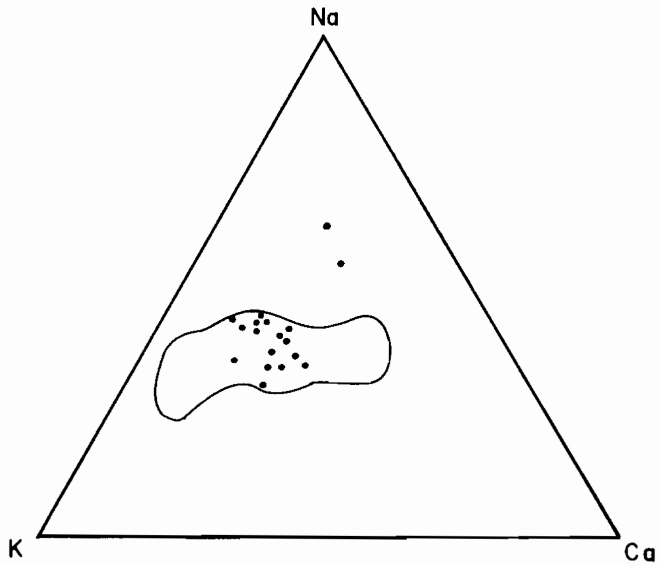

Fig. 6. Plots of Ca, Na, K proportions of the granite masses. The field representing granitic rocks of magmatic origin suggested by Rajau & Rao (1974) is included.

hand, by containing Ni and Co (e.g. Gabal Mudargag, Urf Abu Hamam and Rod Abu Hamam). The distribution of trace elements might therefore indicate that the granite masses under consideration could not have been produced from a single magma.

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(*Received* 3 *October* 1976)

جيوكيميائية بعض كتل الجرانيت الحديث
بجنوب الصحراء الشرقية المصرية

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خلاصـة

يختص هذا البحث بدراسة جيوكيميائية لسبع عشرة كتلة من كتل الجرانيت الحديث الواقعة بين خطى عرض ٢٤°، ٢٥° شمالا تقريبا بالصحراء الشرقية المصرية والتى تشتمل على جرانيت جبل السكرى ، جبل نقرس ، جبل مدراجج ، جبل مويلحة ، منجم قصدير مويلحة ، عرف أبو حمام ، روض أبو حمام ، جبل حماش ، جبل أبو حاد ، جبل حمر عكارم ، جبل غراب ريان ، جبل نصلة مرفوعة ، جبل متويت ، جبل حمرة مكبد ، جبل أم حاد ، جبل غراب عطشان وجبل الحمر .

وقد ثبت من التحليل الكيميائى أن الكتل سالفة الذكر متقاربة فى تفارقها الصهيرى ، كما أنها شديدة التفارق . وقد أظهر البحث أيضا أن كتلتين فقط وهما جرانيت جبل السكرى وجبل متويت لهما صفات صودية ، أما باقى الكتل فلها صفات بوتاسية مميزة . وقد أكدت الدراسة أن الجرانيت البوتاسى من أصل صهيرى ، أما الجرانيت الصودى فمن المحتمل أن يكون قد تأثر بتغاير ميتاسوماتى صودى . وتشير دراسة توزيع العناصر النادرة إلى الاعتقاد بأنه ليس من الممكن انتماء كل الكتل الجرانيتية إلى صهير واحد .

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THE JOURNAL OF THE UNIVERSITY OF KUWAIT (SCIENCE)

VOLUME 3

1976

PUBLISHED BY THE FACULTY OF SCIENCE
UNIVERSITY OF KUWAIT, KUWAIT