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GEOCHEMICAL STUDIES OF SOME GRANITES FROM THE SOUTH WESTERN DESERT, EGYPT

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ABSTRACT

The present work is the first detailed petrochemical and geochemical studies done on some 18 granitic rocks collected from the south Western Desert of Egypt. The petrochemical work includes complete chemical analyses of these rocks beside calculation of the CIPW norms, NIGGLI values, D. I., F. I. and M. I. Thirteen trace elements are quantitatively determined, these are: Ba, Rb, Sr, Y, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn and Cu.

These chemical studies established the presence of five rock types: grey granite, Aswan-type granite, normal pink-red granite, strongly fractionated pink-red granite and syenite. It is concluded that the basement rocks of Egypt developed in the Eastern Desert and Sinai peninsula are extended across the Nile, mostly subsurface, in the southern parts of the Western Desert. To the first time, Aswan coarse granites are proved to occur in the south Western Desert. This makes them of much wider aereal distribution than previously known. On account of their peculiar chemical composition, Aswan plutonites can be grouped in a separate plutonic cycle.

INTRODUCTION

The southern parts of the Western Desert of Egypt particularly the Oweinat plateau and the neighbourhoods are regarded among the most remote areas in Egypt. This inaccessibility restricted the geological studies on the area so that only few geological works are available.

The pioneering works are those of LYONS [1894], BALL [1902], HUME [1908] and BEADNELL [1909] dealing with the geology of separate parts of this remote area. BALL and HUME works embody the results of quick reconnaissance survey across parts of the area under study. For almost half a century the results arrived at by these geologists remained the only geological data known about that area. ISSAWI [1968] paid much attention to the stratigraphy, lithological characteristics, structural relationships and sedimentary history of the rocks of this area, moreover he briefly studied the outcropped basement rocks encountered in the area although he sampled most of these rocks.

The present work is the first detailed geochemical studies done on the outcropping granitic masses occurring in the region lying west of the Nile at Abu Simbil till Oweinat plateau, *(Fig. 1)*. The importance of this work stems out from the fact that most of the mentioned area is difficultly accessible. The work includes the geologic setting of the granitic bodies, tectonic considerations, brief petrographic description of the hand specimens beside petrochemical and geochemical

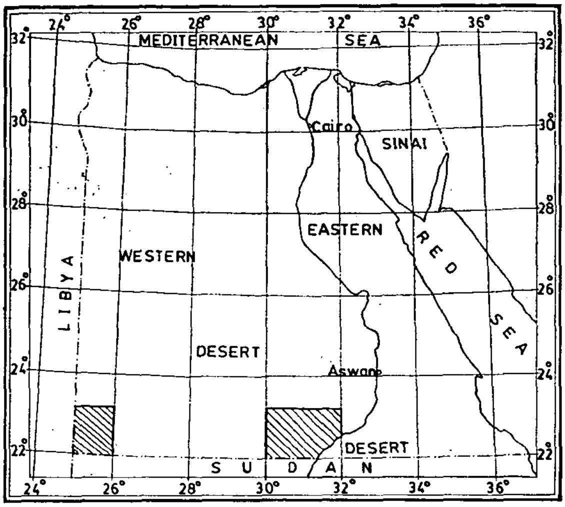

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Fig.(1): Key map showing the sampled areas of granitic masses in the south Western Desert of Egypt.

Sampled areas.

investigations. The latter includes the quantitative determination of 13 major constituents: SiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, H_2O^+ and H_2O^-, beside the quantitative determination of 13 trace elements: Ba, Rb, Sr, Y, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn and Cu.

CIPW norms, NIGGLI-values, differentiation indices, mafic indices and felsic indices are calculated for the 18 analyzed rocks. The present study shed some light on the various types of granitic rocks present in that remote part of the country beside giving an idea about their origin and mode of emplacement.

FIELD OCCURRENCE OF THE GRANITES

The granitic masses outcropping in the area rise about 500 m above the plain which rises gradually west in the direction of Gebel Oweinat whose elevation is 1114 m. At the extreme south western corner of the Western Desert, there occurs the Oweinat mountain which is composed mainly of older granitoids including the so-called grey granites beside some cataclased granites. But at the southern parts of Oweinat mountain, some younger granites are developed. The area west of Abu Simbil includes several outcrops of different types of pink-red or younger granites. Among these are Aswan granites, normal pink-red granites and strongly differentiated pink-red granites beside some granosyenites and syenites. *Fig. 2* and *3* are geological maps of the Oweinat area and the Dunqul-Abu Simbil area showing the different granitic exposures and the sampled localites.

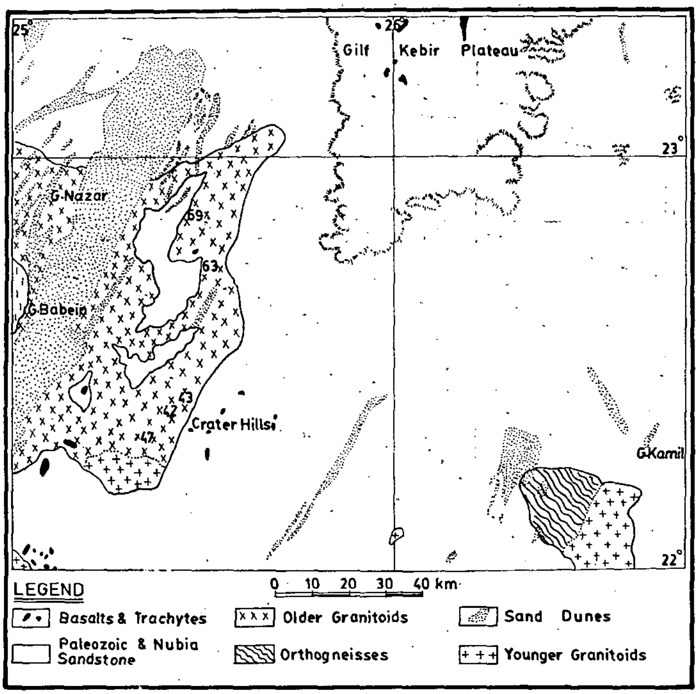

FIG.(2): RECONNAISSANCE GEOLOGICAL MAP OF OWEINAT AREA.
Sample Localities Are Indicated.

TECTONIC CONSIDERATIONS

The structural pattern of the area in question *i.e.* the area west of Abu Simbil till Oweinat is governed mainly by fault lines trending predominantly in an E—W direction and extending for distances ranging from few kilometers to more than 250 km. Along these major faults, block uplifting occurred resulting in the outcropping of some parts of the basement rocks. Another set of faults is noticed in the vicinity of the Nile and have N—S trend. These faults are generally of secondary importance in manifesting the structural framework of the area. Owing to the uplift of the basement rocks, the overlying sedimentary cover is tilted or uparched [ISSAWI, 1968].

The basement rocks of that part of the Western Desert are correlated with those outcropping in the Eastern Desert and Aswan region. Gravimetric survey [Geofizika, 1966] of the southern Western Desert has shown that the basement highs exist beneath the ground in the stretch of land between Aswan and Oweinat. The occurrence of several basement outcrops attest the presence of such a belt.

The E—W fault system is developed as a result of the block uplifting of the earth's crust of the south Western Desert and the contemporaneous regression of the Tethys towards the north direction. The Hercynian phase of tectonism plays the predominant role in the area under consideration and generally in the whole of the Western Desert. It is clear that the uplift movement started at the south

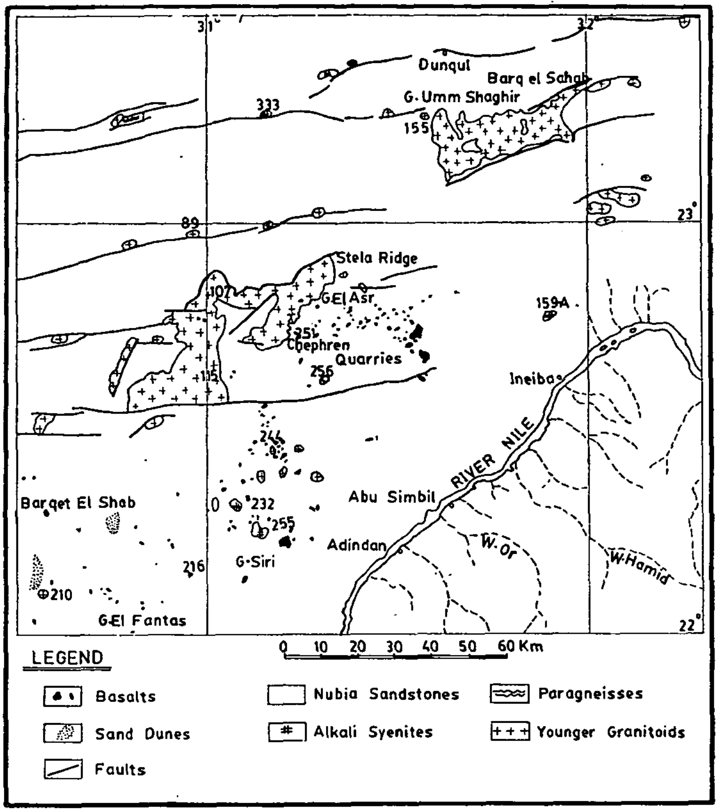

FIG.(3): GEOLOGICAL MAP OF THE DUNQUL – ABU SIMBIL AREA. Sample Localities Are Indicated.

and gradually moved towards the north and was accompanied by the regression of the Tethys and its shore line. The faults are rejuvenated from time to time.

PETROGRAPHIC DESCRIPTION

In the following paragraphs, brief petrographic description is given for the various types of granites that occur in the southern part of the Western Desert. The description includes the grey granites, Aswan-type granites, younger pink-red granites beside certain syenites.

Grey Granite:

This includes samples 42, 43, 47, 63 and 69. The rock is holocrystalline, medium to fine grained, tending to be grey in color but some pinkish varieties are present (sample 47). Some of the specimens are hard and not altered (sample 42), others are friable and weathered (sample 43).

Composed of plagioclase feldspars that constitute about 50% of the rock, fine anhedral quartz grains that reach about 30% of the rock beside some ferromagnesian minerals that amount to about 20%. The mineralogical character of the latter minerals varies with the specimen investigated. In some samples (43 and 63) it is mainly biotite, in others (sample 47) it is biotite with some hornblende while in sample 42, it is composed of small prismatic and black crystals of amphiboles.

The rocks in general develop no gneissic texture, however, sample 69 develops gneissic texture and being composed of green amphiboles that contain buff feldspars and violet quartz patches which are sometimes arranged alternatively in layers with the original greenish minerals.

Aswan-Type Granite:

This includes three samples 159-A, 232 and 244. This rock is holocrystalline, coarse grained, pink in color. Composed of pink potash feldspars with porphyritic crystals that attain 3.5 cm in length, white plagioclases, abundant quartz, rich in black mica sometimes associated with hornblende. Some samples (232 and 244) develop subparallel arrangement of biotite crystals, in other cases (sample 159-A) schlieren texture is developed. Sample 232 shows some kaolinization of the feldspars.

Pink-Red Granite:

This group of rocks includes eight granite samples with numbers: 89, 107, 115, 210, 216, 251, 256 and 333. It comprises different granite types such as: pink, red, porphyritic, gneissic, muscovite-bearing and biotite-bearing. The granites are holocrystalline, generally medium grained and pinkish in color. Some rocks are hard and look not altered (e.g. sample 333), while others are weathered and cracked (e.g. sample 210).

Composed of pinkish feldspars mostly potash feldspars but may be mixed with a lower proportion of plagioclases together form about 60% of the rock. Quartz is the next abundant mineral and forms about 30%. Minor amount of ferromagnesian minerals is always present, this may be biotite as in samples 210 and 251, or muscovite (sample 216). Some red varieties of these granitic rocks (sample 333) show quite dropping amount of biotite.

Most of the rock samples develop typical granitic texture. However, sample 216 shows graphic texture, sample 251 develops porphyritic texture while sample 256 has gneissic texture. Schlieren patches may be present in few specimens like sample 210.

Syenite:

Two syenite samples are used in this study with numbers 155 and 255. The rock is holocrystalline, coarse or medium grained and pink in color, composed of pinkish feldspars including potash and plagioclases together amount to 70%, an abundance of biotite or amphibole (20%), beside a subordinate amount of quartz.

PETROCHEMISTRY

The complete chemical analyses expressed in weight per cent of the oxides for the 18 investigated rocks are given in Table 1. The same Table includes data of differentiation index (D.I.), felsic index (F.I.) and mafic index (M.I.). Table 2 on the other hand gives some reference analyses used for comparative purposes. Thus the Table reproduces the analyses of the high and low-Ca granites of Turekian and Wedepohl [1961], a reference syenite [Turekian and Wedepohl, 1961], typical grey, Aswan, normal pink-red and strongly differentiated pink-red granites as given by El-Sokkary [1970]. Table 3 gives CIPW norms of the same group of rocks while

Table 1

Complete chemical analyses (wt. %) of the investigated granitic rocks

Oxide	Grey Granite			Aswan-Type Granite					Syenite
	42	43	47	63	69	159-A	232	244	155
SiO_2	63.87	60.73	64.00	65.04	66.75	68.34	69.31	71.40	65.49
Al_2O_3	15.05	16.15	13.25	14.54	14.28	13.77	13.52	14.60	15.56
Fe_2O_3	1.37	1.84	4.76	1.50	2.03	1.17	2.49	Tr.	0.76
FeO	3.72	3.53	2.74	1.96	3.13	2.25	1.27	0.79	3.86
MnO	0.15	0.10	0.10	0.08	0.10	0.10	0.06	0.03	0.13
MgO	0.93	4.18	0.98	0.93	1.06	0.46	0.69	0.35	0.46
CaO	2.58	5.01	3.86	3.86	2.56	1.93	2.25	1.82	2.58
Na_2O	6.58	4.03	4.31	6.58	6.36	3.86	4.15	3.49	4.46
K_2O	2.80	2.10	3.71	3.62	2.00	6.27	4.10	4.95	4.53
TiO_2	0.73	0.56	0.55	0.51	0.61	0.17	0.21	0.12	0.73
P_2O_5	0.15	0.22	0.17	0.11	0.11	0.18	0.17	0.07	0.09
H_2O^+	2.40	1.86	1.45	0.95	1.15	1.18	1.25	1.18	1.69
H_2O^-	0.15	0.28	0.20	0.30	0.25	0.20	0.29	0.22	0.31
Total	100.48	100.59	100.08	99.98	100.41	99.88	99.76	99.02	100.65
D.I.	9.86	5.10	9.69	9.81	9.58	14.18	12.16	13.72	11.84
F.I.	79.65	56.92	69.47	74.06	77.71	85.38	80.10	83.75	79.35
M.I.	87.30	61.53	90.25	82.11	85.75	90.18	86.67	74.39	92.65

Table 1.: Continued

Oxide	Syenite	Pink-Red Granite							
	255	89	107	115	210	216	251	256	333
SiO_2	63.99	73.03	73.19	71.35	74.27	71.53	71.95	72.83	77.87
Al_2O_3	12.50	13.25	13.49	13.52	14.12	13.52	13.01	14.28	10.24
Fe_2O_3	6.92	1.44	1.16	0.83	Ttr.	0.82	2.17	0.74	1.73
FeO	0.39	0.39	0.19	0.49	0.79	0.29	1.76	0.98	0.28
MnO	0.11	0.02	0.01	0.02	0.03	0.01	0.07	0.05	0.05
MgO	0.69	0.46	1.19	0.23	0.39	0.23	0.46	0.46	0.22
CaO	1.29	1.93	1.61	1.29	2.00	1.61	0.64	1.29	0.65
Na_2O	6.79	3.86	2.97	2.59	2.80	2.26	3.07	4.15	3.08
K_2O	4.48	3.62	4.39	8.19	4.91	7.57	5.11	4.58	3.89
TiO_2	0.29	0.21	0.11	0.12	0.08	0.06	0.31	0.30	0.25
P_2O_2	0.09	0.15	0.14	0.08	0.03	0.13	0.16	0.10	Tr.
H_2O^+	1.88	1.13	1.06	0.86	1.02	1.32	0.93	0.88	1.18
H_2O^-	0.28	0.24	0.22	0.18	0.31	0.24	0.19	0.31	0.33
Total	99.70	99.73	99.73	99.75	100.75	99.59	99.83	99.95	99.77
D.I.	12.07	12.71	13.17	16.85	13.95	16.13	14.70	13.78	14.76
F.I.	90.50	80.94	83.55	90.46	81.16	87.38	93.41	88.21	92.31
M.I.	92.45	82.39	57.14	87.27	71.76	85.11	91.17	82.05	91.02

Table 2

Analyses (wt.%) of the reference high-Ca, low-Ca granite, syenite beside typical grey, Aswan normal pink-red and strongly differentiated pink-red granites

Oxide	High-Ca[1]	Low-Ca[2]	Syenite[3]	Grey[4]	Aswan[5]	Normal Pink-Red[6]	Strongly Diff.[7]
SiO_2	67.23	74.29	62.30	67.84	70.29	74.08	75.41
Al_2O_3	15.50	13.61	16.63	14.34	13.79	13.14	13.18
Fe_2O_3	4.23*	2.03*	5.25*	—	0.43	0.30	0.31
FeO				3.53	2.00	1.13	0.30
MnO	0.07	0.05	0.11	0.05	0.06	0.02	—
MgO	1.56	0.27	0.96	2.32	1.10	0.29	Tr.
CaO	3.54	0.71	2.52	1.95	1.24	0.82	0.76
Na_2O	3.83	3.48	5.45	3.65	3.00	4.24	3.22
K_2O	3.04	5.06	5.78	3.02	6.00	4.49	5.94
TiO_2	0.57	0.20	0.58	0.76	0.60	0.25	0.25
P_2O_5	0.21	0.14	0.18	0.18	0.15	0.05	—
H_2O^+	—	—	—	1.33	0.69	0.62	0.65
H_2O^-	—	—	—	0.06	0.20	0.10	0.14
Total	99.87	99.84	99.76	99.03	99.55	99.53	100.16

1,2: High-Ca and low-Ca granites of Turekian and Wedepohl [1961].
3: Average syenite from Turekian and Wedepohl [1961].
4, 5, 6 & 7: Analyses of typical grey, Aswan, normal pink-red and strongly differentiated pink-red granites respectively as given by El Sokkary [1970].
*: Total iron is calculated as Fe_2O_3.

Table 3

CIPW norms of the investigated granitic rocks

Normative Mineral	Grey Granite 42	43	47	63	69	Aswan-Type Granite 159-A	232	244	Syenite 155
Ap	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Il	1.0	0.8	0.8	0.6	0.8	0.2	0.4	0.2	1.0
Or	17.0	12.5	22.5	21.5	11.5	37.0	25.0	30.5	27.0
Ab	59.5	46.5	40.0	58.5	57.5	35.0	38.0	32.0	40.5
An	3.2	20.0	6.0	—	4.5	1.7	6.5	9.2	9.5
Wo	3.5	1.4	5.0	7.2	3.0	2.7	1.6	—	1.0
Mt	1.5	1.9	5.1	1.6	2.1	1.2	2.4	—	0.9
Hm	—	—	—	—	—	—	0.2	—	—
En	2.6	11.8	2.8	2.6	3.0	1.8	2.0	1.0	1.4
Fs	4.0	3.5	0.2	1.9	2.8	2.8	—	1.2	4.6
C	—	—	—	—	—	—	—	0.7	—
Q	7.4	11.1	17.2	6.1	14.4	16.5	23.6	25.6	13.8

Table 4 shows the Niggli-values. Analyses are carried out according to the procedure described by El Sokkary [1970].

The grey granites of Gebel Oweinat show the chemical characteristics of typical high-Ca granites. They show decreasing trend in SiO_2 which ranges from 60.73—66.75% and rising trend in CaO with a range from 2.56—5.01%. The reference high-Ca granite of Turekian and Wedepohl [1961] has an average CaO content of

TABLE 3: Continued

Normative Mineral	Syenite 255	Pink-Red Granite 89	107	115	210	216	251	256	333
Ap	0.3	0.3	0.3	0.3	—	0.3	0.3	0.3	—
Il	0.4	0.4	0.2	0.2	0.2	0.2	0.4	0.4	0.4
Or	27.0	22.0	27.0	49.5	29.5	46.5	31.0	27.5	23.5
Ab	42.5	35.5	27.5	34.0	25.5	20.5	28.5	38.0	29.0
An	—	8.5	7.5	1.0	10.0	4.6	2.0	5.5	2.7
Wo	2.2	—	—	1.8	—	1.3	—	—	0.3
Mt	0.6	0.3	0.3	0.9	—	0.3	2.2	0.7	0.3
Hm	0.5	0.8	0.7	—	—	0.4	—	—	1.1
En	2.0	1.4	3.4	0.6	1.2	0.6	1.4	1.4	0.6
Fs	—	—	—	—	1.0	—	1.1	0.7	—
C	—	—	1.2	±	0.6	—	2.0	0.5	—
Ac	16.0	—	—	—	—	—	—	—	—
Q	8.5	30.8	32.2	21.8	32.0	25.2	30.9	25.0	42.0

TABLE 4

Niggli values of the investigated granitic rocks

NIGGLI value	Grey Granite 42	43	47	63	69	Aswan-Type Granite 159-A	232	244	Syenite 155
si	251	198	247	254	273	318	330	391	276
al	34.9	30.9	30.1	33.5	24.4	37.7	38.0	47.0	38.6
fm	22.2	34.8	28.7	16.4	23.8	16.8	18.9	6.6	19.4
c	10.8	1ü4	16.0	16.2	11.3	9.5	11.4	10.5	11.6
al	32.1	17.0	25.2	34.0	30.5	36.0	31.7	35.9	30.3
mg	0.24	0.59	0.20	0.33	0.28	0.20	0.26	0.45	0.16
k	0.22	0.25	0.36	0.27	0.17	0.52	0.40	0.49	0.40
ti	2.1	1.4	1.6	1.4	2.0	0.6	0.8	0.6	2.3
p	0.2	0.4	0.2	0.2	0.2	0.3	0.3	0.0	0.2

TABLE 4: Continued

NIGGLI value	Syenite 255	Pink-Red Granite 89	107	115	210	216	251	256	333
si	257	404	401	386	424	399	389	381	550
al	29.6	43.2	43.4	43.2	47.3	44.5	41.6	44.6	42.4
fm	26.7	12.0	15.8	7.5	7.2	6.7	21.1	11.1	14.0
c	5.5	11.3	9.5	7.5	12.3	9.7	3.6	7.3	5.1
alk	38.1	33.6	31.5	41.9	33.2	39.1	33.8	36.9	38.6
mg	0.15	0.33	0.63	0.26	0.48	0.30	0.18	0.34	0.18
k	0.30	0.39	0.49	0.67	0.54	0.69	0.52	0.42	0.45
ti	1.0	1.0	0.3	0.6	0.3	0.3	1.3	1.3	1.3
p	0.2	0.3	0.3	0.3	0.0	0.3	0.3	0.3	0.0

3.54% which fits well the range for the studied grey granites. The latter rocks show as well rising trends in total Fe_2O_3, MgO, Na_2O and TiO_2 while K_2O tends to drop.

On comparing the analyses of the Oweinat grey granites with that of the typical grey granite from the basement rocks of Egypt, there appears close similarity between the two sets of data particularly evident from the contents of SiO_2, FeO, MgO, CaO, K_2O and TiO_2, while Na_2O content is notably enriched in the Oweinat rocks. Therefore the Oweinat grey granites are high-Ca granites and are similar to the grey granites of the basement rocks of Egypt as developed in the Eastern Desert and Sinai peninsula.

The group of rocks with sample numbers 159-A, 232 and 244 has analyses which are intermediate between the reference low-Ca and high-Ca granites. This is clear from the contents of SiO_2, MgO, CaO while K_2O keeps a high level like the reference low-Ca granite. These are precisely the chemical characteristics of Aswan coarse granites as explained by EL SOKKARY [1970]. The CaO values for this group of rocks as given in Table 1 range from 1.82—2.25% which are intermediate when compared with the corresponding values of 0.71% and 3.54% for the low and high-Ca granites respectively.

Comparison of the analyses of samples 159-A; 232 and 244 with that of Aswan coarse granite as given in Table 2 reveals strong similarity between the two rocks exempting TiO_2 content which tends to drop in the studied group of rocks. This establishes the latter rocks as varieties of Aswan granite and will be termed hereafter Aswan-type granites. This is the first time to prove the occurrence of this granite type *i.e.* Aswan granites in the south Western Desert of Egypt.

Pink-red or younger granites have the chemical characteristics of low-Ca granites. This is particularly clear from the contents of SiO_2, total Fe_2O_3, MgO, CaO, Na_2O and K_2O which are close to corresponding values of the reference low-Ca granite. The pink-red granites are marked by enrichment trends in both SiO_2 and K_2O with simultaneous decreasing trends in total Fe_2O_3, MgO and CaO. Samples 115 and 216 show abnormally high contents of K_2O which amount to 8.19% and 7.57% K_2O, respectively. This is because the pink granite sample 115 develops more feldspars and less quartz than usual i.e. it represents relative inhomogenity in the distribution of these two minerals. Sample 216 contains some muscovite as the ferromagnesian mineral. It appears that sample 107 is somewhat enriched in biotite in order to account for the rising MgO content which equals 1.19% for this sample.

On comparing the analyses of the present pink granites with corresponding values of the normal pink-red granite as given by EL SOKKARY [1970], it is revealed that the former rocks are similar to the reference normal pink-red granite particularly from the point of view of the elements: SiO_2, Al_2O_3, total Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and TiO_2. The red granite sample 333 reveals more similarity with the strongly differentiated pink-red granite especially clear from the high content of SiO_2 (77.87%) and the low value of CaO (0.65%). However, this point will be substantiated later on the basis of trace elements.

Thus the south Western Desert collection of pink-red granites are low-Ca granites. Most of them are similar to the normal variety of pink-red granites of the basement rocks of Egypt as developed in the Eastern Desert and Sinai peninsula. Rare members of the south Western Desert collection belong to the strongly fractionated granite variety.

Analytical data of sample 155 are very close to corresponding values of the reference syenite as given by TUREKIAN and WEDEPOHL [1961]. This parallelism becomes particularly evident from the contents of the elements: SiO_2, Al_2O_3, total

Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and TiO_2. Sample 255 shows the chemical characteristics of femic syenite. This is because of marked deficiency in Al_2O_3 content (12.50%) and a simultaneous rise of total Fe_2O_3 (7.35%). Thus the two samples 155 and 255 represent two varieties of syenite.

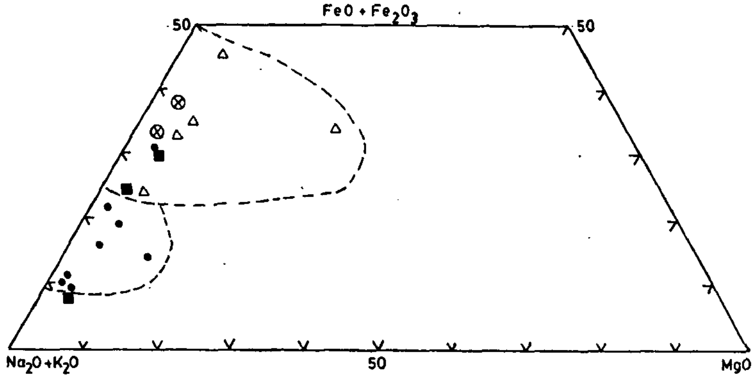

Fig.(4): The ternary relation (Na_2O+K_2O) - MgO - ($FeO+Fe_2O_3$) of the studied granitic rocks.

Symbols used: △ Grey Granite ■ Aswan-Type Granite
• Pink-Red Granite ⊗ Syenite

Fig. 4 is a ternary relation between (Na_2O+K_2O)$-$MgO$-$($FeO+Fe_2O_3$). It reveals that the grey granites are more enriched in total Fe_2O_3 and MgO with respect to the group of pink-red granites that tend to occupy the alkali end of the triangle. *Fig. 5* illustrates the ternary relation of the three normative minerals Or-Ab-An and shows that the studied grey granites are more enriched in Ab+An with respect to the pink-red granites that are located nearer to the Or field. *Fig. 6* is

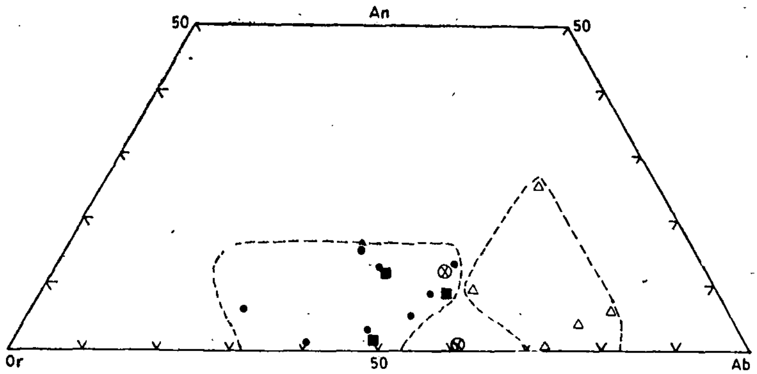

Fig.(5): The ternary relation Or-Ab-An of the studied granitic rocks.

a presentation of the ternary relation between the three NIGGLI values *c-alk-fm* and assures the fact that the Oweinat grey granites are more enriched in the *fm* and *c* components relative to the pink-red granites that tend to be enriched in the *alk* component. Moreover the pink-red granites show rising trends of their differentiation indices, felsic indices and mafic indices relative to the grey granites. Therefore the pink-red granites are in a more advanced state of differentiation relative to the grey granites and at least the two groups of granites may represent consanguineous rocks.

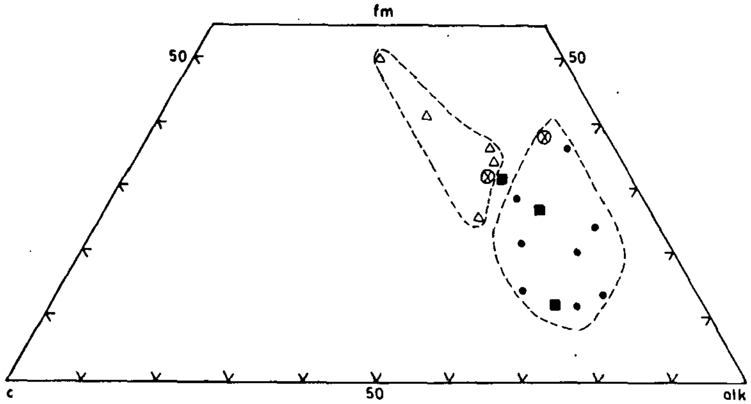

Fig.(6): Ternary diagram c - alk - fm of the studied granitic rocks.

GEOCHEMISTRY

Table 5 gives the trace elements data of the 18 investigated granites from the south Western Desert. The Table exposes the abundance values expressed in ppm of 13 trace elements: Ba, Rb, Sr, Y, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn and Cu. Table 6 on the other hand reproduces the corresponding trace elements data of some reference rocks used for comparative purposes.

TABLE 5

Trace elements (ppm) of the investigated granitic rocks

Element	Grey Granite					Aswan-Type Granite			Syenite
	42	43	47	63	69	159-A	232	244	155
Ba	939	901	1359	1170	1054	1280	553	1172	2072
Rb	60	59	99	65	31	113	165	94	89
Sr	730	712	491	953	646	278	123	453	431
Y	12	9	15	8	7	30	23	3	38
Zr	158	151	205	179	144	199	193	95	626
Nb	8	7	12	4	6	18	25	8	36
La	30	27	24	38	19	17	2	3	63
Ce	59	46	41	53	42	57	28	15	123
Nd	28	22	22	26	15	46	8	5	77
Cr	96	110	42	49	72	19	17	16	19
Ni	56	64	27	38	61	12	12	14	11
Zn	76	74	59	59	75	58	54	29	95
Cu	33	30	18	31	75	12	17	21	15

Element	Syenite	Pink-Red Granite							
	255	89	107	115	210	216	251	256	333
Ba	159	745	539	799	889	1264	906	1124	191
Rb	209	82	63	160	99	127	149	95	126
Sr	21	362	98	157	193	153	152	631	49
Y	35	5	8	5	4	6	90	13	60
Zr	784	280	72	16	121	22	398	153	1006
Nb	54	7	12	9	8	11	48	10	94
La	52	5	5	3	12	1	141	21	90
Ce	107	19	31	7	35	13	242	48	146
Nd	61	9	13	0	8	3	139	22	72
Cr	17	22	18	17	17	19	25	25	19
Ni	11	15	12	13	12	13	14	16	12
Zn	115	25	25	22	24	20	96	44	62
Cu	13	23	50	17	18	19	20	25	20

The Oweinat grey granites show trace elements distribution expected from high-Ca granitic rocks. The two elements Ba and Sr tend to show rising quantities in the Oweinat rocks. Ba has a range of 901—1359 ppm while Sr has a range of 491—953 ppm as compared with 420 and 440 ppm for these two elements respectively in the reference high-Ca granite.

Samples 159-A, 232 and 244 show that their trace elements distribution generally follows that of typical Aswan coarse granite as given in Table 6. These samples develop enrichment trends in Ba, Rb and Sr. Nevertheless the south Western Desert

TABLE 6

Trace elements (ppm) of some reference rocks

Element	High-Ca[1]	Low-Ca[2]	Syenite[3]	Grey[4]	Aswan[5]	Normal Pink-Red[6]	Strongly Diff.[7]
Ba	420	840	1600	635	1625	900	50
Rb	110	170	110	76	92	66	168
Sr	440	100	200	578	195	56	18
Y	35	40	20	6	24	22	23
Zr	140	175	500	234	235	137	75
Nb	20	21	35	—	—	—	—
La	45	55	70	4	248	6	4
Ce	—	—	161	—	—	—	—
Nd	—	—	56	—	—	—	—
Cr	23	4	2	80	0.4	1	1
Ni	15	5	4	4	2	1	1
Zn	60	39	130	—	—	—	—
Cu	30	10	5	8	8	8	5

1, 2: High-Ca and Low-Ca granites of TUREKIAN and WEDEPOHLT [1961].
3: Average syenite of TUREKIAN and WEDEPOHL [1961].
4, 5, 6, 7: Typical grey, Aswan, normal pink-red and strongly differentiated pink-red granites as given by EL SOKKARY [1970].

samples are impoverished in La together with Nd. The element La has a range from 2—17 ppm in the studied samples as compared with 248 ppm in the reference Aswan coarse granite.

The pink-red granites of the south Western Desert of Egypt show Ba, Rb and Sr contents which are in general similar to corresponding values of the reference low-Ca granite. Certain specimens with numbers 89, 210 and 256 have anomalously higher contents for their Sr. The gneissose granite sample 256 might be subjected to metasomatic processes in order to account for the high Sr content (631 ppm) of this sample. Other elements like Y, Nb, La, Ce and Nd tend to be depleted in the analysed rocks. This marks many members of the pink-red granites of the south Western Desert to be depleted in certain rare earth elements.

It seems that the porphyritic pink granite sample 251 is enriched in the rare earth elements Y, Zr, Nb, La, Ce and Nd possibly because of the presence of few grains of an accessory mineral which carries these rare earths. The red granite sample 333 has dropping Ba (191 ppm) and Sr (49 ppm) contents with rising Rb (126 ppm) which is in agreement with the contents of these elements in the strongly differentiated pink-red granite as given by El Sokkary (1970). The same sample tends to show enrichment trends in Y, Zr, Nb, La, Ce and Nd. Thus the mentioned red granite is classified here with the strongly fractionated rocks.

The trace elements contents of the syenite sample 155 are close to those of the average syenite of Turekian and Wedepohl [1961], exempting Sr which is almost doubled in the analysed sample. On the other hand, the trace elements data of sample 255 reveal general parallelism with those of the reference syenite except a sharp drop in Ba (159 ppm) and Sr (21 ppm) with an increase in Rb (209 ppm). The reference syenite has its Ba content equals 1600 ppm, Sr 200 ppm and Rb 110 ppm. Zr is enriched as well in the analysed femic syenite (784 ppm) as compared with 500 ppm Zr in the reference syenite. The unusual distribution of Ba, Rb, Sr and Zr in sample 255 may be due to the presence of an abundance of an alkali amphibole in this sample.

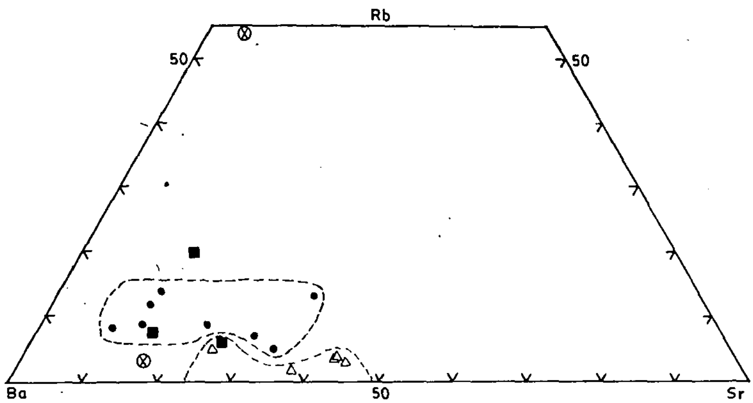

Fig.(7): The ternary relation Rb-Ba-Sr of the studied granitic rocks.

Fig. 7 is a diagramatic representation of the ternary relation of the three trace elements Ba, Sr and Rb. This relation is already used by El Bouseily and El Sokkary [1975] in tracing differentiation trends in acidic suites. The diagram shows that the grey granites are located in a field that is rich in Ba and Sr but being poor in Rb, while the pink-red granites tend to occupy a field more enriched in Rb. This means that the pink-red granites are collectively in a more advanced state of differentiation relative to the grey granites and that the two groups are consanguineous. *Fig. 8* represents another ternary relation between the elements Ti/10-Zr-Y.

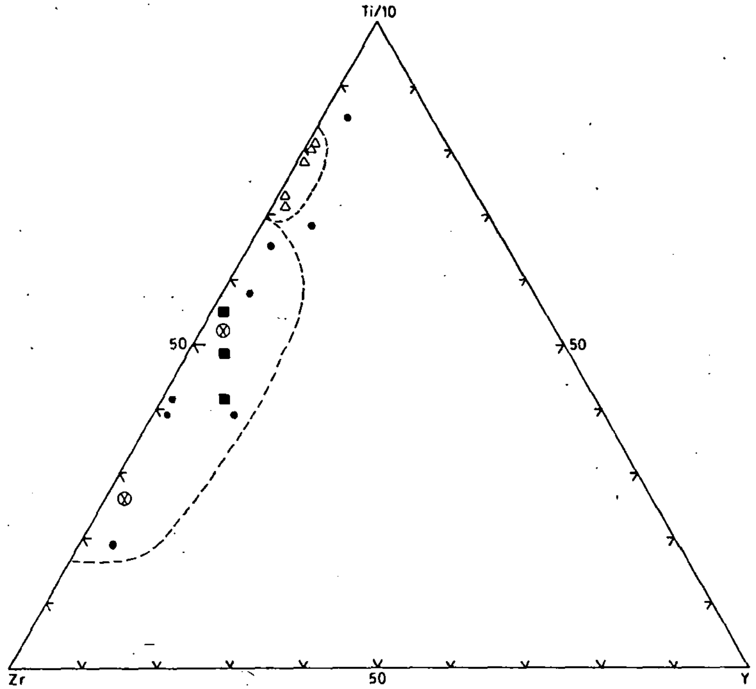

Fig.(8): Ternary diagrm Ti/10-Zr-Y of the studied granitic rocks.

It clarifies that the Oweinat grey granites occupy a position nearer to the Ti apex while the pink-red group is located somewhat away from that apex. A differentiation trend is then postulated between the two rock groups. These two diagrams assure that at least the grey granites and the pink-red granites are consanguineous rocks.

DISCUSSION

The present petrochemical and geochemical studies on the acidic igneous rocks from the south Western Desert of Egypt shed some light on the nature of these rocks. Admittedly such igneous rocks include the following types: grey granites, Aswan-type granites, normal pink-red granites, strongly differentiated pink-red granites and syenites. These rock units are the same like those in the basement rocks of the Eastern Desert and Sinai peninsula. Thus the basement rocks outcropping in the Eastern Desert and Sinai peninsula are extended across the Nile, though mostly subsurface, in the southern parts of the Western Desert. It is shown that at least both the grey granites and the pink-red granites are consanguineous rocks.

With respect to Aswan-type granites, this is the first time to prove their occurrence in the south Western Desert of Egypt. Thus Aswan granites are extended far west across the Nile (at Abu Simbil) till the area of Gebel Siri at longitude 31° E. These new occurrences make Aswan plutonites of much wider aereal distribution then previously known. Because of their peculiar chemical composition, Aswan plutonites can be grouped in a separate plutonic cycle.

From a tectonic point of view, all the above mentioned igneous rocks particularly the granite masses occurring in the south Western Desert are uplifted along dominant E—W fault system. This system is not the original deep seated system along which the granites were emplaced, but is a later system developed as a result of the gradual uplift of the southern parts of the Western Desert which caused the retreat of the Cretaceous Tethys. This situation is to be compared with the granitic groups occurring in the Eastern Desert and Sinai peninsula where each of them has its own geochemical and structural characteristics that make it distinguishable from others [EL SOKKARY and SALLOUM, 1974].

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