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MINERAL CHEMISTRY OF BIOTITES AND HORNBLENDES AS A GUIDE TO MAGMA TYPE OF ABU EL-HASAN GRANITOIDS, NORTHERN EASTERN DESERT, EGYPT

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ABSTRACT

Thirty eight microprobe chemical analyses of biotites and twenty seven microprobe analyses of hornblendes from the older and younger granitoids of Abu El-Hasan Northern Eastern Desert are presented. The behavior of major elements in the examined biotites is discussed according to different variation diagrams and element ratios. Biotite shows a regular variation from the older granitoids (the least silicic) to the younger granitoids (the most silicic). Broadly the examined bioties are characterized by high Fe, Al, Ti and low Mg contents. Biotites of the older granitoids show a clear affinity toward phlogopite while those of the younger granitoids plot close to annite. The chemical composition of biotites has proved a reasonable guide to the magma type of the host granitoids.

The chemistry of hornblendes from the older and the younger granitoids are completely different. This variation is apparent in silica of hornblendes from the older granitoids. The other elements are more variable in hornblendes of the younger granitoids. The most important difference between hornblendes of the older and the younger granitoids is the Mg and Fe contents which indicates different temperatures of crystallization. Proper nomenclature and classification based on mineral chemistry are presented.

Mineral chemistry of hornblende clearly discriminates between the host granitoid groups. The much higher Mg content in hornblende of the older granitoids is an indication of higher temperature and higher pressure.

INTRODUCTION

Gebel Abu El-Hasan lies in the northern part of the E.D. of

Egypt. It forms a conspicuous landmark rising up to 1558 m. above sea level and lies approximately between lats 26° 52' and 27° 02' N and longs 33° 13' and 33° 23° E (Fig. 1). Broadly, the area is characterized by high relief and rough topography. It is covered by Precambrian basement rocks which comprise metasediments, metavolcanics, serpentines, metagabbros, older granitoids, younger granitoids (phase I and phase II), basic dikes, younger red granitoids (phase III), later mafic intrusions and acidic pegmatitic dikes. The granitoids form the major part of the exposed basement rocks. The older granitoids are mostly medium-grained characterized by grey color in the field. Both porphyritic and even-grained types are observed. They show diversity in composition from granodiorite, tonalite, qz-diorite qz-monzodiorite to diorite with variable mafic contents.

The younger granitoids constitute the majority of the granitoid rocks in the studied area. They show different bright colors from buff, pink to red due to the fresh and clear feldspars.

Details of field relations and petrographic characters of these granitoids are given by Dawoud (1995).

Biotites:

Biotites are the most common mafic minerals in the studied granitoids. The compositional variations of biotites in relation to variations in the nature of the host rocks were studied as early as the 1930's. Recently Lalonde 1993 used the composition and color of biotites from granitoids to characterize the plutonic suites tectogenetically.

Recent studies by Nachit et al., 1985 and Ague Brimhall (1988) have certainly demonstrated the potential of using biotite as a

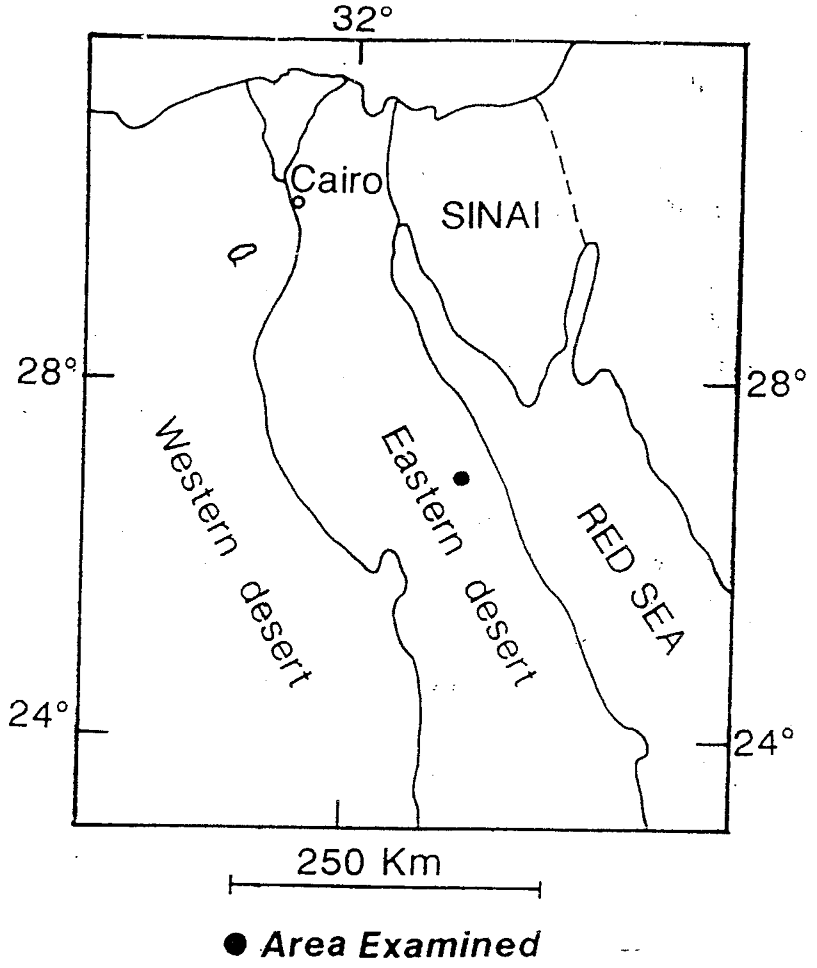

Fig.(1)Location map

petrogenetic and tectonomagmatic indicator in granitoids. Therefore, classifications of granitic rocks based on peraluminosity or oxidation state could gain much by considering the composition of biotite.

Abdel Rahman (1994) using a data bank containing over 325 major element analyses of biotites minerals from many localities around the world, ascertained that biotite compositions depend largely upon the nature of magmas from which they have crystallized.

Biotites from the Egyptian granitic rocks were also subjected to rather detailed research which was pioneered by Kabesh and Refaat (1972), followed by many others by Kabesh et al., 1977; Kabesh et al., 1982; Kabesh et al., 1989. These studies gave more light on the origin of the host granitoid rocks.

From the preceding, the importance of the study of biotites as an indicator for the genesis of the host is very clear. Rather than other minerals, biotites are very sensitive recorder for all changes which occur in the magma either chemical or physical, in addition to, the later processes which could affect the rocks after consolidation. This is very obvious where samples of the studied older granitoids and younger granitoids are not so different in the chemistry, but their biotites show large difference even in the major elements as Mg and Fe. For this purpose and to see what are the differences between biotites from the older and younger granitoids and their characterization, three samples from the biotite granitoids (the oldest phase of the younger granitoids) and two samples from the older granitoids were prepared for the microprobe analyses. It was taken into account that these samples cover all the possible variation in the biotite chemistry as it was inferred from petrography, modal analyses, chemistry of the rock, in addition to the field work.

Composition of Biotites :

The chemical compositions of the studied biotites as well as the chemical formulae calculated on the basis of 22 oxygens are given in Table (1). The most striking differences between the biotite of the older granitoids and that of the younger granitoids are the contents of Mg and Fe. MgO ranges from 13.82 to 9.03 % and FeO (t) ranges from 20.63 to 15.47 % in the older granitoids. This is compared with 6.2 to 3.00 % for MgO and 31.10 to 25.63 % for FeO (t) in the younger granitoids. Fe / (Fe+Mg) for the older granitoids ranges from 0.39 to 0.56 while that for the younger granitoids ranges between 0.69 to 0.85. This is a clear distinction between both groups and reflects the difference in the temperature of the magma from which they were derived being higher in case of the older granitoids as compared to the younger granitoids. It also reflects higher depth and lower acidity of the older granitic magma and the shallower depth of the younger granitic magma. Another feature is that the analyses from each sample tend to cluster close together indicating homogeneity in low scale. The variation between the samples from the older granitoids is higher than that in the younger granitoids leading to the conclusion that the younger magma was more homogeneous. All the studied biotites plot in the field of biotite (Fig. 2), however the samples from the older granitoids are more close to phologopite, whereas those from the younger granitoids are close to annite.

Structural formulae :

The structural formulae of the analyzed biotites are represented in Tab. (1). The calculations are based on 22 (O) to the general mica formulae $X_2Mg_6Z_{22}(F, Cl)$. Most of Al occupies Z position and sometimes is not enough to accomplish the position with silica, so some titanium (Tiv) is needed while the rest of Ti (T_{vi}) is used to fill the Y position with Fe, Mg, Mn, Zn and Alvi when exists. In X position Ca, Ba, Na, K, and Rb are the main constituents.

Tab.1 Chemical analyses of the biotites and their structural formulae.

S. No.	3-9m	3-9r	3-10m	3-10r	3-11m	3-11r	65-12m	65-12r	65-13m	65-13r	70-1	70-2	70-2-3
SiO2	33,89	34,71	35,07	35,47	34,41	34,73	35,89	36,08	36,67	35,58	34,75	34,43	34,56
TiO2	3,88	3,57	4,18	4,34	3,57	3,88	3,33	3,77	3,04	3,34	2,57	2,84	3,24
Al2O3	11,55	11,44	11,61	11,67	11,49	11,44	12,25	13,02	12,23	12,48	12,41	12,01	11,82
FeO	31,10	30,54	30,97	29,56	31,03	31,00	28,97	28,13	28,36	28,69	28,67	28,51	26,79
MnO	0,57	0,55	0,61	0,48	0,62	0,64	0,90	0,77	0,92	0,87	0,70	0,78	0,53
MgO	3,09	3,34	3,04	3,24	3,00	3,08	4,71	4,20	4,64	4,77	5,78	5,68	6,20
CaO	[illegible]	0,04	0,01	0,01	0,04	0,03	0,06	0,22	0,03	0,20	0,00	0,04	0,03
Na2O	0,05	0,07	0,07	0,04	0,18	0,15	0,05	0,05	0,08	0,08	0,07	0,23	0,08
K2O	9,44	9,40	9,60	9,91	8,76	9,40	9,90	10,28	9,98	8,71	10,01	9,81	9,66
P2O5	0,00	0,02	0,00	0,00	0,08	0,05	0,02	0,18	0,01	0,00	0,02	0,05	0,00
ZnO	0,24	0,23	0,60	0,60	0,35	0,32	0,16	0,22	0,18	0,22	0,19	0,20	0,14
Rb2O	0,10	0,16	0,06	0,17	0,00	0,09	0,06	0,10	0,78	0,24	0,45	0,54	0,43
BaO	0,43	0,00	0,29	0,00	0,27	0,00	0,35	0,08	0,00	0,00	0,00	0,15	0,15
SrO	[illegible]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,00	0,00
Y2O3	0,00	0,00	0,00	0,00	0,07	0,00	0,00	0,00	0,00	0,03	0,00	0,00	0,00
F	0,23	0,28	0,22	0,17	0,19	0,12	0,52	0,34	0,80	0,56	0,47	0,58	0,50
Cl	0,08	0,07	0,06	0,05	0,07	0,08	0,04	0,03	0,02	0,02	0,01	0,02	0,02
Tot.	94,57	94,52	96,34	95,66	94,08	94,99	97,21	97,45	97,24	95,79	94,14	93,85	93,94

S. No.	70-2-4	70-3-1	70-4-1	70-4-3	70-5-1	70-6-1	70-6-2	70-6-3	70-6-4	2-1m	2-1r	2-2m
SiO2	34,34	33,64	35,35	35,85	34,33	34,46	34,87	34,51	34,48	37,77	38,18	37,93
TiO2	3,55	3,70	3,72	4,01	3,49	3,93	4,59	4,51	4,10	3,53	3,20	2,58
Al2O3	11,86	12,06	11,71	12,50	11,81	11,57	11,86	12,12	11,83	11,84	12,12	12,03
FeO	26,68	26,15	26,58	25,73	27,46	28,11	26,86	25,63	26,51	18,32	15,94	18,03
MnO	0,63	0,63	0,63	0,59	0,85	0,93	0,87	0,83	0,81	0,62	0,63	0,72
MgO	5,83	5,86	5,72	5,47	5,56	5,48	4,84	0,05	5,78	13,03	13,44	13,82
CaO	0,00	0,05	0,07	0,04	0,02	0,02	0,03	0,00	0,00	0,03	0,01	0,04
Na2O	0,19	0,07	0,07	0,03	0,06	0,09	0,10	0,10	0,08	0,06	0,06	0,08
K2O	9,88	9,88	9,80	10,09	9,82	9,73	9,96	9,93	9,87	9,90	10,06	9,92
P2O5	0,00	0,04	0,05	0,04	0,00	0,00	0,02	0,07	0,03	0,00	0,00	0,03
ZnO	0,12	0,15	0,16	0,19	0,15	0,16	0,26	0,27	0,21	0,11	0,14	0,15
Rb2O	0,31	0,23	0,18	0,16	0,13	0,13	0,30	0,30	0,18	0,11	0,12	0,17
BaO	0,11	0,08	0,07	0,09	0,57	0,76	0,08	0,50	0,46	0,18	0,00	0,16
SrO	0,00	0,00	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Y2O3	0,00	0,03	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00	0,00	0,00
F	0,78	0,52	0,71	0,38	0,77	1,04	0,57	1,51	0,89	0,98	1,04	1,04
Cl	0,02	0,01	0,01	0,02	0,01	0,02	0,02	0,03	0,03	0,04	0,03	0,04
Tot.	94,28	93,10	94,90	95,19	94,82	96,41	95,17	95,17	95,74	94,57	94,97	94,78

S. No.	2-2r	2-3m	2-3r	2-4m	2-4r	90-7-1	90-7-2	90-7-3	90-8-1	90-10-1	90-10-2	90-11-1	90-11-2
SiO2	37,90	37,86	38,20	37,77	37,64	35,83	35,33	36,01	36,77	36,63	35,99	35,97	37,37
TiO2	3,06	3,25	3,17	2,76	3,40	3,32	3,11	3,41	3,65	3,68	3,84	3,83	3,42
Al2O3	12,20	12,05	12,23	12,05	12,17	12,51	12,72	12,98	13,56	12,68	12,76	12,17	12,47
FeO	18,52	16,67	16,01	16,18	15,47	22,44	22,57	22,57	21,28	22,25	21,71	22,83	21,47
MnO	0,78	0,73	0,64	0,65	0,59	0,31	0,31	0,41	0,45	0,41	0,38	0,48	0,39
MgO	12,80	12,89	13,04	13,61	13,23	9,28	9,24	9,11	9,03	9,29	9,04	9,08	9,78
CaO	0,03	0,07		0,04	0,02	0,03	0,00	0,03	0,03	0,02	0,03	0,04	0,04
Na2O	0,09	0,08	0,07	0,09	0,09	0,11	0,08	0,12	0,11	0,12	0,12	0,14	0,15
K2O	10,07	10,01	9,51	9,90	10,12	9,74	9,27	9,53	8,14	9,13	9,88	9,73	9,38
P2O5	0,03	0,00	0,00	0,00	0,07	0,00	0,00	0,00	0,00	0,02	0,02	0,02	0,00
ZnO	0,20	0,21	0,13	0,13	0,17	0,21	0,11	0,04	0,09	0,20	0,13	0,22	0,23
Rb2O	0,09	0,07	0,22	0,08	0,08	0,12	0,19	0,18	0,18	0,18	0,44	0,27	0,00
BaO	0,00	0,13	0,00	0,06	0,09	0,43	0,52	0,64	0,56	0,43	0,00	0,35	0,11
SrO	0,00	0,00	0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Y2O3	0,03	0,00	0,03	0,05	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
F	0,98	0,89	1,00	1,13	1,11	0,00	0,83	0,68	0,82	0,98	0,58	0,99	0,99
Cl	0,04	0,04	0,04	0,04	0,05	0,05	0,04	0,05	0,03	0,06	0,03	0,05	0,06
Tot.	94,77	94,90	94,74	94,54	94,31	94,38	94,33	95,74	94,68	96,08	94,75	95,97	95,84

Structural formulae of the studied biotites

Sample	3-9m	3-9r	3-10m	3-10r	3-11m	3-11r	65-12m	65-12r	65-13m	65-13r	70-1	70-2	70-2-3
Si	[illegible]	5,74	5,71	5,78	5,73	5,73	5,72	5,70	5,81	5,71	5,72	5,71	5,71
Al(IV)	2,26	2,23	2,23	2,24	2,25	2,22	2,28	2,30	2,19	2,29	2,28	2,29	2,26
Ti(IV)	[illegible]	0,02	0,06	0,00	0,02	0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,03
Z	8	8	8	8	8	8	8	8	8	8	8	8	8
Al(VI)	[illegible]	0,00	0,00	0,00	0,00	0,00	0,02	0,12	0,09	0,07	0,13	0,06	0,00
Ti(VI)	[illegible]	0,43	0,45	0,53	0,42	0,43	0,40	0,45	0,36	0,40	0,32	0,35	0,37
Fe	[illegible]	4,23	4,22	4,02	4,32	4,28	3,88	3,72	3,75	3,85	3,67	3,66	3,70
Mg	[illegible]	0,82	0,74	0,79	0,75	0,76	1,12	0,99	1,09	1,14	1,42	1,40	1,53
Mn	0,06	0,08	0,09	0,07	0,09	0,09	0,12	0,10	0,12	0,12	0,10	0,11	0,07
Zn	0,03	0,03	0,07	0,07	0,04	0,04	0,02	0,03	0,02	0,03	0,02	0,03	0,02
Y	[illegible]	5,59	5,57	5,48	5,62	5,60	5,54	5,41	5,43	5,61	5,66	5,63	5,69
Ca	[illegible]	0,01	0,00	0,00	0,01	0,01	0,10	0,04	0,01	0,03	0,00	0,01	0,01
Ba	[illegible]	0,00	0,02	0,00	0,02	0,00	0,02	0,01	0,00	0,00	0,00	0,00	0,00
Na	[illegible]	0,02	0,02	0,01	0,06	0,06	0,02	0,07	0,03	0,02	0,02	0,07	0,03
K	[illegible]	1,98	2,00	2,06	1,86	1,98	2,01	2,01	2,02	1,78	2,10	2,08	2,04
Rb	[illegible]	0,02	0,01	0,02	0,00	0,01	0,01	0,01	0,03	0,03	0,00	0,00	0,00
X	[illegible]	2,03	2,05	2,09	1,95	2,05	2,10	2,09	2,09	1,86	2,12	2,16	2,08
F	[illegible]	0,15	0,11	0,09	0,10	0,06	0,26	0,17	0,40	0,29	0,17	0,21	0,18
Cl	[illegible]	0,02	0,02	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,00	0,01	0,01
Fe/(Fe+Mg)	0,85	0,84	0,85	0,84	0,85	0,85	0,78	0,79	0,77	0,77	0,72	0,72	0,71

Sample	70-2-4	70-3-1	70-4-1	70-4-3	70-5-1	70-6-1	70-6-2	70-6-3	70-6-4	2-1m	2-1r	2-2m
Si	5,67	5,60	5,76	5,76	5,67	5,64	5,68	5,63	5,65	5,79	5,80	5,79
Al(IV)	2,31	2,37	2,24	2,24	2,26	2,23	2,28	2,33	2,28	2,14	2,17	2,17
Ti(IV)	0,02	0,03	0,00	0,00	0,07	0,13	0,04	0,04	0,07	0,07	0,03	0,04
Z	8	8	8	8	8	8	8	8	8	8	8	8
Al(VI)	0,00	0,00	0,01	0,13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ti(VI)	0,42	0,43	0,46	0,48	0,36	0,35	0,52	0,51	0,43	0,34	0,34	0,26
Fe	3,68	3,64	3,62	3,46	3,79	3,85	3,67	3,50	3,63	2,09	2,03	2,05
Mg	1,44	1,45	1,39	1,31	1,37	1,33	1,18	1,36	1,41	2,98	3,06	3,14
Mn	0,09	0,09	0,09	0,06	0,12	0,13	0,11	0,11	0,11	0,08	0,08	0,09
Zn	0,02	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,01	0,01	0,02	0,02
Y	5,65	5,62	5,58	5,47	5,65	5,67	5,50	5,57	5,59	5,50	5,52	5,56
Ca	0,00	0,01	0,01	0,01	0,00	0,00	0,01	0,00	0,00	0,01	0,00	0,01
Ba	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,01
Na	0,06	0,02	0,02	0,01	0,02	0,03	0,03	0,03	0,03	0,02	0,02	0,02
K	2,09	2,10	2,04	2,07	2,07	2,00	2,07	2,07	2,06	1,94	1,95	1,93
Rb	0,00	0,02	0,01	0,00	0,00	0,00	0,00	0,01	0,00	0,01	0,01	0,02
X	2,14	2,15	2,09	2,09	2,09	2,06	2,11	2,10	2,09	1,99	1,98	1,99
F	0,27	0,20	0,25	0,13	0,28	0,37	0,21	0,53	0,37	0,47	0,50	0,50
Cl	0,00	0,00	0,00	0,01	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Fe/(Fe+Mg)	0,72	0,72	0,72	0,73	0,73	0,74	0,76	0,72	0,72	0,41	0,40	0,39

Sample	2-2r	2-3m	2-3r	2-4m	2-4r	90-7-1	90-7-2	90-7-3	90-8-1	90-10-1	90-10-2	90-11-1	90-11-2
Si	5,79	5,79	5,82	5,78	5,76	5,70	5,67	5,68	5,76	5,74	5,71	5,69	5,81
Al(IV)	2,20	2,17	2,18	2,17	2,20	2,30	2,33	2,32	2,24	2,26	2,29	2,31	2,19
Ti(IV)	0,01	0,04	0,00	0,05	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Z	8	8	8	8	8	8	8	8	8	8	8	8	8
Al(VI)	0,00	0,00	0,02	0,00	0,00	0,05	0,08	0,09	0,28	0,08	0,10	0,00	0,00
Ti(VI)	0,34	0,33	0,36	0,27	0,35	0,40	0,38	0,40	0,43	0,43	0,43	0,43	0,40
Fe	2,11	2,13	2,04	2,07	1,98	2,98	3,03	2,98	2,78	2,91	2,88	3,00	2,83
Mg	2,92	2,94	2,96	3,10	3,02	2,20	2,21	2,14	2,11	2,17	2,14	2,15	2,28
Mn	0,10	0,10	0,08	0,08	0,08	0,04	0,04	0,05	0,06	0,05	0,05	0,06	0,05
Zn	0,02	0,02	0,02	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,02	0,01	0,00
Y	5,49	5,57	5,48	5,54	5,45	5,68	5,75	5,67	5,67	5,66	5,62	5,65	5,54
Ca	0,00	0,00	0,01	0,01	0,00	0,01	0,00	0,01	0,01	0,00	0,01	0,01	0,01
Ba	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Na	0,03	0,02	0,02	0,03	0,03	0,03	0,00	0,04	0,03	0,04	0,04	0,04	0,06
K	1,96	1,95	1,93	1,93	1,98	1,98	1,90	1,92	1,63	1,83	2,00	1,97	1,86
Rb	0,01	0,01	0,02	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X	2,00	1,99	1,98	1,98	2,03	2,02	1,93	1,97	1,67	1,87	2,05	2,02	1,92
F	0,47	0,43	0,48	0,55	0,54	0,00	0,29	0,23	0,29	0,33	0,20	0,34	0,34
Cl	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Fe/(Fe+Mg)	0,42	0,42	0,41	0,40	0,40	0,58	0,58	0,58	0,57	0,57	0,57	0,58	0,56

Variation diagrams :

To show the behaviour of elements during the crystallization, different variation diagrams are constructed. It was found that the variation in silica is more than that of Fe/(Fe + Mg) in the studied rocks and accordingly silica was taken as a criterion of differentiation. What is interesting is that silica and magnesia show a clear positive correlation between the different samples (but not clear between the analyses from the same sample), while silica shows a negative correlation with iron (Fig. 3). This means that biotites from the older granitoids (lower silica content) have higher silica content than those from the younger granitoids (higher silica content). However the simultaneous growing phases (mainly more basic plagioclase with lower silica content in the case of the older granitoids and more acidic plagioclase with higher silica content in the case of the younger granitoids) could affect the silica incorporated by biotites. The relation between alumina and silica (which is positively correlated with magnesia) is not clear although rough positive correlation could be observed in biotites from the younger granitoids and rough negative correlation in the biotites from the older granitoids. Generally biotites from the older granitoids have alumina (and higher magnesia) indicating higher temperature of crystallization favoring higher corporation of alumina in biotites with increasing temperature. Potassium does not show distinct relation with silica although slight increase is hardly seen. Titanium also has no definite relation but rough negative correlation with silica is observed. What is noteworthy is that titanium and magnesium show wide and rough negative correlation leading to the conclusion that low temperature biotites have higher titanium contents. This is against the conclusion of Lyahkovich et al., (1994), and could be explained due to growing of titanium-bearing minerals especially sphene which is more in the case of the older granitoids rather than the younger granitoids. From the traces which show defined relation with silica fluorine shows positive correlation while zinc has negative correlation. The higher fluorine content in the biotite from the older granitoids reflects higher fluid activity which is also confirmed by the higher contents of hydrous minerals. Higher flourine content of the younger granitoids than that of the older granitoids is however common known.

Biotites as indicator of the tectonic environment of their host granitoids :

The tectonic diagrams constructed by Abdel Rahman (1994) are used to reveal the tectonic setting of Abu El Hasan granitoids. Four diagrams are used for this purpose and gave excellent and confirmatory tool for the tectonic setting previously deduced from the whole rock chemistry. Biotites from the younger granitoids always plot in the alkaline anorogenic (A-type) suites, and those from the older granitoids plot in the calc-alkaline orogenic suites, (Fig.4).

Hornblendes :

The geochemistry of some hornblendes is treated to throw more light on the origin and discrimination between the granitic groups, although hornblendes are present in few samples and in low concentrations (less than 1 % modal). During the microprobe work altered parts were excluded. Discrimination between the two granitic groups using hornblende analyses is very clear nearly in all analyzed elements.

One of the advantages of studying the amphiboles is their indications in pressure as well as temperature. The use of chemistry and mineralogy of amphiboles barometry is established long ago. It is widely recognized that the amphiboles from mafic rocks of high

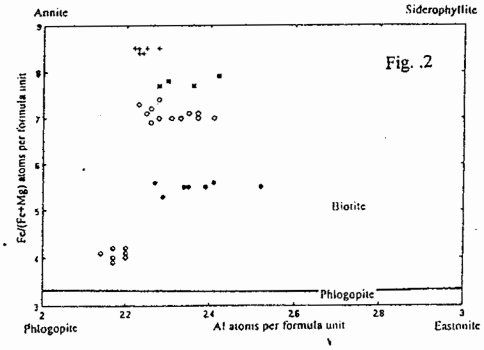

Fig. .2

Fig. 3 next page

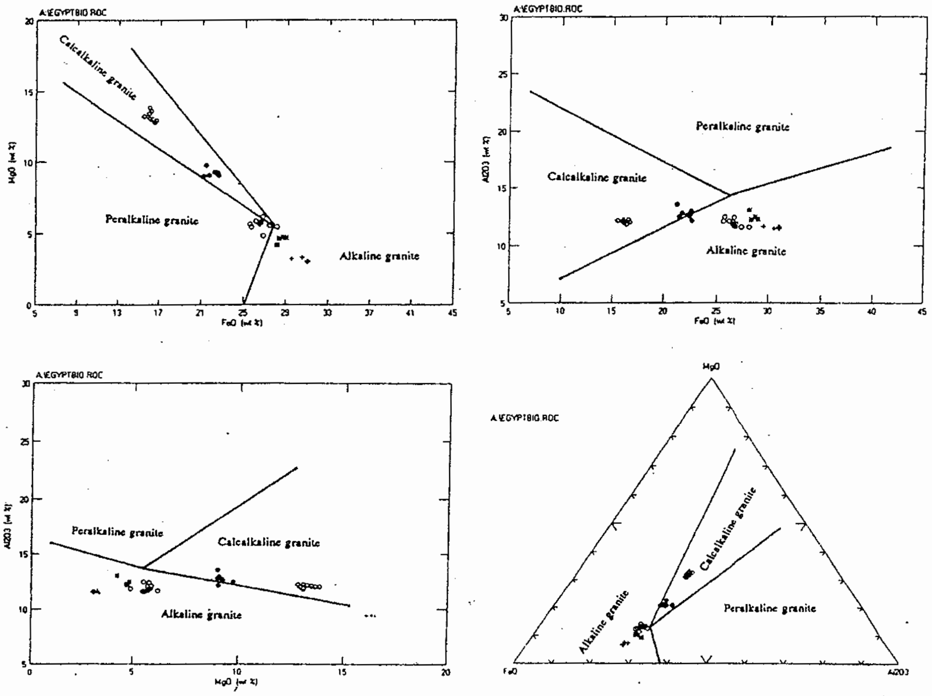

Fig. 4 •,° Biotites from the older granites. °, + ,* Biotites from the younger granites.

All symbols are the same throughout the paper.

pressure facies (Miyashiro 1961) are rich in glaucophane, and it has been suggested (Brown 1977) that even Barrovian (medium-pressure) facies series rocks may contain more glaucophane rich amphibole than those of lower pressure. Other features that have been used to distinguish low-pressure from medium pressure amphiboles are their lower Alvi (Leake 1965; Kostyuk and Sobelev 1969; Rassa 1974; Laird and Albee 1981a) and their higher Na (edenite) contents (Holland and Richardson 1979; Laird and Albee 1981a).

Enrichment in Ti at low-pressures is due to the positive slope of reactions partitioning Ti into the amphibole. The composition gap in amphiboles at medium-pressure is due to overstepping of the tschermakite-enriching equilibrium. The relatively low-grade appearance of oligoclase at low pressures is due to convergence of tschermakite- and anorthite-enriching equlibria with decreasing pressure.

Chemical Composition of Hornblendes :

Two main features can be deduced for the first while. The first is that the chemistry of hornblendes from the older granitoids and younger granitoids are completely different. The second is that the variation is much between the different spots although all are from the same sample. This variation is more pronounced in the silica of hornblendes from the older granitoids. The range of silica for seven analyses is about 4 %, while this range is about 2 % for 20 analyses from the younger granitoids. The other elements are more variable in hornblendes of the older and younger granitoids (Fig. 5). As in biotites, the most important difference between hornblendes of the older and the younger granitoids is the magnesium and iron contents, about 10 % in magnesium and 15 % in iron, which indicates different temperatures of crystallization. Table (2) shows the composition of the analyzed amphiboles and their chemical formulae.

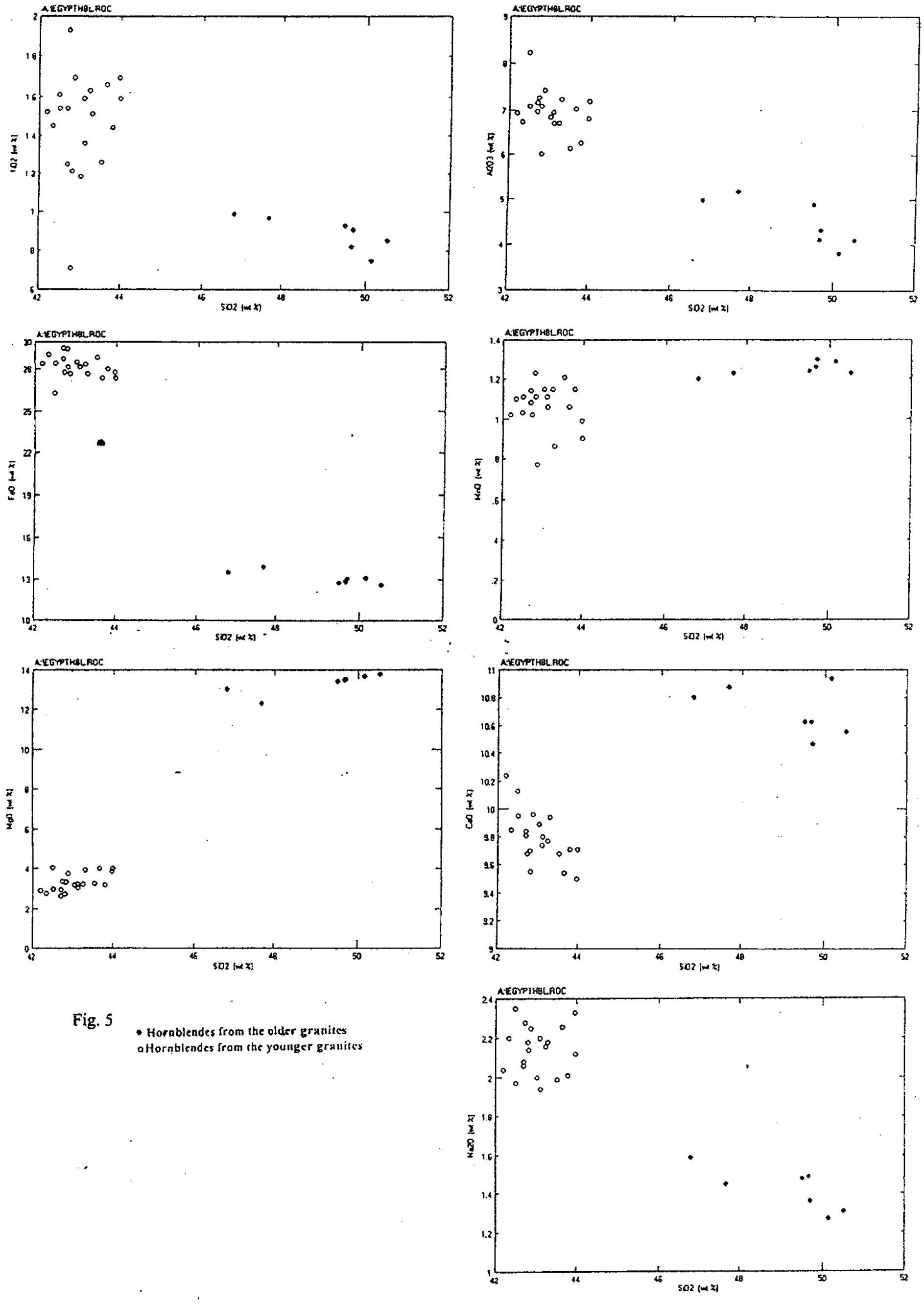

Fig. 5

- ● Hornblendes from the older granites
- ○ Hornblendes from the younger granites

All symbols are the same throughout the paper.

Tab.2 Chemical analyses of the amphiboles and their structural fotmulae.

S. No	3-1-1	3-1-3	3-1-4	3-1	3-1-1	3-1-2	3-1-3	3-1-4	3-2-1	3-2-2	3-2-3	3-2-4	3-3-1	3-3-2	3-3-3	3-3-4	3-4-1	3-4-2	3-9m	3-9r	2-1-1	2-1-2	2-2-2	2-1	2-1r	2-2	2-2r
SiO2	43,99	42,88	43,30	43,96	42,73	42,49	43,65	43.10	43,80	43,12	42,20	42,71	43,25	43,03	42,51	43,53	42,81	42,71	42,33	42,83	50,50	49,50	49,69	47,68	50,13	46,79	49,66
TiO2	1,59	1,69	1,51	1,69	1,93	1,61	1,68	1,59	1,44	1,36	1,52	1,54	1,63	1,18	1,54	1,26	0,71	1,25	1,45	1,21	0,85	0,93	0,91	0,97	0,75	0,99	0,82
I2O3	7,19	7,44	7,24	6,81	7,27	8,22	7,03	6,95	6,26	6,70	6,93	6,96	6,70	6,84	7,08	6,14	7,09	7,16	6,74	6,02	4,11	4,90	4,33	5,18	3,82	4,99	4,13
FeO	27,36	27,66	27,68	27,79	27,76	26,27	27,35	28,19	28,00	28,17	28,41	28,76	28,40	28,54	28,41	28,87	29,49	29,56	29,10	28,19	12,60	12,71	13,05	13,91	13,07	13,47	12,86
MnO	0,90	0,77	0,86	0,99	1,02	1,03	1,06	1,11	1,15	1,06	1,02	1,08	1,15	1,15	1,11	1,21	1,23	1,14	1,10	1,11	1,23	1,24	1,30	1,23	1,29	1,20	1,26
MgO	3,99	3,74	3,93	3,86	3,36	4,03	4,00	3,21	3,19	3,04	2,90	2,95	3,23	3,20	2,98	3,28	2,73	2,61	2,78	3,33	13,79	13,43	13,54	12,34	13,68	13,06	13,51
CaO	9,71	9,96	9,94	9,50	9,68	10,13	9,54	9,74	9,71	9,80	10,24	9,84	9,77	9,89	9,95	9,88	9,70	9,81	9,85	9,55	10,56	10,63	10,47	10,88	10,94	10,81	10,63
Na2O	2,12	2,25	2,18	2,33	2,28	2,35	2,26	2,20	2,01	1,94	2,04	2,08	2,16	2,00	1,97	1,99	2,18	2,08	2,20	2,14	1,31	1,48	1,36	1,45	1,27	1,59	1,49
K2O	1,29	1,43	1,32	0,86	1,02	0,76	0,93	0,94	0,82	1,07	1,02	0,97	0,90	1,10	1,11	0,96	1,00	1,09	0,99	0,82	0,52	0,60	0,58	0,72	0,54	0,74	0,58
Z	0,33	0,34	0,35	0,32	0,48	0,36	0,38	0,34	0,35	0,28	0,25	0,35	0,32	0,33	0,33	0,28	0,28	0,34	0,23	0,21	0,15	0,10	0,14	0,08	0,09	0,11	0,07
F	1,04	1,26	1,09	0,66	0,70	0,54	0,57	0,63	0,55	0,38	0,43	0,46	0,56	0,53	0,46	0,48	0,46	0,50	0,44	0,40	0,58	0,60	0,58	0,49	0,49	0,54	0,56
Cl	0,15	0,16	0,14	0,12	0,15	0,02	0,12	0,18	0,10	0,08	0,09	0,11	0,10	0,05	0,05	0,09	0,13	0,13	0,09	0,09	0,03	0,03	0,03	0,03	0,03	0,04	0,04
Tot.	99,66	99,58	99,54	98,89	98,38	97,81	98,55	98,18	97,38	96,98	97,05	97,81	98,17	97,84	97,50	97,75	97,81	98,36	97,30	95,90	96,23	96,15	95,98	94,96	96,10	94,33	95,61

Structural formulae.

Sample	3-1-1	3-1-3	3-1-4	3-1	3.1-1	3-1-2	3-1-3	3-1-4	3-2-1	3-2-2	3-2-3	3-2-4	3-3-1	3-3-2	3-3-3	3-3-4	3-4-1	3-4-2	3-9m	3-9r	2-1-1	2-1-2	2-2-2	2-1	2-1r	2-2	2-2r
Si	6,87	6,76	6,81	6,84	6,72	6,55	6,79	6,8	6,92	6,89	6,81	6,84	6,86	6,84	6,82	6,96	6,79	6,79	6,97	6,83	7,45	7,31	7,38	7,41	7,16	7,45	7,23
Al(IV)	1,13	1,24	1,19	1,16	1,28	1,45	1,21	1,2	1,08	1,11	1,19	1,16	1,14	1,16	1,18	1,04	1,21	1,21	1,03	1,17	0,55	0,69	0,62	0,59	0,84	0,55	0,77
Z	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Al(VI)	0,11	0,05	0,07	0,09	0,07	0,04	0,08	0,09	0,09	0,15	0,09	0,15	0,11	0,12	0,16	0,12	0,12	0,13	0,12	0,11	0,17	0,16	0,14	0,14	0,06	0,12	0,16
Ti	0,18	0,19	0,17	0,2	0,23	0,19	0,19	0,19	0,17	0,16	0,17	0,19	0,2	0,14	0,13	0,15	0,2	0,15	0,15	0,18	0,09	0,1	0,1	0,09	0,11	0,08	0,11
Fe	3,35	3,41	3,41	3,62	3,65	3,39	3,56	3,72	3,7	3,77	3,49	3,65	3,77	3,79	3,81	3,86	3,91	3,93	3,84	3,93	1,55	1,57	1,62	1,6	1,72	1,62	1,76
Mg	0,87	0,82	0,86	0,9	0,79	0,93	0,93	0,76	0,75	0,72	0,63	0,7	0,76	0,76	0,71	0,78	0,65	0,62	0,81	0,67	3,03	2,96	3	3	2,98	3,03	2,79
Mn	0,11	0,1	0,11	0,13	0,14	0,13	0,14	0,15	0,15	0,14	0,13	0,15	0,15	0,16	0,15	0,16	0,17	0,15	0,15	0,15	0,15	0,16	0,16	0,16	0,16	0,16	0,16
Zn	0,07	0,07	0,08	0,19	0,22	0,21	0,22	0,2	0,21	0,17	0,03	0,04	0,04	0,04	0,04	0,03	0,03	0,04	0,03	0,03	0,02	0,01	0,02	0,01	0,01	0,01	0,01
Y	4,69	4,64	4,7	5,13	5,1	4,89	5,12	5,11	5,07	5,11	4,54	5,08	5,03	5,01	5,06	5,1	5,08	5,02	5,1	5,07	5,01	4,96	5,04	5	5,04	5,02	4,99
Ca	1,52	1,57	1,57	1,58	1,63	1,67	1,59	1,65	1,65	1,68	1,61	1,69	1,66	1,68	1,71	1,66	1,65	1,67	1,66	1,7	1,67	1,68	1,67	1,7	1,77	1,74	1,77
Na	0,73	0,75	0,74	0,7	0,69	0,7	0,68	0,67	0,62	0,6	0,58	0,65	0,66	0,62	0,61	0,62	0,67	0,64	0,69	0,69	0,37	0,42	0,39	0,43	0,47	0,37	0,43
K	0,24	0,27	0,25	0,17	0,21	0,15	0,19	0,19	0,17	0,22	0,19	0,7	0,18	0,22	0,23	0,2	0,2	0,22	0,17	0,2	0,1	0,11	0,11	0,11	0,14	0,1	0,14
X	2,49	2,59	2,56	2,45	2,53	2,57	2,46	2,51	2,44	2,5	2,38	2,54	2,5	2,52	2,55	2,48	2,52	2,53	2,52	2,59	2,14	2,21	2,17	2,24	2,38	2,21	2,34
F	0,48	0,59	0,51	0,33	0,35	0,26	0,28	0,32	0,28	0,19	0,2	0,23	0,28	0,27	0,23	0,24	0,23	0,25	0,21	0,22	0,27	0,28	0,27	0,26	0,26	0,23	0,24
Cl	0,04	0,04	0,04	0,03	0,04	0,01	0,[illegible]3	0,03	0,03	0,02	0,02	0,03	0,03	0,01	0,02	0,02	0,03	0,04	0,03	0,03	0,01	0,01	0,01	0,01	0,01	0,01	0,01
K+Na	0,97	1,02	0,99	0,87	0,9	0,85	0,87	0,86	0,79	0,82	0,77	0,85	0,84	0,84	0,84	0,82	0,87	0,86	0,86	0,89	0,47	0,53	0,5	0,54	0,61	0,47	0,57
Al	1,24	1,29	1,26	1,25	1,35	1,49	1,29	1,29	1,17	1,26	1,28	1,31	1,25	1,28	1,34	1,16	1,33	1,34	1,15	1,28	0,72	0,85	0,76	0,73	0,9	0,67	0,93

Classification of the studied amphiboles :

The present analyses are plotted on Leake's (1978) diagram for classification, Fig (6). Amphiboles from the younger granitoids plot mostly in the edenite field and rarely in the edenitic hornblende field. Amphiboles from the older granitoids plot however in both the edenite and actinolitic hornblende fields with lower alkalis and higher silica contents.

Hornblendes as indicator of the pressure of their host :

Using Raase's (1974)ís diagram both hornblendes either from both the older and younger granitoids plot in the field of low pressure regional metamorphic terrains. The analyses of the older granitoids are more close to the high pressure metamorphic terrain field (Fig. 7). The same result can be obtained using Ti versus Al diagram (Hynes, 1982) where the analyses of the older granitoids are also more close to the field of medium pressure amphiboles, Fig. (7).

From the preceding it is obvious that the study of the hornblendes makes the picture more clear and discriminates between the two granitic groups. The much higher magnesium content in hornblendes of the older granitoids is an indicator of higher temperature, (Raase, 1974 and Hynes, 1982) and higher pressure too.

CONCLUSIONS

The examined biotites of Abu El-Hasan granitoids, northern Eastern Desert, Egypt, are characterized by high Fe, Al, Ti and low mg contents. Biotites of the older granitoids show clear affinity towards phlogopite while those of the younger ones plot close to annite.

The chemistry of hornblendes ofboth the studied younger and

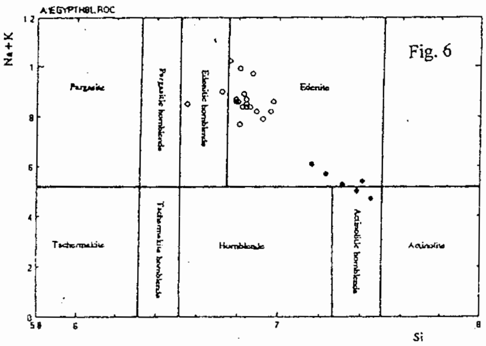

Fig. 6

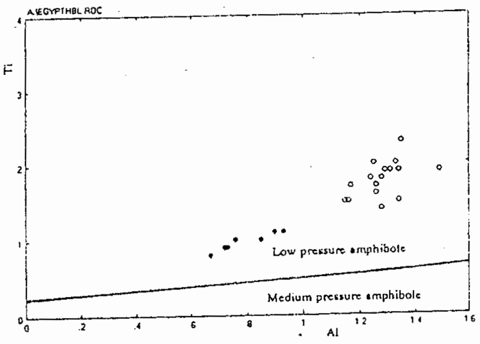

Fig. 8

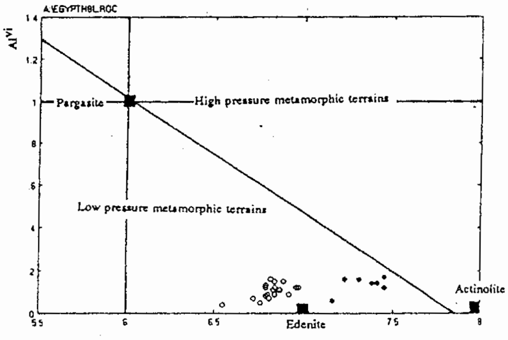

Fig. 7

older granitoids are completely different. The Mg content is higher in the older granitoids than that in the younger ones whereas Fe content is lower in the older granitoids than that of the younger ones. The higher Mg content in the hornblende of the older granitoids may be an indication of higher temperature and pressure.

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REFERENCES

Abdel Rahman, A. M., 1994. Nature of biotites from alkaline, calcalkaline and peraluminous magmas. Jour. Pet., Vol.35, Part 2, pp.525-541.

Ague, J. J. and G. H. Brimhall, 1988. Regional variations in bulk chemistry, mineralogy and the compositions of mafic and accessory minerals in the batholiths of California. Geol. Soc. Am. Bull., 100: 891-911. .

Brown, E. H., 1977. The crossite content of Ca-amphibole as a guide to pressure of metamorphism. J. Petrol., 18, pp.53-72.

Dawoud, M., 1995. Petrology, geochemistry and tectonic environment of the granitic rocks of Gebel Abu El-Hassan- Gebel Abu Samyuk, northern Eastern Desert, Egypt. Ph.D. Thesis, Menoufia Univ., Egypt, 157p.

Hammarstrom, J. M., and Zen, E. A., 1986. Aluminum in hornblende: an empirical igneous geobarometer. Am. Mineral., 71, p.1297-1313.

Holland, T. J. B., and Richardson, S. W., 1979. Amphibole zonation in metabasites as a guide to the evolution of metamorphic conditions. Contr. Min. Petrol. 70, p.143-148.

Hollister, L. S., Grisson, G. C., Peters, E. K., Stowell, H. H., and Sisson, B. B., 1987. Confirmation of the emprical calibaration of Al in hornblende with pressure of solidification of calc-alkaline plutions. Am. Mineral., 72, p.231-239.

Hynes, A. 1982. A comparison of amphiboles from medium - and low - pressure metabasites. Cont. Min. Petrol. 81 : 119 - 125.

Kabesh, M. L., Hilmy, M. E., Refaat, A. M., and Abdallah, Z. M., 1977. The geochemistry of biotite from Ras Barud granitic rocks, Eastern Desert. N.Jb.Miner.Abh., 12, No.2,p.201-210.

Kabesh, M. L., and Refaat, A. M., 1972. The chemical composition of biotites as a guide to the petrogenesis of the granitic rocks of Wadi El Mellaha, northern Eastern Desert. N.Jb.Miner.Abh., 17, p.85-95.

Kabesh. M.L., Salem. A.K.A., and El-Nashar. S. 1982. Remarks on the Samadai granitic complex, Eastern Desert, Egypt. Z. Geol. Wiss., Berlin 10. H. 11, S. 1439 - 1447.

Kabesh, M. L., Salem, A.K.A., and Sheshtawi, Y. A., 1989. Contribution to the chemistry of biotites as a guide to the petrogenesis of some granitoids rocks, Eastern Desert, Egypt. J. Fac. Sci. United Arab Emirates Univ., 1, p.71-83.

Kostyuk, E. A., and Sobolev, V. S., 1969. Paragenetic types of calciferous amphiboles of metamorphic rocks. Lithos 2, p.67-82.

Laird, J., and Albee, A. L., 1981a. Pressure, temperature and time indicators in mafic schist: their application to reconstructing the polymetamorphism history of Vermont. Am. J. Sci. 281, p.127-175.

Lalonde, A., 1993. Composition and colour of biotite from granites: two useful properties in the characterization of plutonic suites from the Hepburn internal zone of Wopmay orogen, Northeast Territories. Can. Min., B.31, p.203-217.

Leake, B. E., 1965. The relationship between the composition of calciferous amphibole and grande of metamorphism. In: Pitcher, W. S., and Flinn, G. W. (eds) Controls of metamorphism. Geol. J. Spec. Issue 1, p.299-318.

Leake, B. E., 1978. Nomenclature of amphiboles. Minerl. Mag. 42, p.533-563.

Leake, B. E., and Said, Y. A., 1994. Hornblende barometry of the Galway batholith, Ireland: an empirical test. Minerl Petrol. 51, p.243-250.

Le Maitre, R. W. (ed.) 1989. A classification of igneous rocks and glossary of terms. Blackwell Scientific, Oxford, 193p.

Lyakhovich, B.V., Katayeva, Z. T. and Semenov, Ye. I., 1994. Variations in biotite composition in a vertical section of a north Caucasus granite intrusion. Geochem. Internat., 31 (11), p.72-84.

Miyashiro, A., 1961. Evolution of metamorphic belts J. Petr., 2 : 277 - 311.

Nachit, H., Razafimahefa, N., Stussi, J. M., and Carron, J. P. 1985. Comosition chimique des biotites et typologie magmatique des granitoids. C. R. Acad. Sci., Ser.II 301, p.813-818.

Raase, P. 1974. Al and Ti contents of hornblende, indicators of pressure and temperature of regional metamorphism. Cont. Min. Petrol., 45, p.231-216.

Schmidt, M. W., 1992. Amphibole composition in tonalite as a function of pressure. an experimental calibaration of the Al in hornblende barometer. Contrib. Min. Petrol., 110, p.304-310.

Figure Captions

Fig. 1: Location map.

Fig. 2: Fe/(Fe+Mg) atoms per formula unit versus Al atoms per formula unit.

Fig. 3: Variation diagrams showing the behaviour of some elements during the crystallization of biotite.

Fig. 4: Tectonic setting diagrams (Abdel Rahman, 1994).

Fig .5: Variation diagrams showing the behaviour of some elements during the crystallization of hornblende.

Fig. 6: Leake (1978) diagram, (Na+K) versus Si.

Fig. 7: Rasse (1974) diagram, Alvi versus Si.

Fig. 8 :Hynes (1982) diagram Ti versus Al.

كيميائية معدنى البيوتايت والهورنبلند كدليل على نوع المجما لجرانيتات ، أبو الحسن الصحراء الشرقية الشمالية ، مصر.

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تم تحليل ثمانية وثلاثون عينة بيوتايت ، باستخدام المسبار الإلكترونى الدقيق ، بينما تم تحليل سبعة وعشرون عينة هورنبلند ، من كل الجرانيتات القديمة والحديثة. وقد نوقشت النتائج تبعا للعديد من الأشكال والرسومات البيانية .

ويظهر البيوتايت تغير منتظم من الجرانيت القديم إلى الجرانيت الحديث الغنى بالسيليكا. وبصورة عامة فان البيوتايت فى صخور منطقة الدراسة يتميز بوفرة الحديد والألومنيوم والتيتانيوم مع نقص فى محتوى المغنسيوم . والبيوتايت فى الجرانيت القديم يظهر ميل واضح نحو الفلوجوبايت ، بينما تلك الموجودة فى الجرانيت الحديث تقع بالقرب من الأنيت . ولقد أظهرت تحاليل البيوتايت مرشدا واضحا لنوع المجما فى الصخور الجرانيتية محل الدارسة .

وتختلف كيميائية الهورنبلند إختلافا متباينا ، فالإختلاف فى نسبة السيلسكا أوضح فى الجرانيت القديم . ويمثل المغنيسيوم الإختلاف الرئيسى فى الهورنبلند فى الجرانيت القديم والحديث وكذا محتوى الحديد . وهذا يظهر إختلافا فى درجة حرارة التبلور ولقد تم توضيح التقاسيم والتسميات والتى تعتمد على التحليل الكيميائى والمحتوى الأعلى للمغنيسيوم فى الهورنبلند من الجرانيت القديم يدل على درجة حرارة وضغط أعلى للتبلور .