Acta Mineralogica-Petrographica,.Szeged, XXXIX, 49–76, 1998

GEOCHEMISTRY, TECTONIC SETTING AND CLASSIFICATION OF SOME GRANITOIDS, GEBEL ABU EL-HASAN, NORTH EASTERN DESERT, EGYPT

M. S. ATIA*, M. L. KABESH** and M. DAWOUD*

* Geology Dept., Faculty of Science, Menoufia University
** Earth Sciences Dept., National Research Centre, Cairo

ABSTRACT

Fifty six new chemical analyses for major and selected trace and REE of some granitoid rocks from Abu El-Hasan pluton, North Eastern Desert are presented. The petrochemical and geochemical characters of these granitoids. The studied rocks have a calc-alkaline to rather alkaline nature. Their chemical features reveal that they are well differentiated with an average THORNTON and TUTTLE D. I. 95. 83. These granitoids are low-calcium somewhat potassic rather than sodic and peraluminous. According to the different chemical classifications, Abu El-Hasan granitoids fall in the fields of granite, alkali granite, alkali feldspare granite, syenogranite and monzogranite. Variation and discrimination diagrams of major, selected trace and REE suggest that Abu El-Hasan granitoids are derived from partial fusion of the upper mantle with some crustal melt contribution. The source magma was subjected to high fractionation during successive pulses. The studied granitoids mostly pertain to the syn-and late-to post-orogenic highly fractionated calc-alkaline-granite suite. The younger granitoids (late-to post-orogenic) formed under extensional enviroment, while the older (synorogenic) are comparable with the compessional suite of PETRO et al., (1979).

INTRODUCTION

Abu El-Hasan pluton constitutes an igneous province characterized by high relief. It lies in the northern part of the Eastern Desert of Egypt rising to 1558 m above the sea level. The granitoids of Abu-Hasan are intruded into an older igneous-metamorphic sequence including meta-sediments and meta-volcanics, serpentinites and metagabbros. (*Fig. 1.*)

Broadly, the granitoid rocks constitute about 40% of the Egyptian Basement. They are classified into two major groups, víz.: Older Granites and Younger Granites (EL-RAMLY, 1972; EL-GABY, 1975; HASHAD, 1980; HUSSEIN ET AL., 1982; EL-GABY et al., 1988; HASAN and HASHAD, 1990). The Older granitoids (850-630 Ma, HASAN and HASHAD, 1990) cover about 26.7% of the total basement area. They are synorogenic (EL-SHAZLY, 1964), syntectonic (SABET, 1972) and calc-alkaline mesozonal (STERN et al., 1984). HUSSEIN et al., (1982) classified them into G-I-(subdection-related) and G-II-(suturerelated).

The younger granites constitute about 16.2% of the Basement in the Eastern Desert (STERN, 1979) and are mainly concentrated in its northern part. They are late to postorogenic (620-530 Ma, HASAN and HASHAD, 1990). These granites are late-orogenic (EL-SHAZLY, 1964), late to post-tectonic (EL-RAMLY, 1964), late to post-tectonic (EL-RAMLY, 1972), epizonal (STERN et al., 1984) and alkaline to peralkaline intraplate anorogenic (G-II granites), according to HUSSEIN et al., (1982).

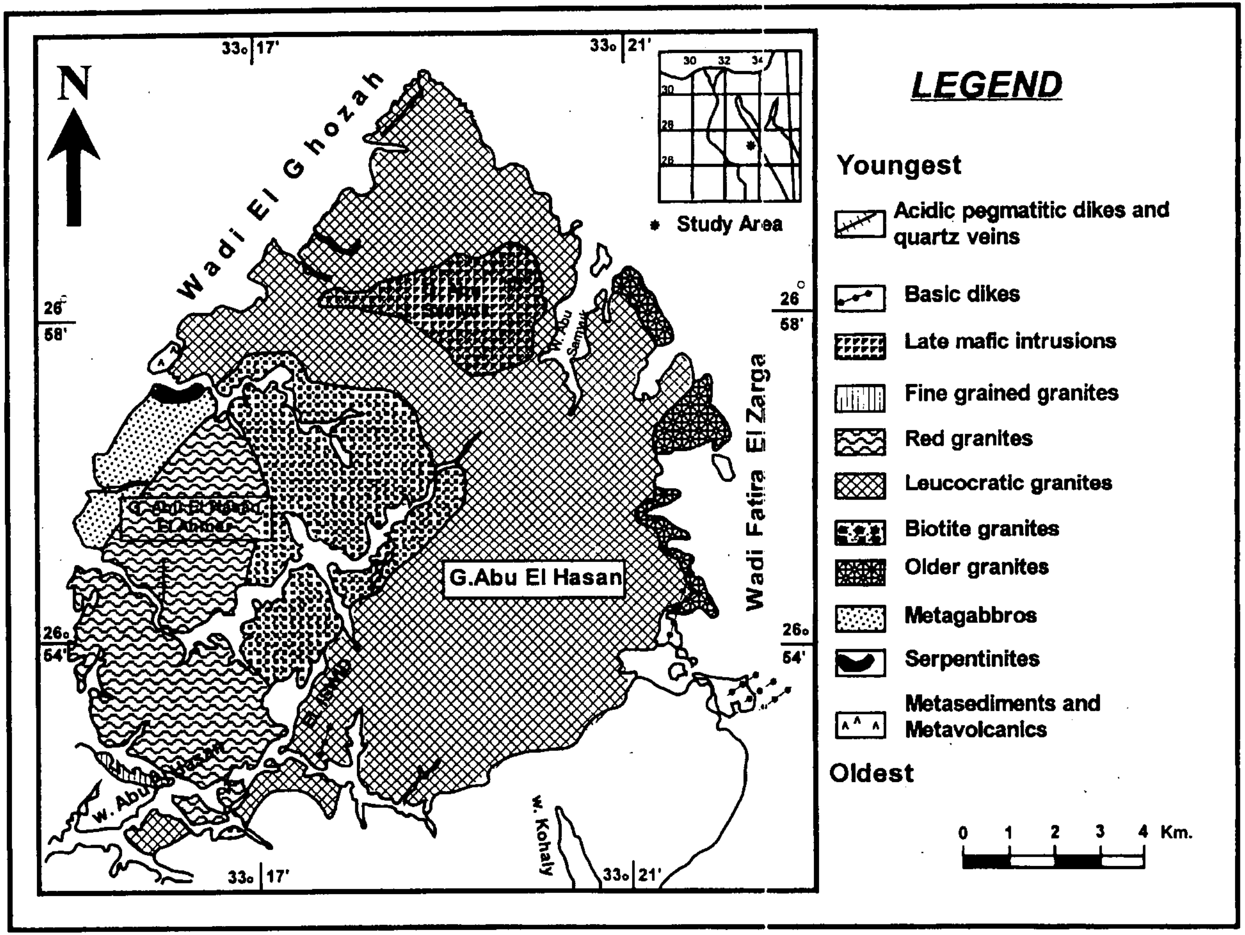

Fig. 1. Geological Map of Abu El-Hasan Pluton

The present study deals with the petrography, geochemistry, tectonic setting and classification of Abu El-Hasan granitoid pluton in the northern part of the Pan-African belt (*Fig. 1.*)

The granite in the present area were considered as Lower Gattarian on Schurmann's map (1966) of the Precambrian along the Gulf of Suez and the northern part of the Red Sea.

SABET et al., (1972) and ZALATA (1972) studied the geology of the basement rocks in the northern parts of Gebel El-Shayeb and Safaga sheets, Eastern Desert. According to their map, the present area comprises mainly calc-alkaline granite and alkaline granite. These authors did not give any chemical analyses of the granites in the present area. ZALATA (op. cit), gave only the modal analysis of one sample of Abu El-Hasan pluton. Eastern and South Western Desert of Egypt to the scale of 1:1.000.000, the present area was recorded as younger granitoids. According to the geological map of the Quena quadrangle published by the Geological Survey of Egypt in scale of 1:500.000, the present area is covered by younger granitoids.

HILMY et al., (1997) gave a petrological study of Abu El-Hasan area, Eastern Desert, Egypt, with special emphasis of the origin of the granitic rocks. According to Hilmy et al., (op. cit) the present area includes mesozonal granites (granodiorites – quartz diorite) and epizonal granites (phase II, phase III). These authors presented the chemical analyses of 19 granitic samples and 11 biotites for their major and some trace elements. More recently, TAKLA et al. (1997), Studied the Precambrian rock units of Wadi Safaga area, south-east the present area. These rock units comprise meta-volcanics, older granitoids, younger gabbros and younger granites. According to these authors (op. cit), the older granitoids are essentially calc-alkaline, island arc granites, while the younger granites represent alkaline post-organic type. They further added that the older granitoids pertain to the I-type granites and were formed in an arc environment, while the younger granites could be comparable with the I-type granite and with the extensional suites of PETRO et al., (1979).

Details of field observations, fracture analysis and modal classification of the granitoids of the present area are given by DAWOUD (1995).

CHARACTERIZATION OF THE GRANITOIDS

The present study deals with the petrography, geochemistry, tectonic setting and classification of the granitoids of Abu El-Hasan pluton.

PETROGRAPHY OF THE GRANITOID ROCKS

The granitoid rocks of Abu El-Hasan pluton include older and younger groups. The older granitoids occur in the eastern part of the pluton as minor outcrops. They are represented by biotite-hornblended granodiorite. Under the microscope the granodiorite is composed mainly of plagioclase, biotile, k-feldspar, with minor quartz and hornblende. Accessory minerals are opaques, apatite, zircon, sphene and allanite. Plagioclase occurs as subhedral to anhedral laths and shows wide variation in composition from ablite, oligoclase to sodic andesine (An_{6-35}). It also shows well-developed zoning and twinning (Carlsbad, albite, combined albite-Carlsbad, pericline and Baveno are present).

Plagioclase phenocrysts, up to 1.5 cm across may be corroded by quartz and microcline. Micrographic and myrmekitic textures are produced as a result of interaction between plagioclase, quartz and K-feldspar. Plagioclase may be rimmed and replaced by K-feldspar.

K-feldspars occur as xenomorphic crystals of orthoclase or microline. They show different types of perthitic textures (as string, vein and patch). Biotite is the main mafic mineral. It shows strong pleochroism from straw yellow to dark brown, some may exhibit grene colour. It may be chloritized and epidotized. Hornblende is found in small amount. It occurs in large crystals about 0.7 cm in length and shows pleochroism from yellowish green to bluish green and brown.

The younger granitoids occupy the major part of Abu El-Hasan pluton. Broadly, they comprise the following types: biotite granite, leucocratic granite, fine-grained granite and red granite. Petrographically biotite granites consist of K-feldspar, plagioclase, quartz and biotite. Accessory minerals are zircon, sphene, opaques, allanite and apatite. K-feldspar usually occurs as perthitic orthoclase which may be string, patch or braid perthite. K-feldspar may show carlsbad twinning. Plagioclase varies in composition from albite to oligoclase (An_{0-18}). They show albite, combined albite-Carlsbad and pericline twinning, also zoning may be present with more saussuritized core. The contact between K-feldspar and plagioclase may show fine blebs and vermicules directed to the plagioclase forming the myrmekitic texture. Biotite is the sole mafic. It suffered from tearing, chloritization, and vermiculitization. It shows brown colour and strong pleochroism from straw yellow to dark brown, but green and reddish brown flakes may be present.

Leucocratic granites microscopically are formed by K-feldspar, quartz and plagioclase with negligible amounts of biotite and hornblende. K-feldspar occurs as perthitic orthoclase. Plagioclase ranges in composition from albite to oligoclase and it occurs as perthitic orthoclase. Plagioclase in composition ranges from albite to oligoclase (An4-14) with albite, Carlsbad and albite-Carlsbad twinning. Accessories are mainly opaques, apatite, allanite and zircon.

Red granites are microscopically formed of K-feldspar, quartz, plagioclase and minor biotite. Accessories include opaques, zircon and apatite. K-feldspar occurs as perthitic orthoclase. It is usually intergrown with albite giving patch, vein, string and braid perthite.

Plagioclase in composition ranges from albite to oligoclase (An_{6-16}). Biotite is pleochroic from greenish yellow, pale yellow to dark brown. It is frequently altered to chlorite and iron oxides.

Fine-grained granites are microscopically formed by K-feldspar, plagioclase and biotite. K-feldspars are represented by altered orthoclase and perthite. Plagioclase is albite to oligoclase (An_{8-16}). It is usually saussuritized and exhibits albite, Carlsbad and combined albite-Carlsbad twinning, Biotite forms scattered delicate flakes suffering from severe tearing and alteration to chlorite and iron osides. Accessories are zircon, allanite and apatite.

MAJOR ELEMENTS CHEMISTRY

Microprobe analyses for major elements were carried out on the JEOL probe JXA-800 of Institute für Mineralogie and Institute für Geologie and Palaontologie, Salzburg University, Austria.

Table 1 presents the chemical analyses of the studied granitoids for major elements.

TABLE 1

Chemical analyses of Abu El Hasan granitoids. Major Elements (WT%)

S. No.	1. R.G.	2. R.G.	3. R.G.	4. R.G.	5. R.G.	6. R.G.	7. R.G.	8. R.G.	9. R.G.	10. F.G.G.	11. F.G.G.
D.I.	95.84	95.79	94.73	93.04	94.01	96.96	94.63	97.04	94.19	92.38	95.61
SiO_2	76.07	75.62	72.81	73.98	74.77	79.09	74.04	77.25	75.03	73.93	75.74
TiO_2	0.10	0.11	0.10	0.16	0.09	0.11	0.09	0.08	0.10	0.15	0.06
Al_2O_3	12.40	12.69	13.30	13.30	12.46	12.17	12.61	12.52	12.08	12.66	12.80
Fe_2O_3	0.94	1.64	1.22	1.35	1.66	1.36	1.32	1.14	0.86	1.55	0.55
MnO	0.01	0.03	0.01	0.02	0.05	0.02	0.03	0.02	0.01	0.04	0.01
MgO	0.02	0.03	0.05	0.13	0.00	0.08	0.04	0.04	0.05	0.07	0.08
CaO	0.16	0.34	0.29	0.53	0.50	0.38	0.29	0.19	0.24	0.64	0.40
Na_2O	3.87	4.50	4.31	3.99	3.62	3.36	4.30	3.93	3.84	4.36	4.29
K_2O	4.72	4.30	5.36	4.68	5.13	4.72	4.71	4.72	4.58	3.99	4.55
P_2O_5	0.03	0.03	0.02	0.04	0.02	0.03	0.03	0.01	0.02	0.03	0.01
LOI	0.81	0.86	0.77	1.44	0.83	0.67	0.88	0.92	0.67	1.08	0.74
Total	99.13	100.15	98.34	99.62	99.13	101.99	98.34	100.82	97.48	98.50	99.23

S. No.	12. F.G.G.	13. F.G.G.	14. F.G.G.	15. F. G.G.	16. L. G.	17. L.G.	18. L.G.	19. L.G.	20. L. G.	21. L.G.	22. L.G.
D.I.	96.10	94.36	94.07	96.29	98.08	91.93	93.44	97.80	95.11	95.16	97.56
SiO_2	76.84	74.47	75.35	77.27	78.43	72.70	74.00	79.39	78.81	75.60	79.06
TiO_2	0.06	0.13	0.04	0.08	0.07	0.11	0.10	0.09	0.10	0.12	0.07
Al_2O_3	12.74	12.81	12.47	12.90	13.25	12.87	12.80	12.09	11.37	12.37	11.48
Fe_2O_3	0.81	2.02	0.65	0.94	0.99	1.44	1.22	1.34	1.06	1.42	0.31
MnO	0.01	0.05	0.00	0.01	0.02	0.02	0.03	0.01	0.02	0.03	0.01
MgO	0.07	0.11	0.07	0.06	0.02	0.15	0.04	0.05	0.11	0.14	0.12
CaO	0.54	0.45	0.53	0.36	0.38	0.74	0.49	0.31	0.55	0.24	0.19
Na_2O	4.07	3.45	4.06	4.08	3.81	4.25	3.99	3.37	3.36	3.98	3.31
K_2O	4.66	5.68	4.42	4.34	4.97	4.57	4.76	4.89	4.15	4.63	4.93
P_2O_5	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.02	0.04	0.04	0.02
LOI	0.97	1.16	1.21	0.71	0.62	0.74	0.84	0.70	1.55	0.78	0.65
Total	100.81	100.34	98.81	100.77	102.58	97.62	98.30	102.26	101.12	99.35	100.15

S. No.	23. L.G.	24. L. G.	25. L. G.	26. L. G.	27. L. G.	28. L. G.	29. L. G.	30. L. G.	31. L. G.	32. L. G.	33. L. G.
D.I.	96.45	96.57	97.13	94.49	97.59	96.53	95.37	94.03	93.43	95.50	94.21
SiO_2	78.43	76.04	76.04	74.28	77.53	76.10	76.36	75.36	74.19	76.82	74.42
TiO_2	0.07	0.05	0.05	0.05	0.07	0.05	0.12	0.14	0.19	0.12	0.07
Al_2O_3	12.27	12.73	12.55	12.35	12.37	13.08	11.88	11.76	12.79	12.50	12.66
Fe_2O_3	1.20	1.12	1.04	0.48	0.83	0.94	2.12	0.96	1.28	1.15	0.65
MnO	0.05	0.00	0.02	0.01	0.01	0.05	0.02	0.01	0.02	0.02	0.02
MgO	0.04	0.08	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.06	0.04
CaO	0.44	0.10	0.07	0.22	0.13	0.23	0.39	0.23	0.54	0.40	0.36
Na_2O	3.87	4.29	4.55	4.30	4.06	4.20	4.40	3.74	3.93	3.74	4.06
K_2O	4.19	4.53	4.04	4.46	4.63	4.72	3.86	4.41	4.71	4.65	4.72
P_2O_5	0.02	0.03	0.01	0.01	0.01	0.02	0.02	0.03	0.07	0.02	0.02
LOI	0.92	0.60	0.91	1.49	0.70	0.70	0.84	0.87	1.32	1.07	0.91
Total	101.50	99.57	97.65	97.65	100.39	100.14	100.01	97.51	99.04	100.55	97.93

S. No.	34. L.G.	35. L.G.	36. B.G.	37. B.G.	38. B.G.	39. B.G.	40. B.G.	41. B.G.	42. B.G.	43. B.G.	44. B.G
D.I.	95.62	95.52	91.10	93.87	90.12	90.14	93.56	92.19	90.24	91.59	92.05
SiO_2	76.13	76.43	72.88	73.99	71.72	70.27	74.42	75.53	73.12	74.28	73.26
TiO_2	0.07	0.13	0.21	0.12	0.15	0.14	0.06	0.16	0.14	0.16	0.15
Al_2O_3	13.01	13.85	13.18	13.57	13.14	13.45	12.08	12.59	12.86	12.75	13.57
Fe_2O_3	1.06	1.13	2.32	1.20	1.50	1.72	0.72	1.64	1.47	1.72	1.57
MnO	0.02	0.01	0.05	0.02	0.04	0.04	0.03	0.04	0.05	0.04	0.04
MgO	0.07	0.13	0.15	0.10	0.21	0.27	0.05	0.17	0.17	0.22	0.19
CaO	0.35	0.26	0.81	0.46	0.90	0.75	0.51	0.92	0.82	0.91	0.90
Na_2O	4.03	3.69	4.19	3.69	3.95	4.28	3.71	3.76	3.66	4.00	3.98
K_2O	4.62	4.79	4.33	5.35	4.81	4.95	4.94	4.24	4.48	4.26	4.98
P_2O_5	0.02	0.04	0.03	0.04	0.04	0.05	0.02	0.04	0.04	0.05	0.04
LOI	1.07	1.28	0.74	0.75	0.73	1.28	0.47	0.75	0.81	0.46	0.98
Total	100.45	101.74	98.89	99.29	97.19	97.20	97.01	99.84	97.62	98.85	99.66

S. No.	45. B.G.	46. B.G.	47. B.G.	48. O.G.	49. O.G.	50. O.G.	51. O.G.	52. O.G.	53. O.G.	54. O.G.	55. O.G.	56. O.G.
D.I.	92.01	92.33	92.71	86.95	87.49	88.36	73.84	90.38	90.00	90.23	87.68	90.63
SiO_2	74.78	73.54	74.07	69.94	70.58	72.59	67.63	73.28	72.44	73.68	70.69	72.78
TiO_2	0.15	0.13	0.16	0.49	0.35	0.39	0.65	0.23	0.20	0.20	0.22	0.15
Al_2O_3	13.19	13.06	13.81	14.37	14.68	14.13	14.93	13.91	13.75	13.59	14.23	13.47
Fe_2O_3	1.37	1.41	1.63	2.49	1.92	2.06	3.34	1.66	1.50	1.60	1.58	1.51
MnO	0.04	0.04	0.04	0.08	0.05	0.06	0.09	0.05	0.03	0.05	0.03	0.03
MgO	0.20	0.15	0.28	0.63	0.58	0.60	1.00	0.37	0.32	0.35	0.31	0.19
CaO	0.92	0.71	0.84	1.33	1.52	1.48	2.04	0.98	0.87	1.10	1.26	0.89
Na_2O	3.80	3.78	4.17	5.11	4.59	4.15	5.20	3.86	3.87	3.77	3.83	3.68
K_2O	4.47	5.01	4.67	3.75	4.16	4.11	3.36	4.50	4.55	4.46	4.70	4.87
P_2O_5	0.05	0.04	0.04	0.12	0.08	0.11	0.22	0.06	0.07	0.06	0.08	0.06
LOI	0.60	0.96	0.73	0.74	0.52	0.94	0.84	1.36	1.43	0.95	0.78	0.78
Total	99.57	98.83	100.44	99.05	99.03	100.62	99.30	100.26	99.03	99.81	97.71	98.41

Late-to post-orogenic granites:

Red granites	R.G.	1-9
Fine-grained granites	F.G.G.	10-15
Leucoeratic granites	L.G.	16-35
Biotite quanites	B.G.	36-47

Syn-orogenic granites

Biotite-Hornblende-granodiorite

	O.G.	48-56
Average	D.I.	95-83

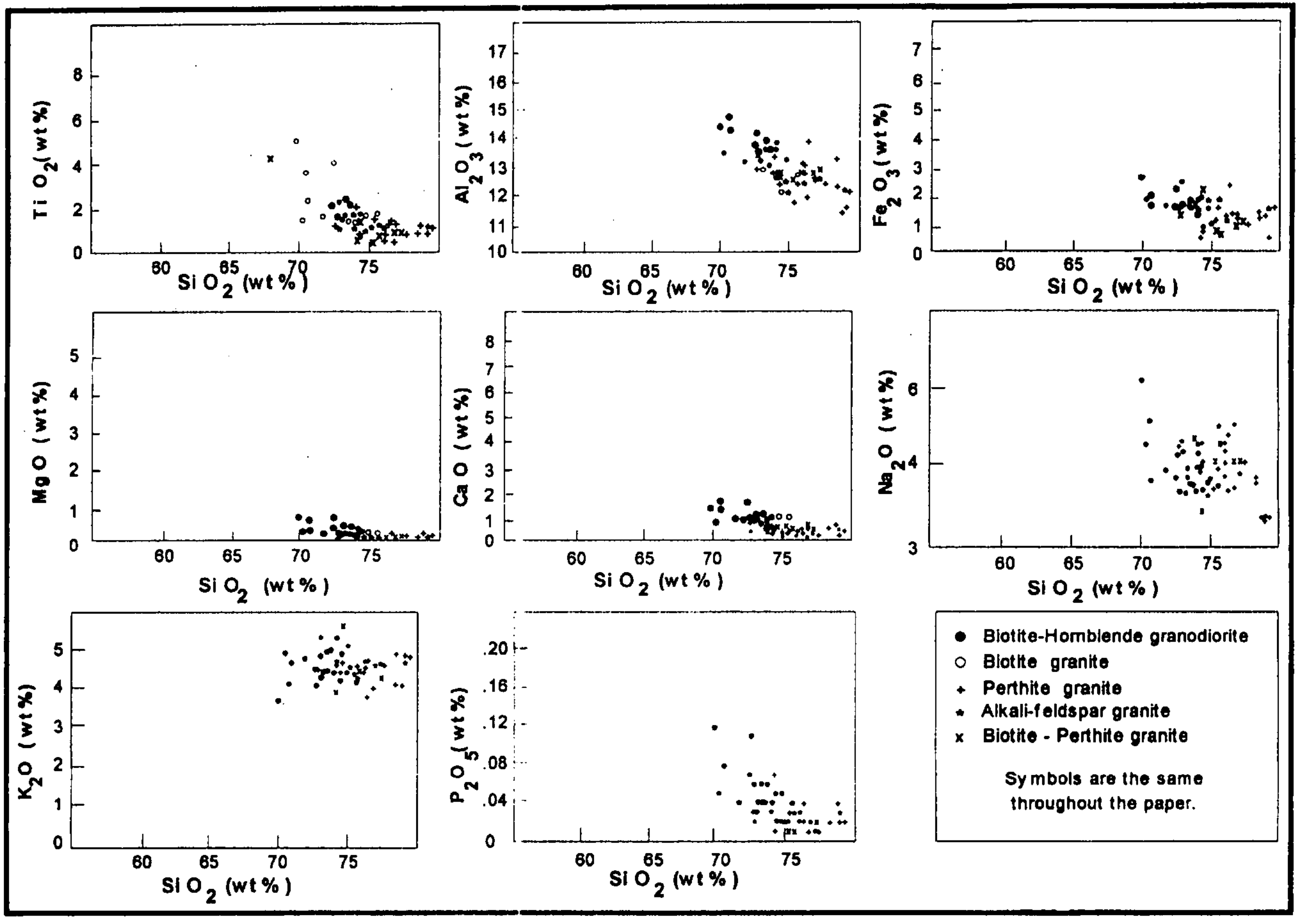

Fig. 2. Harker Variation Diagrams

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Harker Variation Diagrams: The major elements are routinely plotted against silica (*Fig. 2*). It is clear that alumina, titania, magnesia, iron and calcium oxides show more or less well defined negative relations with silica, while sodium and phosphorous show a rough negative correlation. Potassium shows well-defined positive correlation with silica.

CaO-Na_2O-K_2O triangular diagram: shows that the studied granitoids are somewhat potassic rather than sodic (*Fig. 3.*). Fe_2O_3-(t)-MgO-CaO trianglar diagram shows that most of the samples plot near the Fe_2O_3-CaO side line and close to Fe_2O_3 apex (*Fig. 4.*)

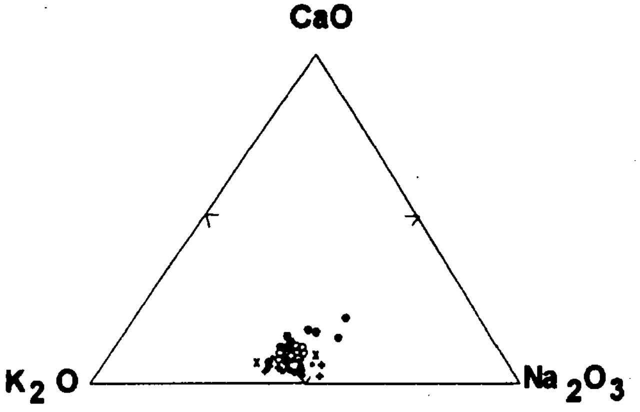

Fig. 3. CaO-Na_2O-K_2O Diagram

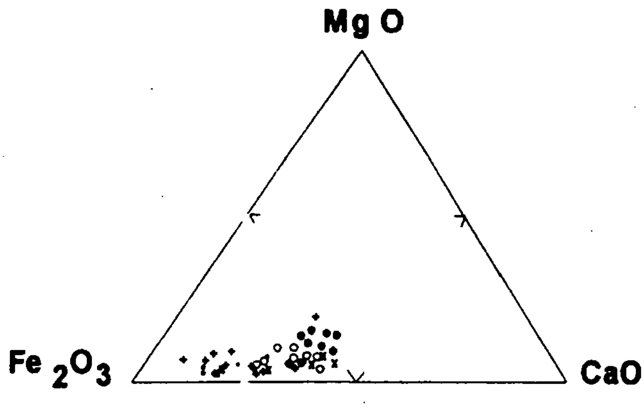

Fig. 4. Fe_2O_3+-MgO-CaO Diagram

Molecular Al_2O_3-CaO-Alkalis triangular diagram proposed by SHAND (1951) distinguished between peraluminous, metaluminous and peralkaline rocks. The studied granitoids plot in the field of peraluminous rocks close to the border with the metaluminous (*Fig. 5.*).

Calc-alkaline/alkaline nature: On the diagram of WRIGHT (1969), is obvious that the studied granitoids plot in the calc-alkaline and alkaline fields (*Fig. 6.*)

CIPW norm values are calculated by Newpet computer program and listed in Table 2.

S. No.	Rock Un.	Qz.	Cor.	Or.	Ab.	An.	Diop.	Woll.	Hyp.	Mag.	Chrom.	Hem.	Ilm.	Sphene	Rutile	Apatite
36	B.G.	30.06	0.2	25.59	35.45	3.82	0	0	0.37	0	0	2.32	0.11	0	0.15	0.07
37		31.03	0.96	31.62	31.22	2.02	0	0	0.25	0	0	1.2	0.04	0.12	0.1	0.09
38		28.27	0	28.43	33.42	3.92	0	0	0.52	0	0	1.5	0.09	0.2	0.02	0.09
39		24.67	0	29.26	36.21	2.87	0.15	0	0.6	0.	0	1.72	0.09	0.23	0	0.12
40		32.97	0	29.2	31.39	1.72	0.27	0.1	0	0	0	0.72	0.06	0.06	0	0.05
41		35.32	0.24	25.06	31.81	4.3	0	0	0.42	0	0	1.64	0.09	0	0.11	0.09
42		32.79	0.6	26.48	30.97	3.81	0	0	0.42	0	0	1.47	0.11	0	0.08	0.09
43		32.57	0.03	25.18	33.84	4.19	0	0	0.55	0	0	1.72	0.09	0	0.11	0.12
44		28.95	0.09	29.43	33.67	4.2	0	0	0.47	0	0	1.57	0.09	0	0.1	0.09
45		33.44	0.55	26.42	32.15	4.24	0	0	0.5	0	0	1.37	0.09	0	0.1	0.12
46		30.74	0.22	29.61	31.98	3.26	0	0	0.37	0	0	1.41	0.09	0	0.08	0.09
47		29.83	0.47	27.6	35.28	3.91	0	0	0.7	0	0	1.63	0.09	0	0.11	0.09
48	O.G.	22.55	0	22.16	43.24	5.2	0	0	1.57	0	0	2.49	0.17	0	0.22	0.28
49		24.06	0.06	24.59	38.84	7.02	0	0	1.44	0	0	1.92	0.11	0	0.29	0.19
50		28.96	0.43	24.29	35.11	6.62	0	0	1.49	0	0	2.06	0.13	0	0.32	0.26
51		19.54	0	19.86	44	7.48	0	0	2.39	0	0	3.34	0.19	0.85	0.2	0.52
52		31.12	1.05	26.6	32.66	4.47	0	0	0.92	0	0	1.66	0.11	0	0.17	0.14
53		30.37	1.05	26.89	32.74	3.86	0	0	0.8	0	0	1.5	0.06	0	0.17	0.17
54		31.97	0.71	26.36	31.9	5.07	0	0	0.87	0	0	1.6	0.11	0	0.14	0.14
55		27.49	0.74	27.78	32.41	5.73	0	0	0.77	0	0	1.58	0.06	0	0.19	0.19
56		30.71	0.67	28.78	31.14	4.02	0	0	0.47	0	0	1.51	0.06	0	0.12	0.14

S. No.	Rock Un.	Qz.	Cor.	Or.	Ab.	An.	Diop.	Woll.	Hyp.	Mag.	Chrom.	Hem.	Ilm.	Sphene	Rutile	Apatite
16	L.G.	36.46	0.96	29.38	32.24	1.75	0	0	0.05	0	0	0.99	0.04	0	0.05	0.05
17		28.96	0	27.01	35.96	2.55	0.49	0	0.15	0	0	1.44	0.04	0.12	0	0.07
18		31.55	0.27	28.13	33.76	2.24	0	0	0.1	0	0	1.22	0.06	0	0.07	0.07
19		40.39	0.74	28.9	28.51	1.41	0	0	0.12	0	0	1.34	0.02	0	0.08	0.05
20		42.15	0.45	24.53	28.43	2.74	0	0	0.27	0	0	1.06	0.04	0	0.08	0.09
21		34.12	1.37	27.37	33.67	0.93	0	0	0.35	0	0	1.42	0.06	0	0.09	0.09
22		40.41	0.4	29.14	28.01	0.81	0	0	0.3	0	0	0.31	0.02	0	0.06	0.05
23		38.94	0.62	24.77	32.74	2.05	0	0	0.1	0	0	1.2	0.11	0	0.01	0.05
24		33.5	0.66	26.77	36.3	0.3	0	0	0.2	0	0	1.12	0	0	0.05	0.07
25		34.75	0.59	23.88	38.5	0.28	0	0	0	0	0	1.04	0.04	0	0.02	0.02
26		31.75	0.07	26.36	36.38	1.03	0	0	0	0	0	0.48	0.02	0	0.04	0.02
27		35.87	0.47	27.37	34.35	0.58	0	0	0.12	0	0	0.83	0.02	0	0.06	0.02
28		33.09	0.69	27.9	35.54	0.01	0	0	0.12	0.02	0	0.93	0.09	0	0	0.05
29		35.33	0	22.81	37.23	1.27	0	0.08	0	0	0	2.12	0.04	0.24	0	0.05
30		36.32	0.49	26.07	31.64	0.95	0	0	0	0	0	0.96	0.02	0	0.13	0.07
31		32.34	0.41	27.84	33.25	2.22	0	0	0	0	0	1.28	0.04	0	0.17	0.17
32		36.38	0.64	27.48	31.64	1.85	0	0	0.15	0	0	1.15	0.04	0	0.1	0.05
33		31.96	0.27	27.9	34.35	1.66	0	0	0.1	0	0	0.65	0.04	0	0.05	0.05
34		34.21	0.79	27.31	34.1	1.61	0	0	0.17	0	0	1.06	0.04	0	0.05	0.05
35		35.99	2.22	28.31	31.22	1.03	0	0	0.32	0	0	1.13	0.02	0	0.12	0.09

S. No.	Rock Un.	Qz.	Cor.	Or.	Ab.	An.	Diop.	Woll.	Hyp.	Mag.	Chrom.	Hem.	Ilm.	Sphene	Rutile	Apatite
36	B.G.	30.06	0.2	25.59	35.45	3.82	0	0	0.37	0	0	2.32	0.11	0	0.15	0.07
37		31.03	0.96	31.62	31.22	2.02	0	0	0.25	0	0	1.2	0.04	0.12	0.1	0.09
38		28.27	0	28.43	33.42	3.92	0	0	0.52	0	0	1.5	0.09	0.2	0.02	0.09
39		24.67	0	29.26	36.21	2.87	0.15	0	0.6	0.	0	1.72	0.09	0.23	0	0.12
40		32.97	0	29.2	31.39	1.72	0.27	0.1	0	0	0	0.72	0.06	0.06	0	0.05
41		35.32	0.24	25.06	31.81	4.3	0	0	0.42	0	0	1.64	0.09	0	0.11	0.09
42		32.79	0.6	26.48	30.97	3.81	0	0	0.42	0	0	1.47	0.11	0	0.08	0.09
43		32.57	0.03	25.18	33.84	4.19	0	0	0.55	0	0	1.72	0.09	0	0.11	0.12
44		28.95	0.09	29.43	33.67	4.2	0	0	0.47	0	0	1.57	0.09	0	0.1	0.09
45		33.44	0.55	26.42	32.15	4.24	0	0	0.5	0	0	1.37	0.09	0	0.1	0.12
46		30.74	0.22	29.61	31.98	3.26	0	0	0.37	0	0	1.41	0.09	0	0.08	0.09
47		29.83	0.47	27.6	35.28	3.91	0	0	0.7	0	0	1.63	0.09	0	0.11	0.09
48	O.G.	22.55	0	22.16	43.24	5.2	0	0	1.57	0	0	2.49	0.17	0	0.22	0.28
49		24.06	0.06	24.59	38.84	7.02	0	0	1.44	0	0	1.92	0.11	0	0.29	0.19
50		28.96	0.43	24.29	35.11	6.62	0	0	1.49	0	0	2.06	0.13	0	0.32	0.26
51		19.54	0	19.86	44	7.48	0	0	2.39	0	0	3.34	0.19	0.85	0.2	0.52
52		31.12	1.05	26.6	32.66	4.47	0	0	0.92	0	0	1.66	0.11	0	0.17	0.14
53		30.37	1.05	26.89	32.74	3.86	0	0	0.8	0	0	1.5	0.06	0	0.17	0.17
54		31.97	0.71	26.36	31.9	5.07	0	0	0.87	0	0	1.6	0.11	0	0.14	0.14
55		27.49	0.74	27.78	32.41	5.73	0	0	0.77	0	0	1.58	0.06	0	0.19	0.19
56		30.71	0.67	28.78	31.14	4.02	0	0	0.47	0	0	1.51	0.06	0	0.12	0.14

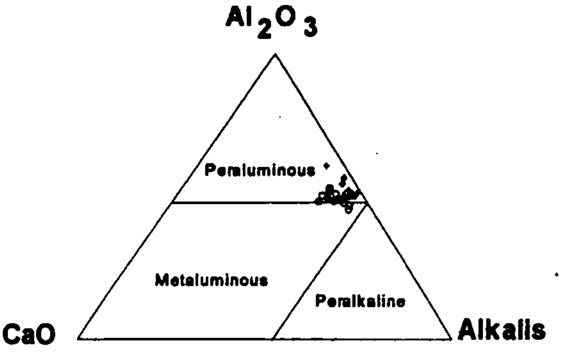

Fig. 5. Molecular Al_2O_3-CaO-Alkalis diagram

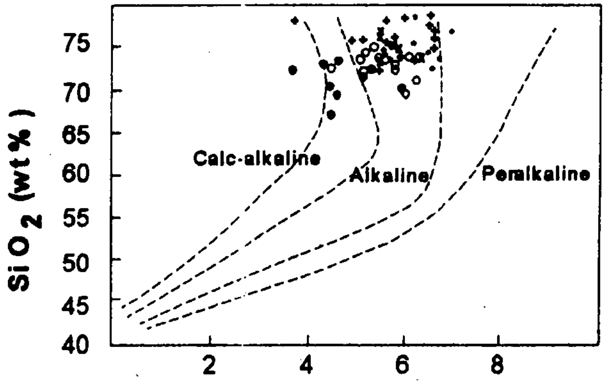

Fig. 6. Wright's Alkalinity diagram

An-Ab-Or diagram: IRVINE and BARAGAR (1971) proposed a classification of igneous rocks based on normative anorthite, albite and orthoclase proportions. The studied rocks plot in the field of average rocks close to the potassic series boundary rather than the sodic series (*Fig. 7.*).

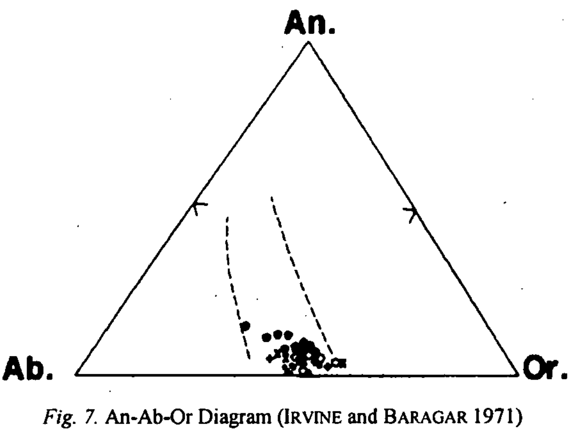

Fig. 7. An-Ab-Or Diagram (IRVINE and BARAGAR 1971)

O-Ab-Or diagram: The studied rocks are plotted on TUTTLE and BOWEN (1958) ternary diagram whereby most of the granitoids fall within the range 0.5 to 7 Kb water vapour pressure while some samples were mostly formed under higher water vapour pressure (10 Kb) and in turn deeper level (*Fig. 8.*).

Chemical Classification: Such classification follows two ways, the first depends on the major oxides or molecular values, the second depends on the calculated molecular norms.

O'CONNOR (1965) classification: This diagram is based on the norm proportions of An, Ab, and Or. Abu El-Hasan granitoids are classified as granites. (*Fig. 9.*)

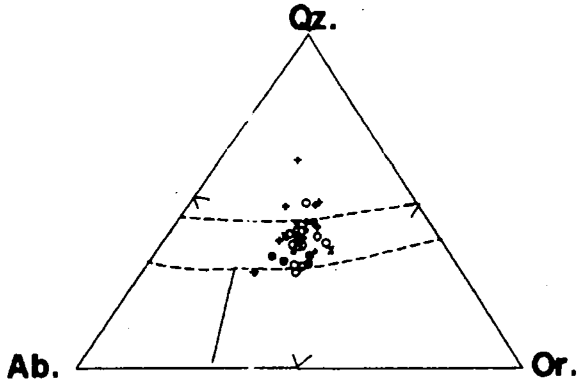

Fig. 8. Qz-Ab-Or Diagram (TUTTLE and BOWEN 1958)

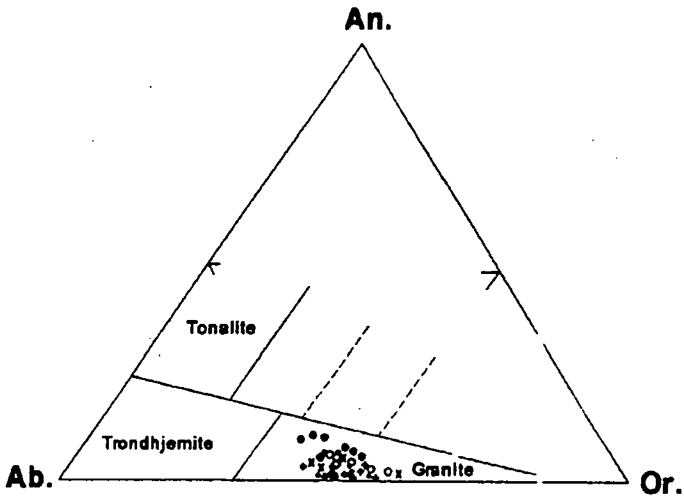

Fig. 9. An-Ab-Or Diagram (O'CONNOR, 1965)

STRECKEISEN (1976b): This diagram is based on the proportions of Or, Ab and An. Most of the studied granitoids plot in the alkali feldspar granite and the alkali granite fields, while some samples plot in the fields of syenogranite and monzogranite (*Fig. 10.*).

MIDDLEMOST (1985) classification: This diagram shows the relation of Na_2O+K_2O against SiO_2, where by Abu El-Hasan granitoids plot in the alkali feldspar granite and the granite fields (*Fig. 11.*).

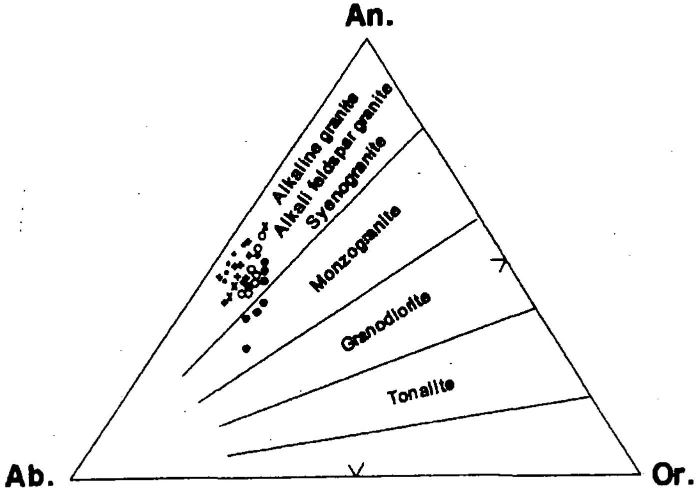

Fig. 10. An-Ab-Or Diagram (STRECKEISEN, 1976b)

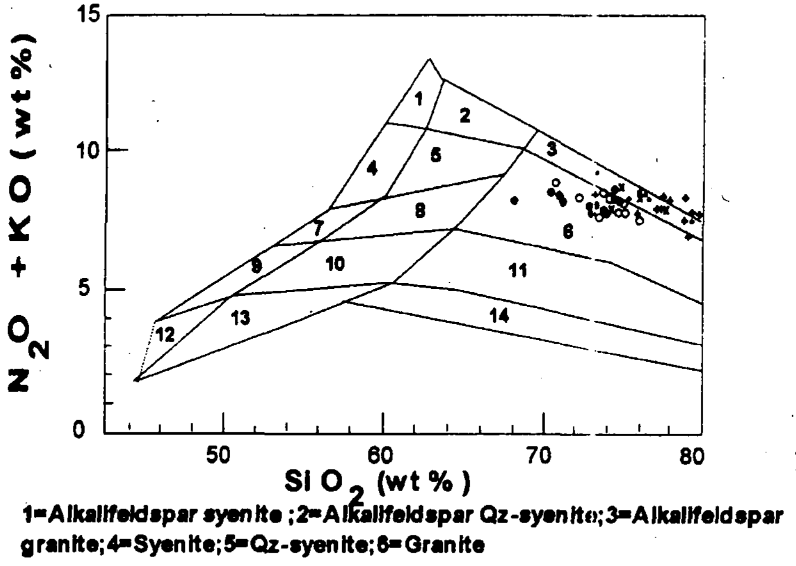

Fig. 11. MIDDLEMOST's (1985) Classification

In the present study, some trace elements are analyzed using XRD and some REE using NAA techniques. Analyses were carried out at the Institute für Mineralogie, Salzburg University, Austria. Results are given in Table 3.

Trace And REE (PPM)

S. No.	1	2	3	4	5	6	7	8	9	10	11
Sc	1	1	0	2	2	0	0	0	0	0	1
Rb	146	133	153	142	150	111	151	118	114	138	231
Cs	0.77	0.72	0.00	2.65	0.00	0.00	0.00	0.00	0.65	0.00	1.47
Ba	192	192	224	377	122	157	226	162	180	179	75
Sr	40	45	55	78	34	40	51	43	51	64	15
Ga	24	25	25	22	24	22	25	25	24	25	31
Ta	2.29	3.10	0.00	2.42	4.10	0.00	0.00	0.00	0.00	0.00	5.30
Nb	41.0	42.0	36.0	34.0	50.0	36.0	35.0	38.0	30.0	45.0	54.0
Hf	7.19	8.93	0.00	8.26	7.62	0.00	0.00	0.00	0.00	0.00	7.30
Zr	148	160	110	192	137	146	138	138	148	204	98
Y	36	42	27	35	47	23	27	27	25	40	46
Th	24.00	19.00	24.00	26.00	20.00	19.00	16.00	16.00	16.00	29.00	26.00
U	7.00	6.00	8.00	7.00	8.00	5.00	5.00	5.00	5.00	8.00	8.00
La	47.71	37.42	0.00	75.21	35.79	0.00	0.00	0.00	0.00	0.00	26.38
Ce	99.86	86.44	63.00	143.43	92.40	75.00	42.00	42.00	47.00	94.00	37.00
Nd	56.06	54.80	0.00	63.62	66.00	0.00	0.00	0.00	0.00	0.00	40.80
Sm	23.16	23.94	0.00	22.09	21.91	0.00	0.00	0.00	0.00	0.00	19.66
Eu	0.54	0.49	0.00	0.94	1.00	0.00	0.00	0.00	0.00	0.00	0.92
Gd	11.59	10.26	0.00	10.91	6.86	0.00	0.00	0.00	0.00	0.00	10.68
Tb	1.98	2.26	0.00	1.88	1.42	0.00	0.00	0.00	0.00	0.00	1.16
Yb	5.82	7.91	0.00	6.10	6.27	0.00	0.00	0.00	0.00	0.00	5.45
Lu	0.75	1.03	0.00	0.87	0.94	0.00	0.00	0.00	0.00	0.00	0.97

S. No.	12	13	14	15	16	17	18	19	20	21	22
Sc	1	0	0	0	1	1	0	1	0	2	1
Rb	205	192	208	113	120	151	138	122	113	163	190
Cs	1.94	0.00	1.41	0.00	1.02	1.69	0.00	0.83	0.00	1.50	0.76
Ba	146	174	55	74	155	262	251	92	439	388	250
Sr	24	46	15	31	31	70	69	19	64	110	34
Ga	28	22	31	27	25	26	24	24	18	22	17
Ta	5.70	0.00	6.30	0.00	1.20	3.40	0.00	1.43	0.00	3.00	3.11
Nb	56.0	35.0	100.0	44.0	23.0	31.0	40.0	35.0	34.0	26.0	40.0
Hf	7.10	0.00	9.89	0.00	4.69	5.62	0.00	6.47	0.00	5.49	3.35
Zr	116	238	157	68	108	139	137	160	116	150	51
Y	48	43	55	20	23	35	31	25	20	26	36
Th	26.00	20.00	44.00	28.00	11.00	23.00	19.00	20.00	22.00	24.00	30.00
U	10.00	6.00	11.00	6.00	5.00	10.00	7.00	7.00	6.00	6.00	6.00
La	27.72	0.00	16.49	0.00	27.75	29.00	0.00	14.76	0.00	26.90	10.73
Ce	58.74	102.00	18.34	0.00	57.13	57.90	53.00	84.48	32.00	71.80	22.90
Nd	35.81	0.00	35.18	0.00	29.19	34.29	0.00	20.94	0.00	34.60	10.56
Sm	23.17	0.00	20.86	0.00	13.29	18.96	0.00	9.24	0.00	11.07	6.53
Eu	0.24	0.00	0.09	0.00	0.43	0.16	0.00	0.28	0.00	0.82	0.30
Gd	11.41	0.00	15.95	0.00	3.97	6.11	0.00	4.44	0.00	8.94	7.75
Tb	2.00	0.00	2.19	0.00	0.99	1.04	0.00	0.93	0.00	0.71	0.99
Yb	7.69	0.00	13.46	0.00	3.03	4.64	0.00	3.51	0.00	3.29	4.15
Lu	1.04	0.00									

S. No.	23	24	25	26	27	28	29	30	31	32	33
Sc	0	0	0	0	0	1	0	0	3	0	0
Rb	169	191	282	242	153	189	138	147	146	116	172
Cs	0.00	1.29	0.00	0.00	0.00	1.22	0.00	0.00	1.73	0.00	0.00
Ba	135	86	47	107	103	80	72	547	749	172	145
Sr	23	23	6	30	26	18	23	84	106	61	66
Ga	22	28	35	28	24	30	27	14	15	23	28
Ta	0.00	2.94	0.00	0.00	0.00	4.25	0.00	0.00	1.85	0.00	0.00
Nb	76.0	55.0	106.0	68.0	31.0	81.0	91.0	31.0	22.0	30.0	50.0
Hf	0.00	2.81	0.00	0.00	0.00	8.38	0.00	0.00	5.69	0.00	0.00
Zr	80	99	103	77	110	123	91.0	137	177	151	136
Y	46	43	100	66	30	66	94	26	23	26	35
Th	22.00	22.00	59.00	28.00	14.00	36.00	37.00	28.00	26.00	20.00	22.00
U	10.00	6.00	17.00	6.00	5.00	12.00	12.00	6.00	8.00	6.00	8.00
La	0.00	6.10	0.00	0.00	0.00	14.54	0.00	0.00	43.14	0.00	0.00
Ce	20.00	14.95	3.00	9.00	30.00	49.88	53.00	45.00	74.19	83.00	31.00
Nd	0.00	13.67	0.00	0.00	0.00	33.37	0.00	0.00	29.62	0.00	0.00
Sm	0.00	9.26	0.00	0.00	0.00	24.41	0.00	0.00	12.21	0.00	0.00
Eu	0.00	0.10	0.00	0.00	0.00	0.19	0.00	0.00	0.73	0.00	0.00
Gd	0.00	6.12	0.00	0.00	0.00	9.52	0.00	0.00	10.57	0.00	0.00
Tb	0.00	1.38	0.00	0.00	0.00	3.62	0.00	0.00	0.87	0.00	0.00
Yb	0.00	6.75	0.00	0.00	0.00	10.11	0.00	0.00	3.01	0.00	0.00
Lu					0.00	1.30	0.00	0.00	0.39	0.00	0.00

S. No.	34	35	36	37	38	39	40	41	42	43	44
Sc	0	2	0	0	3	0	0	2	0	0	0
Rb	165	164	133	170	166	168	173	175	176	144	174
Cs	0.00	1.91	0.00	0.00	4.65	0.00	0.00	3.30	0.00	0.00	0.00
Ba	117	400	281	610	398	439	317	359	348	379	444
Sr	54	113	73	121	89	98	78	93	86	93	98
Ga	27	25	25	22	22	24	22	20	23	22	23
Ta	0.00	3.20	0.00	0.00	2.30	0.00	0.00	3.07	0.00	0.00	0.00
Nb	49.0	37.0	45.0	22.0	37.0	28.0	35.0	44.0	39.0	25.0	25.0
Hf	0.00	5.89	0.00	0.00	5.88	0.00	0.00	6.88	0.00	0.00	0.00
Zr	114	134	204	143	142	161	52	168	137	152	136
Y	42	23	42	23	31	30	25	35	34	27	31
Th	24.00	20.00	20.00	24.00	24.00	18.00	22.00	26.00	22.00	23.00	23.00
U	11.00	8.00	7.00	7.00	7.00	6.00	7.00	8.00	7.00	8.00	12.00
La	0.00	12.56	0.00	0.00	35.02	0.00	0.00	36.81	0.00	0.00	0.00
Ce	25.00	90.30	66.00	51.00	68.04	47.00	11.00	78.41	66.00	45.00	76.00
Nd	0.00	11.20	0.00	0.00	35.11	0.00	0.00	40.58	0.00	0.00	0.00
Sm	0.00	15.56	0.00	0.00	14.73	0.00	0.00	15.23	0.00	0.00	0.00
Eu	0.00	0.80	0.00	0.00	0.72	0.00	0.00	0.76	0.00	0.00	0.00
Gd	0.00	8.16	0.00	0.00	9.37	0.00	0.00	9.50	0.00	0.00	0.00
Tb	0.00	0.67	0.00	0.00	1.44	0.00	0.00	1.60	0.00	0.00	0.00
Yb	0.00	3.93	0.00	0.00	5.00	0.00	0.00	5.70	0.00	0.00	0.00
Lu	0.00	0.64	0.00	0.00	0.70	0.00	0.00	0.81	0.00	0.00	0.00

S. No.	45	46	47	48	49	50	51	52	53	54	55	56
Sc	3	2	2	6	4	6	6	0	0	0	0	3
Rb	178	168	157	90	113	120	72	157	165	173	183	173
Cs	3.44	2.82	2.92	1.12	1.90	2.50	1.31	0.00	0.00	0.00	0.00	2.67
Ba	588	428	456	846	955	701	766	702	723	844	601	614
Sr	131	89	110	258	328	273	356	169	164	209	166	140
Ga	21	21	24	21	18	19	21	21	21	20	21	21
Ta	3.10	2.98	2.20	3.77	1.50	0.70	1.29	0.00	0.00	0.00	0.00	2.30
Nb	30.0	36.0	26.0	24.0	16.0	19.0	27.0	25.0	23.0	24.0	18.0	31.0
Hf	5.70	5.65	6.38	9.50	6.44	5.87	8.52	0.00	0.00	0.00	0.00	5.92
Zr	151	128	159	374	234	204	355	182	184	197	225	159
Y	29	30	27	26	21	18	25	29	27	21	30	26
Th	25.00	22.00	20.00	16.00	19.00	22.00	13.00	26.00	24.00	28.00	36.00	25.00
U	12.00	7.00	7.00	4.00	5.00	7.00	4.00	7.00	5.00	4.00	5.00	8.00
La	49.74	42.11	76.43	52.80	43.45	48.68	45.76	0.00	0.00	0.00	0.00	50.75
Ce	81.40	78.12	122.90	103.00	73.70	73.90	96.90	74.00	73.00	80.00	53.00	87.20
Nd	46.00	35.74	60.60	56.31	32.00	30.80	46.25	0.00	0.00	0.00	0.00	47.49
Sm	13.16	13.95	15.55	14.40	8.78	5.69	12.36	0.00	0.00	0.00	0.00	10.95
Eu	1.13	0.71	0.99	1.10	1.20	1.04	1.15	0.00	0.00	0.00	0.00	1.01
Gd	8.45	7.98	7.45	10.15	3.52	2.51	5.81	0.00	0.00	0.00	0.00	3.98
Tb	0.91	1.25	0.78	1.97	0.70	0.57	1.24	0.00	0.00	0.00	0.00	0.80
Yb	4.10	4.66	3.50	4.45	2.85	2.20	3.71	0.00	0.00	0.00	0.00	3.71
Lu	0.69	0.68	0.51	0.58	0.38	0.34	0.51	0.00	0.00	0.00	0.00	0.53

N.b. Zero in trace elements means not determined.

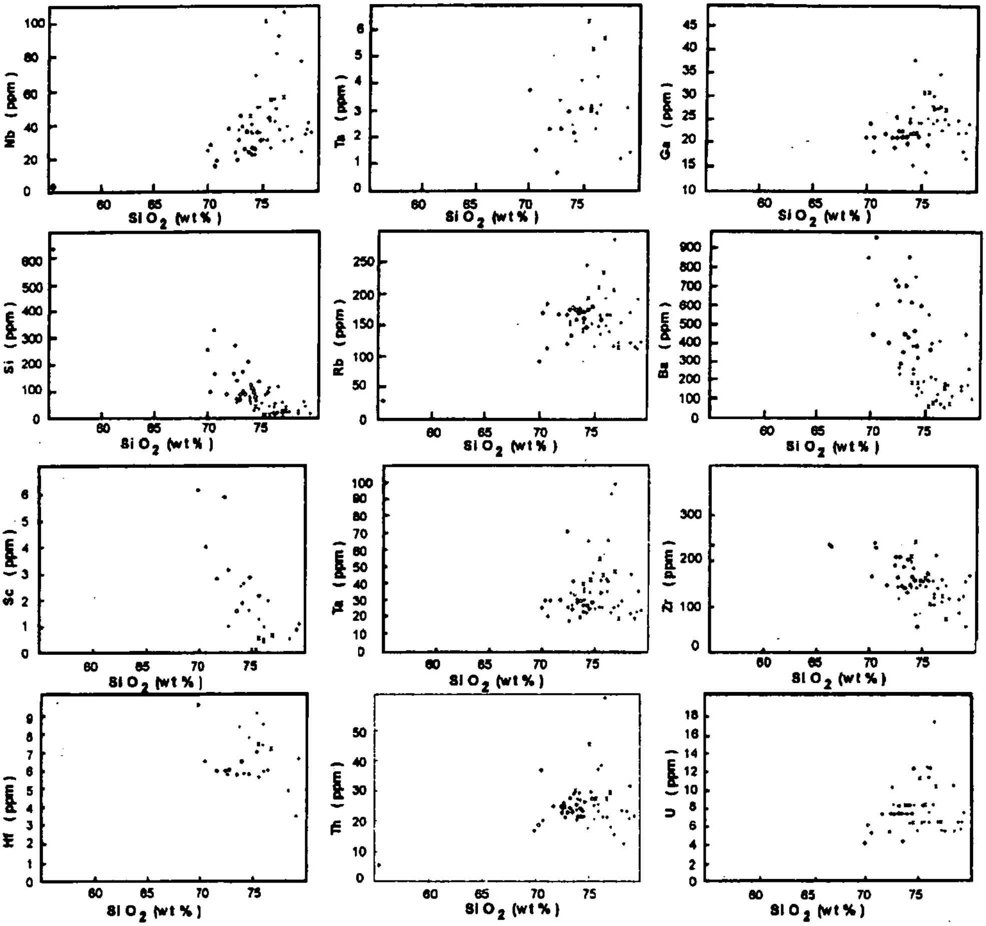

Fig. 12. Trace elements vs. SiO2% variation diagram

Variation diagrams: The analyzed trace elements are routinely plotted against silica to reveal their evolution during the infered fractional crystallization path (*Fig. 12.*). Some elements show more or less defined trends, while others do not show and sometimes have complicated and ambiguous geochemical behaviour such as Rb which shows curvilinear increment, and then increases dramatically at almost constant silica. It seems that Rb behaves as incompatible element during all the magmatic stages and that biotite does not capture all the Rb in the melt.

Ba shows generally defined negative relation. Sr shows well defined negative relation with silica which indicates that Sr behaviour is controlled by feldspar (mainly plagioclase) fractionation which starts early during magma consolidation.

Zr and Sc show negative correlation, while Ga and Y show positive relations with drastic increase at high silica values.

The gradual increment of Y does not imply considerable fractionation of Y-bearing minerals especially garnet, where the drastic decrease in Sc involves fractionation of minerals as magnetite and ilmenite.

Rb-Ba-Sr diagram: EL-BOUSEILY and EL-SOKKARY (1975) proposed a diagram for magmatic differentiation and classification based on the ternary relation Rb-Ba-Sr. According to their classification the studied granitoids plot in the field of anomalous granites close to the boundary between anomalous and normal granites. The majority plot in the strongly differentiated granites field (*Fig. 13.*).

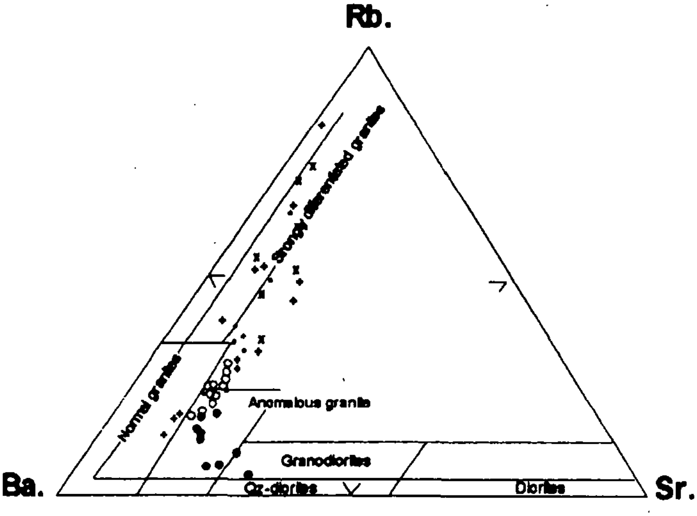

Fig. 13. Rb-Ba-Sr diagram

Normalized trace elements patterns: The trace elements are normalized to MORB and plotted in spider patterns. Fine-grained granites and red granites of the late to post-orogenic suite show three main negative anomalies for Ba, Sr and Ti in addition to a small negative anomaly for Zr. These anomalies gradually decrease in the leucocratic granite and the biotite granite of the same granite suite. In the syn-orogenic suite, only Ti anomaly is recorded, while very minor anomalies of Ba and Sr still remain, Zr anomaly disappeared (*Fig. 14.*).

REE patterns: The analyzed REE are plotted in normalized patterns for the studied granitoids (*Fig. 15.*). All types show negative europium anomaly which gradually increases from the syn-orogenic suites. The syn-orogenic granitoids have a small anomaly with Eu/Eu* ranging from 0.85 to 0.28, while in the late and post-orogenic suite, the anomaly ranges from 0.903 to 0.176 in the biotite granite, from 0.244 to 0.032 in the lecocratic granite, from 0.197 to 0.082 in the red granite and reaches its maximum from 0.176 to 0.015 in the fine-grained granite. There are also differences between these rock groups with respect to the degree of fractionation of the normalized patterns with Ce_N/Yb_N as criterion, thus the red granites, leucocratic granites with Ce_N/Yb_N as a criterion, thus the red granites, leucocratic granites and biotite granites have relatively highly fractionated patterns with Ca_N/Yb_N intervals of 6.09-2.83, 6.39-1.27 and 9.1-3.53 respectively, while the fine-grained granites and the syn-orogenic granites show moderately fractionated normalized patterns, Ce_N/Yb_N ranges are 1.98 0.35 and 8.7-6 respectively.

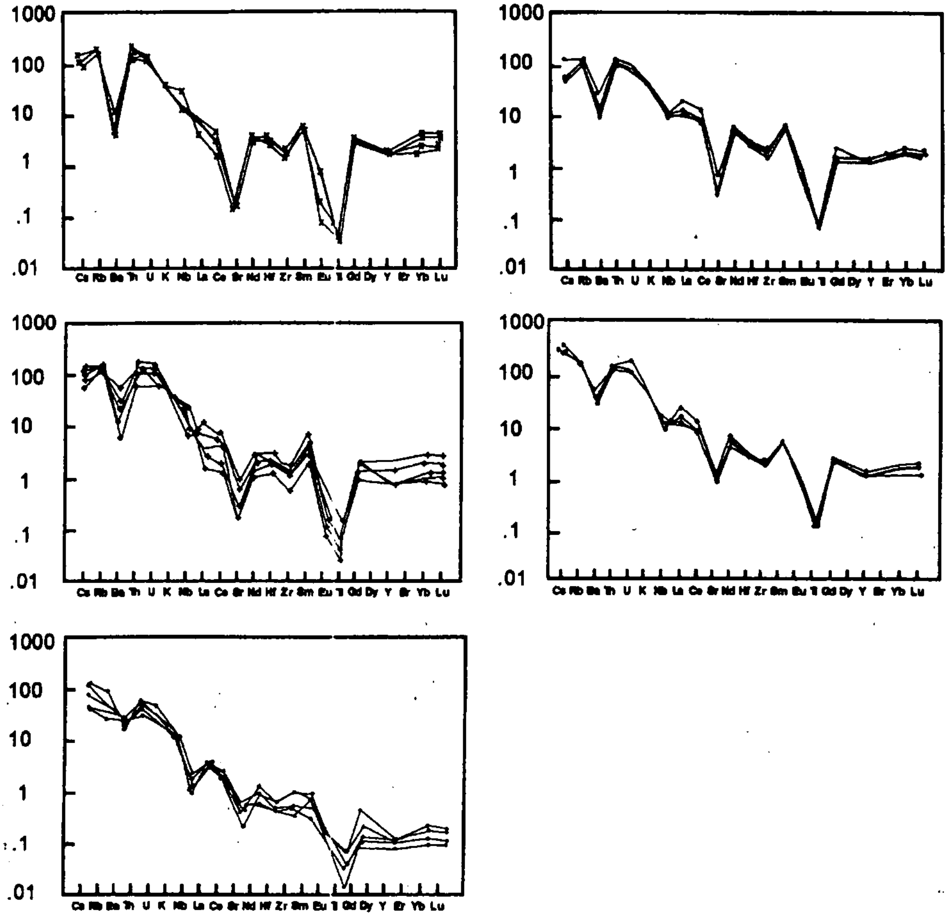

Fig. 14. Normalized trace element pattern

GENETIC CLASSIFICATION AND MAGMA TYPE

CHAPPELL and WHITE (1974) proposed a genetic subdivision of the granitic rocks into those derived from sedimentary protolith (S-type) and those derived from igneous protolith (I-type). Subgroups of I-type granites include those derived from recycled continental crust (A-type: LOISELLE and WONES 1979, COLLINS et al., 1982, WHALEN et al., 1987) and those derived directly from melting of subducted oceanic crust or overlying mantle (M-type: WHITE 1979, COLLINS et al., 1982, WHALEN et al., 1986) and those derived directly from melting of subducted oceanic crust or overlying mantle (M-type: WHITE 1979, PITCHER 1983, WHALEN 1985).

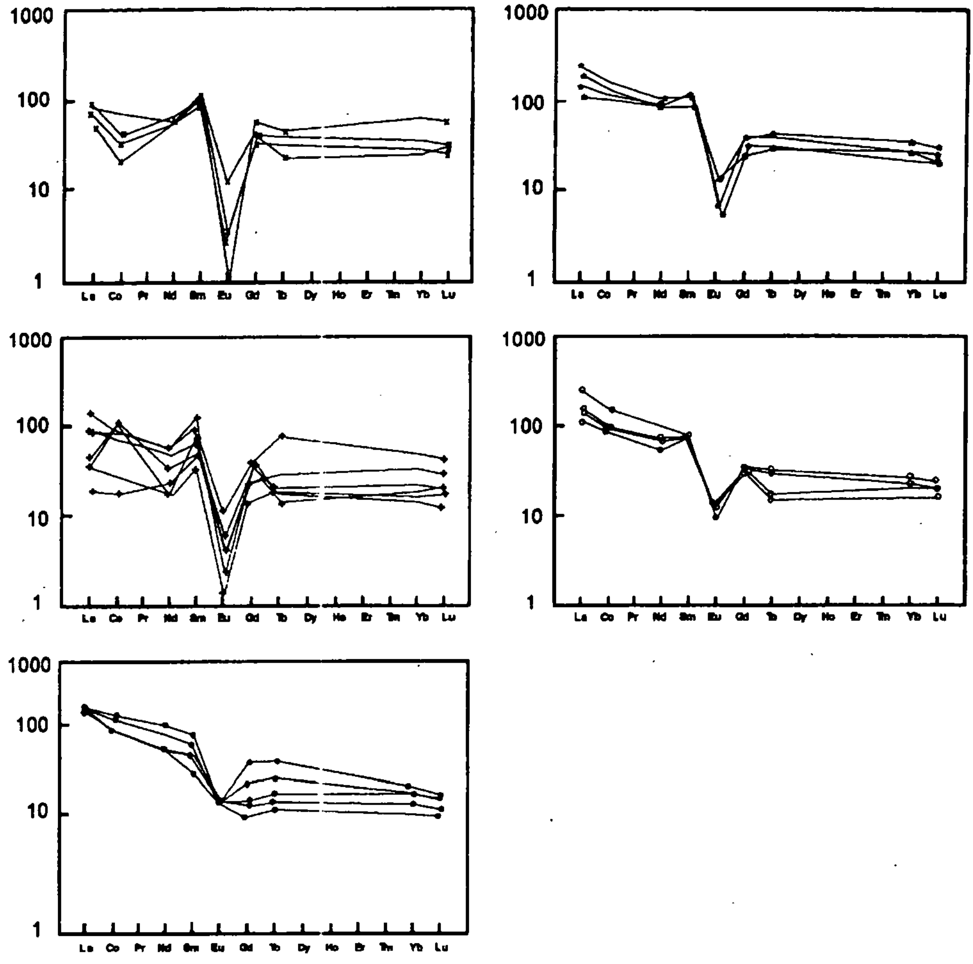

Fig. 15. Normalized REE pattern

The data are plotted on some standard diagrams: on the diagram of SYLVESTER (1989). The syn-orogenic granitoids plot in the field of calc-alkaline I-type, while the late to post orogenic granitoids plot mostly in the field of highly fractioned I-type and alkaline granite (*Fig. 16*). On the diagram of HINE et al. (1979), the syn-orogenic granitoids plot in the I-type field, while the majority of the late to post-orogenic granitoids plot also in the I-type field, with the exception of two samples which plot close the line separating the I-and S-types (*Fig. 17*).

Tectonic setting: some reference diagrams are used to deduce the tectonic environment of Abu El-Hasan granitoids. The syn-orogenic (older) granitoid plots have a general trend roughly perpendicular to the iron magnesium oxide side (*Fig. 18*), thus comparable with the compression suite of PETRO et al., (1979). The late-to post-orogenic younger granitoids plot parallel to the AF side which means that they are comparable with the extension suite of PETRO et al., (op. cit). On the multicationic diagram of BATCHELOR and BOWDEN (1985), it is concluded that the (older) syn-orogenic granites are syncollision, while the (younger) late to post-orogenic granites are post-orogenic (*Fig. 19*). Using the discrimination tectonic diagrams of PEARCE et al. (1984), the older granitoids plot in the volcanic arc granite field, while the younger granitods plot in the field of within plate granite and close to the line separating WPG and VAG (*Fig. 20*).

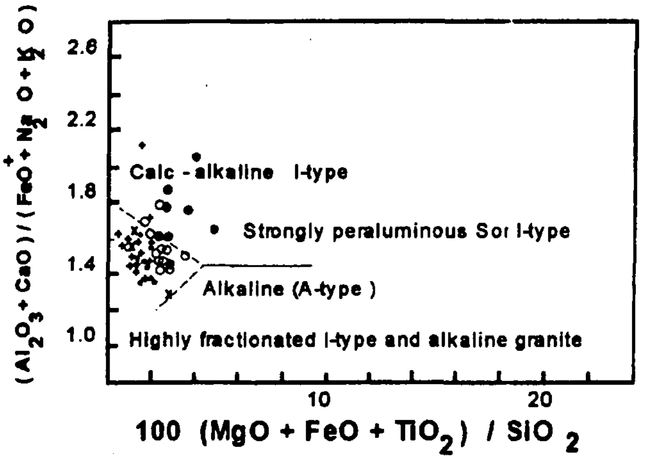

Fig. 16. SYLVESTER's (1989) diagram

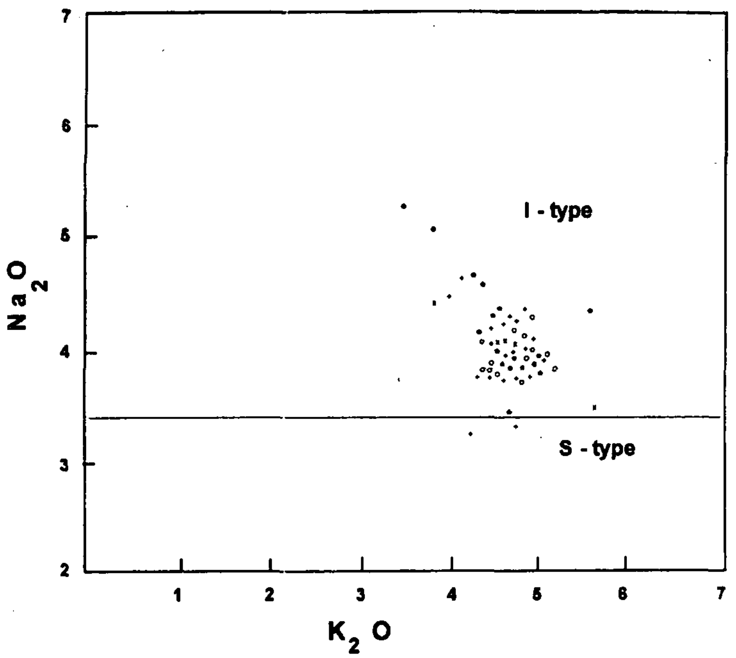

Fig. 17. Na_2O vs. K_2O diagram (HINE et al. 1978)

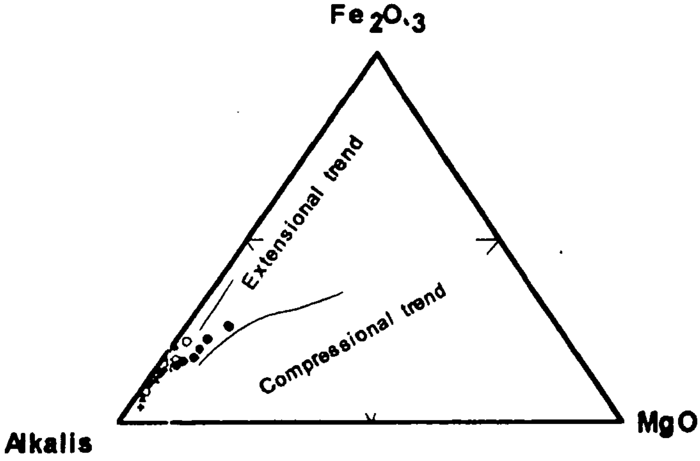

Fig. 18. PETRO et al. (1979) diagram

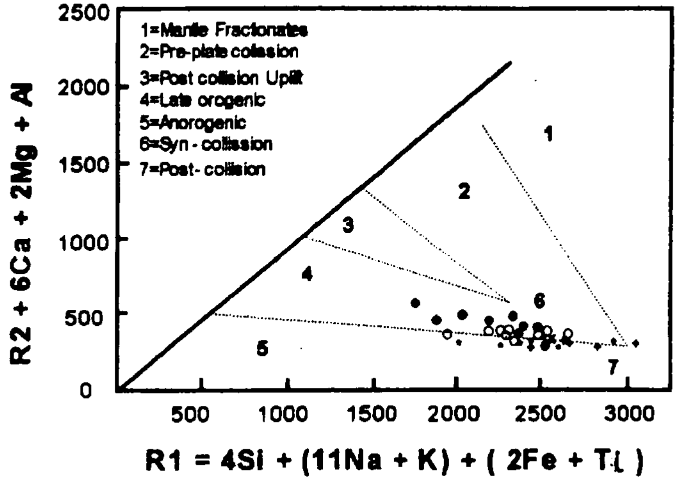

Fig. 19. Multicationic diagram (BATCHELOR and BOWDEN, 1985)

CONCLUSION

The granitic rocks of Abu El-Hasan pluton, north Eastern Desert are petrographically, geochemically and tectonically studied. The investigated rocks comprise older and younger granitoids. Petrographically, the older granitoids comprise biotite-hornblende granodiorite. The younger granitoids are represented petrographically by biotite granite, leucocratic granite, fine-granied granite and red granite.

Chemically, they are calc-alkaline to rather alkaline. They are well-differentiated with an average D.I. 95.83. These granitoids are low-calcium, somewhat potassic rather than sodic and peraluminous.

Chemical classification of Abu El-Hassan granitoids reveals that they comprise granite, alkali-granite, alkali-feldspar granite, syenogranite and monzogranite. Geochemically, Abu-El-Hasan granitoids show low Rb, very-low Sr and moderate Ba. The majority of there rocks fall withing the range 0.5 to 7 Kb water vapour pressure, while some samples were mostly formed under higher water vapour pressure (10 Kb) and in turn deeper levels.

Data for tectonic setting suggest that the older (syn-orogenic) granitoids are comparable with the compression suite of PETRO et al. (1979), while the younger (late to post-orogenic) granitoids are comparable with the extension suite. It is argued that Abu El-Hasan granitoids were derived from partial melting of the upper mantle with some lower crust contribution. The older granitoids are syn-collision and plot in the volcanio arc field, the younger granitoids are post-orogenic and plot in the within plate field and close to the line separating WPG and VAG.

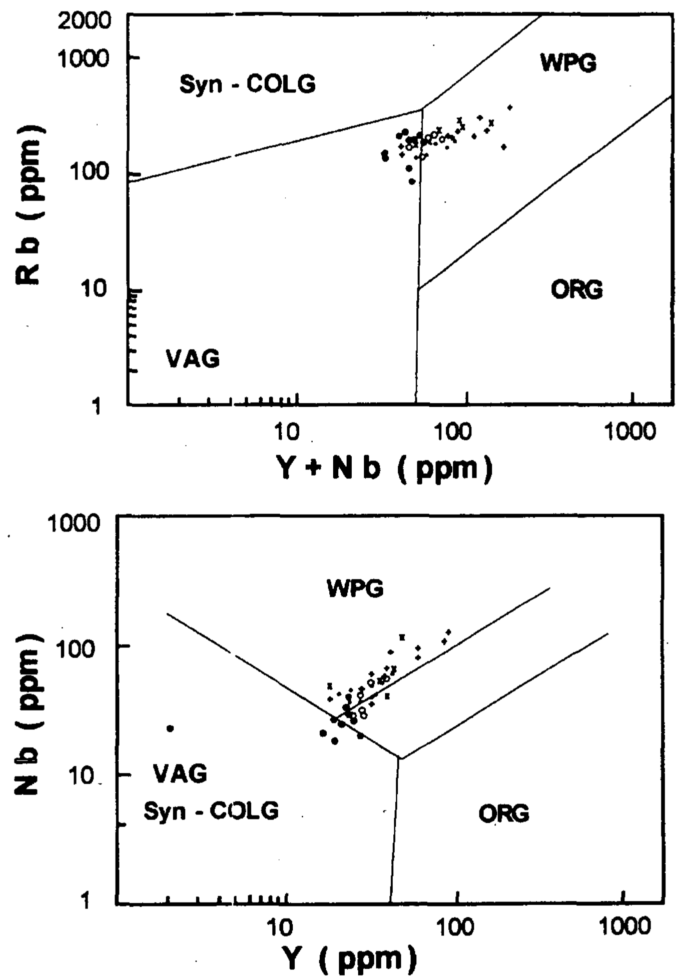

Fig. 20. Tectonic discrimination diagrams (PEARCE et al. 1984)

ACKNOWLEDGEMENT

The authors wish to express their thanks to Prof. Dr. F. FINGER, Salzburg University, Austria for useful suggestions and for facilities offered during the analytical work. The authors are grateful to Prof. M. F. EL-RAMLY, Ain Shams University for useful remarks and fruitful discussion.

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Manuscript received 16 April, 1998.