

Geochemistry And Uranium – Thorium Distributions In The Younger Granites Of Esh El-Mallaha Range, North Eastern Desert, Egypt

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ABSTRACT

Esh El-Mallaha range represents an uplifted rock block forming the western extension of the Arabo-Nubian shield. It forms an elongated ridge parallel to the Gulf of Suez, running in the NW-SE direction. The area is covered by two types of rock suites (metamorphic and magmatic) of late Precambrian age. The metamorphic suite is represented by basic metavolcanic rocks, whereas the magmatic suite is depicted by Dokhan volcanics and granitoid rocks.

In Esh El-Mallaha range, the younger granites crop-out in the form of three large elliptical plutons. These younger granites are mostly represented by Gabal Um Dirra monzogranites, Gabal El-Esh syenogranites and Gabal Homr El-Gerigab alkali feldspar granites. They are originated from peraluminous calc-alkaline highly fractionated magma. This magma is also rich in Rb and depleted in Ba indicating low pressure conditions. They could be considered as post- orogenic granites, intruded in a crust of thickness greater than 20 km at water vapour pressure between 1 and 3 kb and crystallized at temperatures ranging from 800° to 850° C. They could be considered as mesozonal granites.

The rare earth elements show weak to moderate relative enrichment of LREE ($\frac{\square}{\square} \text{LREE} / \text{HREE}_N = 2.5-2.9$) with clear +ve Eu anomaly for the monzogranites. Higher enrichment of the LREE ($\frac{\square}{\square} \text{LREE} / \text{HREE}_N = 7.0-11.0$) with strong –ve Eu anomaly is recorded for the syenogranites and alkali feldspar granites. The REEs chondrite normalized patterns and geochemical ratios suggest that the studied syenogranites and the alkali feldspar granites are differentiated from monzogranites or at least originated from similar magma and tectonic setting. The remaining zigzag effect of the chondrite-normalized patterns of monzogranites, syenogranites and alkali feldspar granites can be interpreted to possible “tetrad-effect”. The similarity in the “tetrad-effect”, except for Eu, can be interpreted to common source and possibly similar fractionation processes.

The studied younger granites are considered as uraniferous granites originated from highly fractionated U-rich magma with trapping high concentrations of uranium in accessory minerals. The syenogranites and alkali feldspar granites show higher U and Th contents and lower Th/U ratios than those of monzogranites; due to the higher quotient of the radioactive accessory minerals (e.g. zircon, apatite and sphene) in the syenogranites with addition of fluorite in alkali feldspar granites.

INTRODUCTION

The basement rocks of Egypt cover about 100,000 km² (about 10 % of the total area of Egypt). Granitoids constitute an important rock group that covers vast areas of the Arabo-Nubian shield. They cover about 38% of the basement out-cropping in Egypt. They are classified into older (synorogenic) and younger (late to post orogenic) granites. In the Eastern Desert of Egypt, granitoid rocks constitute about 61 % of the total basement complex terrain,

but the older granitoids are predominant than the younger granites (Stern et al., 1984).

Esh El-Mallaha range forms a conspicuous segment of Red Sea Hills running in the NW-SE direction parallel to Gulf of Suez. It crops-out as an elongated ridge bounded by two major normal faults of about 60 km in length running in NW-SE direction. It represents one of three horsts recorded in the Eastern Desert (Said, 1962). Generally, the area of study is characterized by its rugged topography. Granitoid rocks are the highest elevation in the area. The highest peaks are represented by Gabal Homra El-Gerigab (431 m above sea level) and Gabal Um Dirra (295 m). The main target of this study is to evaluate the granitoid rocks of Esh El-Mallaha range from the geochemical and radioactivity points of view.

GEOLOGIC OUTLINE

The study area, Esh El-Mallaha range, is located at the northern parts of the Eastern Desert of Egypt, some 37 km north of Hurghada city, at the Red Sea coast, between latitudes $27^{\circ} 23'$ and $27^{\circ} 56'$ N and longitudes $33^{\circ} 11'$ and $33^{\circ} 38'$ E and extends for about 75 km. The basement rocks, of Precambrian age, cropping out in the studied area are classified into:- (1) Metavolcanics (oldest), (2) Dokhan volcanics, (3) Hammamat sedimentary rocks, and (4) younger granites (youngest). The basement rocks of the range occupy an area of about 300 km². They are invaded by basic dykes mainly striking NE-SW directions (Fig.1a). The basement rocks which form the major part of the range are unconformably overlain by a sedimentary cover of Miocene rocks on their eastern side, while in westwards, the basement rocks unconformably overlain by Nubian Sandstone as well as Cretaceous and Eocene formations. The gamma radioactivity of the different rock types in the studied area are of specific normal type.

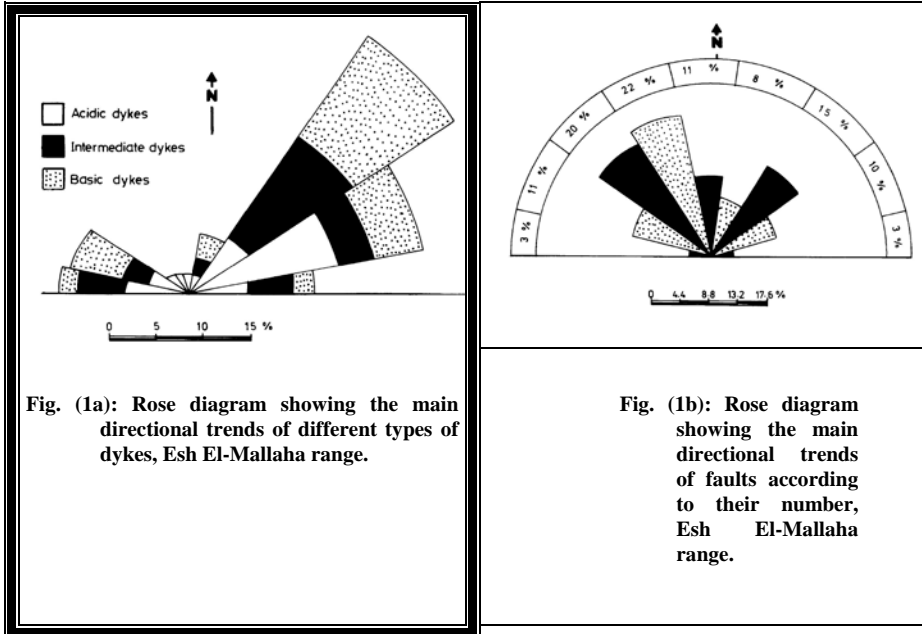
The area of Esh El-Mallaha range was subjected to successive tectonic events. Thus, the area is dissected by various trends of faults and shear zones. Several parameters of the faults are recorded, e.g.: slicken sides, displacement of vertical dykes and joints, fault gauge, mylonites and fault breccia. The main trends of the faults are represented by NNW-SSE and NW-SE sets which are nearly parallel to the older late Proterozoic Pan African lineaments (Fig. 1b). The intersection of late Proterozoic is NE-SW. El-Kholy (1996) concluded that the NW-SE is the oldest, while NNW-SSE fault set is the youngest one. Normal faults are mainly recorded in the Miocene sedimentary rocks.

The metavolcanic rocks are the oldest and less exposed in Esh El-Mallaha Range. They form scattered moderately low hilly outcrops elongated in the NW-SE direction at the western side of wadi Um Dirra. They are represented by metadolerite rocks. These rocks are massive, hard, fine-grained, strongly foliated, highly jointed and blackish green in colour with dark aspects. They are intruded by the granites of Gabal Um Dirra with sharp intrusive contact.

Dokhan volcanics, in the study area, are mainly represented by andesites and are representing the major suite of the basement rocks in the Esh El-Mallaha Range. They include most of the southern and central parts of the range. In the southern parts, they are unconformably overlain by Miocene sediments. In the central parts, Dokhan volcanics are overlain unconformably by the Hammamat sedimentary rocks. These volcanics are well exposed south of wadi Um Dirra, Gabal El-Esh and the eastern part of Gabal Homra El-Gerigab. They outcrop as hills of moderate to high elevations reaching about 448 m above sea level. These volcanic rocks are intruded by the younger granites with sharp intrusive contact. They are extensively invaded by felsite, andesite, andesite porphyry and basaltic dykes which are trending ENE-WSW and NE-SW. They are highly dissected by several faults and joints trend mainly in the NW-SE, N-S and NE-SW directions.

At Esh El-Mallaha Range, the Hammamat sedimentary rocks are mainly composed of conglomerates, greywackes and siltstones. Conglomerates are generally of greenish gray

colour, coarse- to very coarse-grained and contain subrounded to rounded boulders, cobbles and pebbles. Greywackes are fine- to medium-grained, hard, massive rocks of greyish and pale brown colours. Siltstones are of dark purple colour and sometimes they grade into banded hematitic silty mudstone with distinct graded bedding.



The younger granites of the studied area crop-out in the form of three mappable masses. These younger granites are namely; Gabal Um Dirra (greyish pink granites), Gabal El-Esh (pink granites) and Gabal Homr El-Gerigab (pinkish red granites).

I- Gabal El-Esh

Gabal El-Esh granitic mass is located east Gabal El-Esh Dokan volcanics and extend beyond the mapped area (Fig. 2a). It outcrops as a small elevated hill, located at the extreme south eastern part of the mapped area of Esh El-Mallaha range. These granites are unconformably overlain by Miocene sediments on some parts of the eastern side. Some pegmatite pockets are found within these granites. These granites intruded the western Dokhan volcanics of G. El-Esh, their contact with them is sharp and intrusive one. Some fragments of these volcanic rocks are included as xenoliths of different shapes and sizes within the younger granites. Some off-shoots and apophyses of these granites are observed invading the Dokhan volcanics. The granites along their contact are strongly hematitized and silicified. Gabal El-Esh granites are invaded by basic dykes trending in the NE-SW direction. Also, they are cut by faults and fractures trending N-S and NE-SW directions. Along the fault zones, these granites are strongly hematitized, kaolinitized and silicified and are associated with high radioactivity. These granites are dissected by several sets of joints predominating in the NW-SE, NNE-SSW and ENE-WSW directions(Fig. 2b).

II- Gabal Um Dirra

The younger granites of the studied area crop-out in the form of three mappable masses. These younger granites are namely; Gabal Um Dirra (greyish pink granites), Gabal El-Esh (pink granites) and Gabal Homr El-Gerigab (pinkish red granites).

Gabal Um Dirra forms a large excellent outcrop bordering Wadi Um Dirra at the south of the central portion of Esh El-Mallaha range (Fig. 2c). These granites are highly dissected by

faulting. They intrude the country rocks (metavolcanics, Dokhan volcanics and Hammamat sedimentary rocks). They are unconformably overlain by Phanerozoic sediments. Some pegmatite pockets and small xenoliths of dioritic nature are detected within these granites. These granites are intruded by post-granitic dykes comprising acidic, intermediate, basic and alkaline varieties; these dykes generally trend NE-SW, however NW-SE and N-S trend are rare. Um Dirra granitic pluton are well jointed in various directions. The majority of these joints are fairly straight. Joints are mostly vertical but inclined joints with dips of 60° - 70° are recorded. Horizontal joints are also encountered along Wadi Um Dirra. The plotted contour diagram of the recorded joints arranged according to their order of abundance are into the following trends; E-W, NW-SE and NNE-SSW (Fig. 2d).

These granites are strongly dissected by fractures and faults mainly trending N-S, NW-SE and NE-SW. The granites along the shear zones are strongly hematitized, silicified and kaolinitized due to the invasion by late stage of hydrothermal fluids.

III- Gabal Humra El-Gerigab

Gabal Humra El-Gerigab is located northwest of Wadi Abu Had. It is of ovoidal shape and shows rugged topography with high peaks reaching about 430 m above sea level. It forms several isolated outcrops in the western portion. These granites intrude the dark greyish green coloured Dokhan volcanics with sharp intrusive contact (Fig. 2e). The granite rocks of Gabal Humra El-Gerigab are not invaded by post granitic dykes thus, it could be considered as the latest granitic phase among the study younger granite rocks within Esh El-Mallaha range, while the granite rocks of Gabal Um Dirra are the earliest one (El-Kholy, 1996).

The granites of Gabal Humra El-Gerigab are well jointed in several directions; these joints are vertical, inclined, horizontal (sheet-joints), curved or straight. The majority of these joints are filled with hematite, manganese oxides and some with epidote. Some of these joints are major and called master joints showing hundreds of meters in extension. The most common directions of joints in these granites in decreasing order of predominant are WNW-ESE, N-S and NNW-SSE (Fig. 2f).

It is worth to mention that Gabal Humra El-Gerigab is the highest radioactive readings in the area. The granites of Gabal Um Dirra exhibit the lowest radioactivity level among the study younger granites of Esh El-Mallaha range.

PETROGRAPHY

The nomenclature of igneous rocks is mainly related to their mineral composition. In the present work, twenty four representative thin sections were analyzed for modal composition (Table 1) and plotted in QAP diagram of Streckeisen (1976). The Um Dirra samples were plotted in the monzogranite field, while the El-Esh samples were plotted within the syenogranite field, but the Homr El-Gerigab samples were plotted in alkali feldspar granite field (Fig. 3a).

The monzogranites of G. Um Dirra are medium- to coarse-grained, equigranular, hypidiomorphic rocks and are composed of orthoclase perthite, quartz, plagioclase, biotite and hornblende as essential minerals and sphene, apatite, zircon, garnet, epidote muscovite and opaques as accessory and secondary minerals. Both syenogranites (G. El-Esh) and alkali feldspar granites (G. Homr El-Gerigab) are medium- to coarse-grained, hypidiomorphic rocks, and are essentially composed of perthites, quartz, plagioclase, muscovite and biotite. The accessory and secondary minerals are zircon, sphene, apatite, epidote, fluorite and iron oxy-hydroxides. Alkali feldspar granites show high perthites (reach up 58%), the increase in perthites is accompanied by increase in quartz and decrease in the plagioclase contents. They show high contents of deep violet fluorite, metamict zircon and higher contents of iron oxides than those of syenogranites.

GEOCHEMISTRY

The same twenty four samples that were used for petrographic studied were chosen for chemical analysis. The chemical analysis for the major oxides (wt %) was done using wet chemical analysis technique of Shapiro and Brannock (1962) in the Analyses Department of the Nuclear Materials Authority of Egypt. The obtained data with some geochemical ratios as well as the symbols used in plotting for the studied granitic rocks are given in table (2).

Table (1): The modal analysis of the studied younger granites

Rock Type	Sample No.	Mineral composition					
		Quartz	Perthites	Plagioclase	Mica	Hornblende	Accessories and opaques
Biotite-hornblende granites (G. Um Dirrah)	1	21.81	23.92	31.90	8.70	6.69	6.97
	2	22.95	26.95	33.12	7.15	5.10	4.74
	3	23.00	25.41	32.45	8.00	6.10	5.04
	4	22.29	23.50	36.81	6.60	5.10	5.70
	5	23.34	24.12	34.21	8.01	5.50	4.82
	6	21.05	29.75	32.86	7.01	4.79	4.56
	7	25.00	27.70	32.40	5.41	3.69	5.70
	8	22.50	30.34	30.55	8.56	4.04	4.00
Biotite granites (G. El-Esh)	9	40.28	43.50	11.13	1.03	-	4.06
	10	37.00	44.55	14.36	1.50	-	2.59
	11	37.91	48.00	10.00	1.61	-	2.48
	12	34.25	51.81	10.48	1.20	-	2.26
	13	38.83	44.28	11.00	1.52	-	4.37
	14	37.32	42.45	14.23	2.12	-	3.88
	15	42.00	40.80	13.32	1.15	-	2.67
	16	42.63	43.26	10.52	1.41	-	2.15
Muscovite granites (G. Homr El-Gerigab)	17	32.95	60.55	3.00	2.50	-	1.00
	18	33.15	58.00	3.65	2.00	-	3.20
	19	27.87	66.45	2.10	2.15	-	1.43
	20	25.97	70.26	1.65	1.11	-	1.00
	21	29.28	65.71	2.10	1.85	-	1.06
	22	31.45	59.05	4.50	3.87	-	1.13
	23	29.73	63.47	4.35	1.40	-	1.05
	24	30.11	61.59	4.55	2.50	-	1.25

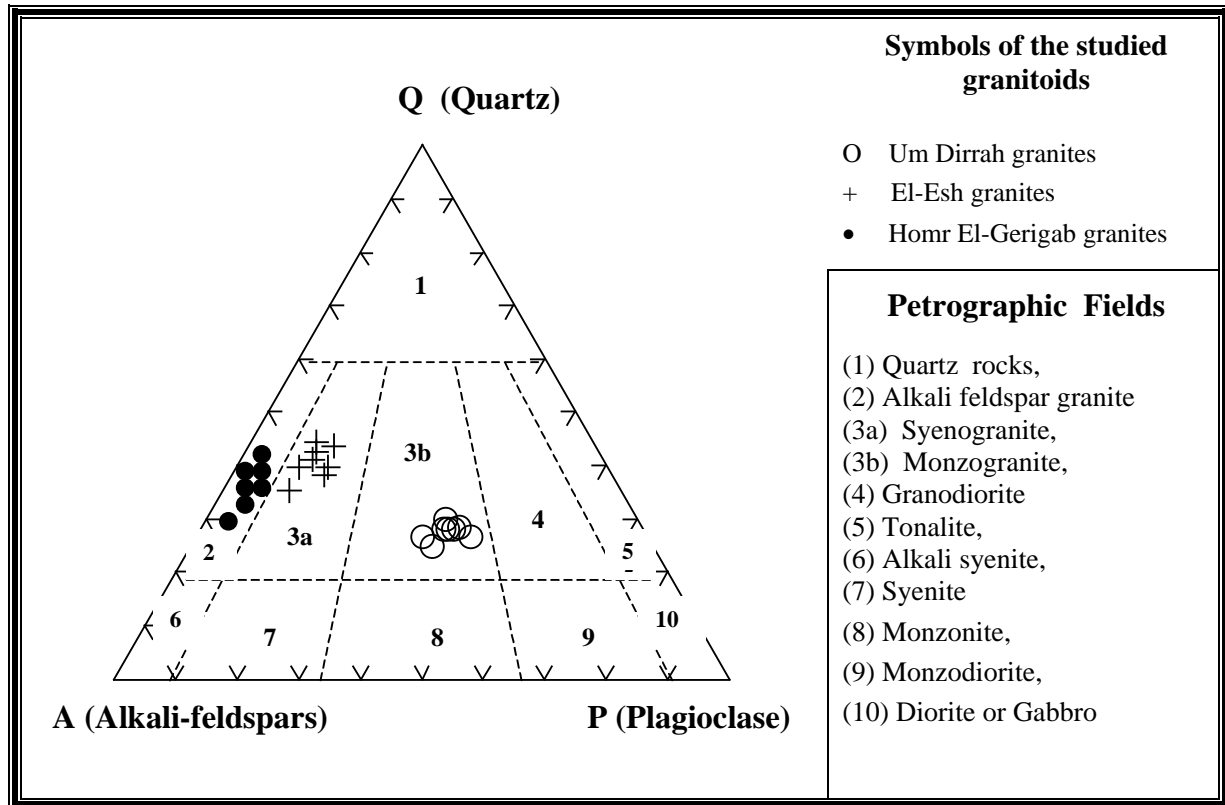


Fig. (3a): Modal composition for the studied granites (after Streckeisen, 1976).

The geochemical data revealed that the monzogranites are characterized by their relatively lower SiO_2 , K_2O , Rb, Zr, Y and Nb, and higher FeO, MgO, Al_2O_3 , L.O.I and Sr compared to the syenogranites and alkali feldspar granites. This suggests that the latter was possibly originated from highly fractionated magma. This magma is rich in Rb and depleted in Ba and Sr. The K/Ba ratio indicates an advanced magmatic differentiation. In spite of these differences, monzogranites, syenogranites and alkali feldspar granites display a rather limited standard deviation due to the narrow variation in their trace and major chemical constituents.

Fig. (3b) shows that the studied granitic samples were separated into three clear groups according to their chemical composition. The first group (samples 1-8) represents Um Dirra monzogranites followed by the second group (samples 9-16) representing El Esh syenogranites and finally the third group (samples 17-24) representing Homr El Girgab alkali feldspar granites. It can be noticed from this diagram that each group represents a magmatic stage or pulse arranged from group 1 to 3.

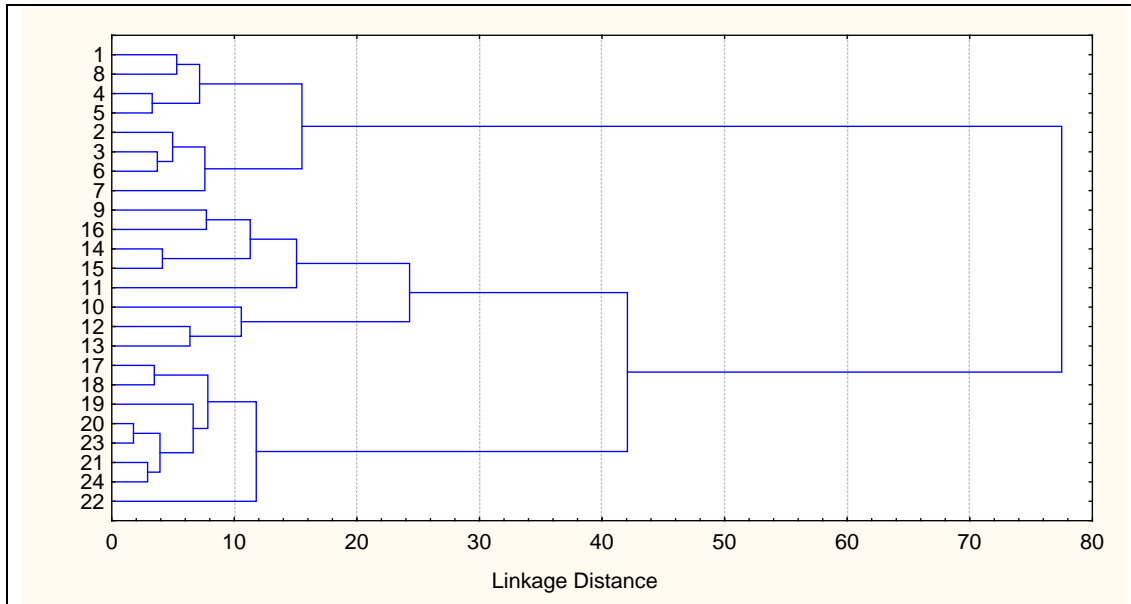


Fig. (3b): R-mode cluster analysis for the studied granitic samples.

Geochemical classification and petrogenesis

Recently, Chapman (2005) took the Ga/Al ratio as a good guide for measuring the degree of differentiation in peraluminous and peralkaline granites. He suggested that the Ga/Al ratio increase from monzogranites (Ga/Al less than 0.0003) to syenogranites (0.0003<Ga/Al<0.0005) to alkali feldspars granite (0.0005<Ga/Al). The increase of the Ga/Al ratio, from monzogranites to syenogranites to alkali feldspars granites, is due to an increase of Ga during the differentiation. In the studied granitoids, the range of Ga/Al ratio values in the Um Dirrah granites is ranging from 0.00027 to 0.00029 classifying this granite as monzogranites. This ratio values in the El-Esh granites is ranging from 0.00036 to 0.00043 classifying this granite as syenogranites, the increasing of this ratio to 0.00051 – 0.00056 in Homr El-Gerigab is classifying this rock into alkali feldspar granites. This classification is in a complete harmony with their petrographic classification.

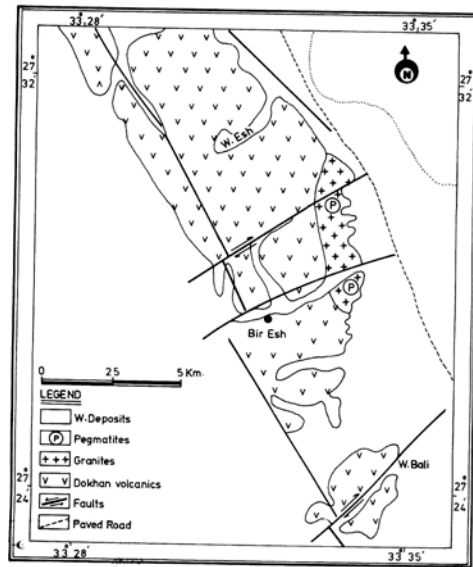


Fig. (2a): Geologic map of G. El-Esh, Esh El-Mallaha range.

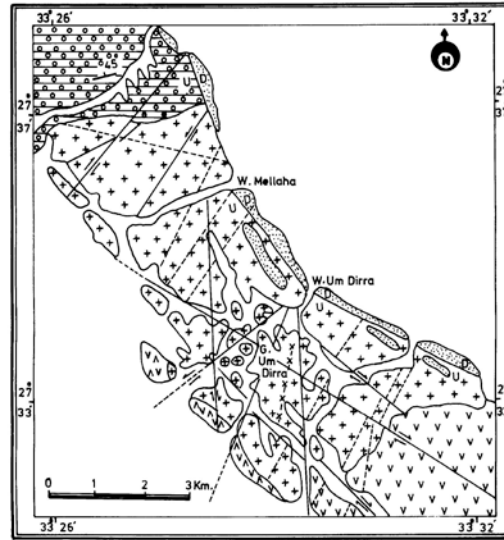
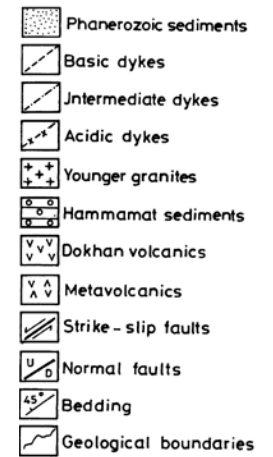


Fig. (2c): Geologic map of G. Um Dirra, Esh El-Mallaha range.



Fig. (2e): Geologic map of G. Homr El-Gerigab, Esh El-Mallaha range.



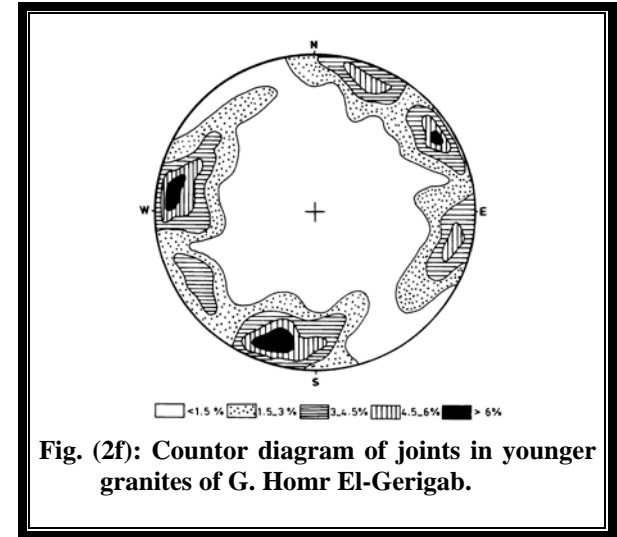
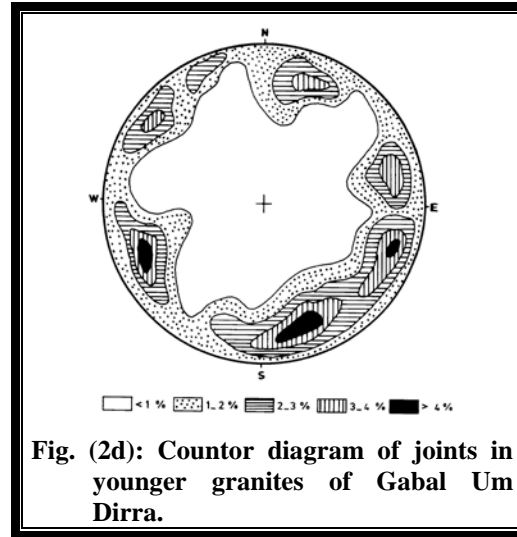
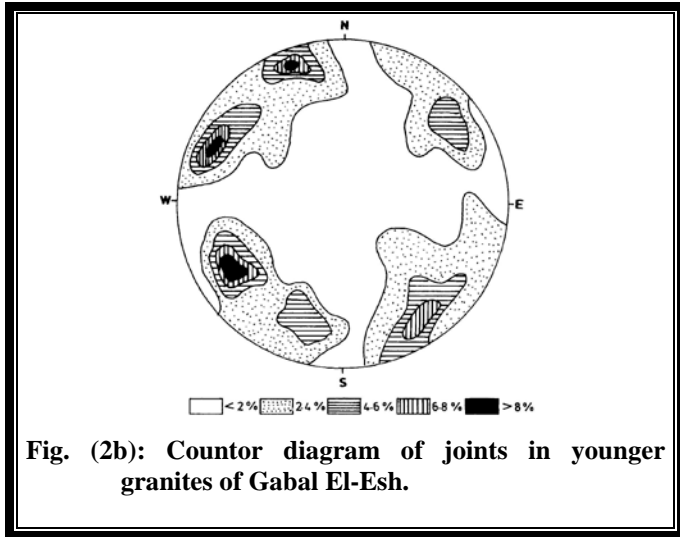


Table (2a): Major oxides (wt%), trace and rare earth elements of Um Dirra monzogranites.

Sample No.	1	2	3	4	5	6	7	8
Symbol	o	o	o	o	o	o	o	o
SiO ₂	71.42	71.70	71.24	71.27	72.40	71.49	71.61	72.00
TiO ₂	0.09	0.14	0.17	0.11	0.09	0.12	0.19	0.13
Al ₂ O ₃	13.77	12.95	14.02	13.78	13.11	13.06	13.05	14.01
Fe ₂ O ₃	0.93	0.88	1.07	1.15	1.04	0.96	0.91	0.72
FeO	2.51	2.28	2.09	2.17	2.25	2.04	2.37	2.16
MnO	0.07	0.07	0.06	0.05	0.06	0.07	0.08	0.09
MgO	0.83	0.73	0.64	0.92	0.68	0.81	0.91	0.79
CaO	1.84	1.97	2.01	2.00	1.79	1.82	1.77	1.76
Na ₂ O	4.21	4.45	4.32	4.36	4.29	4.61	4.51	4.22
K ₂ O	3.07	3.82	3.17	3.31	3.00	3.72	3.46	3.10
P ₂ O ₅	0.10	0.17	0.18	0.12	0.10	0.17	0.20	0.16
L.O.I.	1.04	0.72	0.91	0.62	1.11	0.98	0.84	0.82
Total	99.88	99.84	99.88	99.86	99.92	99.85	99.90	99.86
Trace and rare earth elements (ppm)								
Rb	102	110	115	113	105	113	107	111
Sr	39	44	49	40	47	60	59	53
Ba	36	41	52	38	46	32	41	50
Y	76	80	88	77	89	85	85	91
Zr	140	150	144	158	147	135	149	147
Hf	17	19	20	16	18	20	21	17
Nb	68	64	77	70	64	71	73	71
Ta	3	3	4	3	3	3	3	3
Pb	33	36	30	41	28	30	35	36
Ga	20	19	22	21	20	20	20	20
U	5.5	6.1	6.3	5.3	5.4	5.9	6.5	5.5
Th	15.1	17.3	17.4	15.5	16.2	16.5	17.6	15.7
La	26.1	29.5	29.1	27.1	28.1	28.5	28.4	24.9
Ce	64.0	74.6	72.7	68.1	70.2	71.7	78.8	66.0
Pr	14.7	13.7	17.2	15.3	14.1	15.2	16.2	17.1
Nd	14.0	14.2	14.8	13.8	13.5	13.0	13.9	14.7
Sm	2.5	2.1	3.0	2.2	2.1	2.0	2.2	2.4
Eu	1.1	1.4	1.2	1.0	1.3	1.1	1.0	1.7
Gd	3.7	3.2	3.5	4.0	3.7	3.0	3.3	3.6
Tb	0.5	0.6	0.5	1.0	0.7	0.6	0.5	1.0
Dy	30.1	34.7	33.6	31.5	32.6	34.9	33.5	34.0
Er	6.1	5.5	7.2	6.4	5.9	6.8	5.1	6.1
Yb	6.5	7.1	6.1	6.1	6.0	6.9	7.2	6.5
Lu	1.2	1.1	1.7	1.9	1.4	1.5	1.1	1.3
□REEs	169.4	187.2	188.1	176.4	178.5	184.9	192.5	179.4
Geochemical ratios								
Eu*	1.10	1.65	1.13	1.03	1.42	1.37	1.13	1.76
L/H	2.70	2.77	2.73	2.74	2.74	2.57	2.93	2.56
Ce/Nb	0.94	1.16	0.94	0.97	1.10	1.01	1.08	0.93
Yb/Ta	2.16	2.37	1.53	2.03	2.00	2.30	2.40	2.16
Rb/Sr	2.61	2.50	2.34	2.82	2.23	1.88	1.81	2.09
K/Rb	250	288	230	243	237	273	268	232
K/Ba	702	773	506	726	541	970	700	517
Zr/Sr	3.60	3.41	4.00	3.95	3.18	2.25	2.52	2.77
Zr/Hf	8.2	7.89	7.20	9.87	8.16	6.75	7.10	8.60
Ba/Rb	0.37	0.40	0.43	0.33	0.43	0.32	0.40	0.45
Nb/Ta	22.6	21.3	19.25	23.30	21.3	23.60	24.30	23.60
Y/Nb	1.12	1.25	1.14	1.10	1.39	1.20	1.16	1.28
Th/U	2.74	2.83	2.77	2.87	3.00	2.80	2.73	2.92
A/CNK	1.51	1.26	1.47	1.42	1.45	1.30	1.34	1.54
Ga/Al*	27	28	29	28	29	29	29	27

* Ga/Al = Ga/Al x 10⁻⁵

Eu* = Eu_{CN} / (Sm_{CN} x Gd_{CN})^{1/2}

L/H =

□LREES/□HREES

Table (2b): Major oxides (wt%), trace and rare earth elements of El-Esh syenogranites.

Sample No.	9	10	11	12	13	14	15	16
Symbol	+	+	+	+	+	+	+	+
SiO ₂	75.00	74.68	74.80	74.85	74.65	75.12	75.09	74.88
TiO ₂	0.10	0.10	0.10	0.10	0.11	0.08	0.12	0.11
Al ₂ O ₃	14.00	14.00	14.01	13.70	13.70	14.40	14.00	13.53
Fe ₂ O ₃	1.14	1.03	1.10	1.05	1.08	0.99	1.05	0.90
FeO	0.62	0.64	0.60	0.71	0.76	0.82	0.72	0.80
MnO	0.03	0.04	0.02	0.03	0.03	0.04	0.04	0.03
MgO	0.31	0.30	0.30	0.29	0.26	0.32	0.29	0.28
CaO	0.51	0.50	0.48	0.51	0.60	0.60	0.53	0.49
Na ₂ O	3.82	3.96	3.89	4.04	3.91	3.52	3.74	3.95
K ₂ O	3.71	3.83	3.89	3.97	4.01	3.24	3.55	4.26
P ₂ O ₅	0.09	0.11	0.11	0.11	0.11	0.07	0.08	0.12
L.O.I.	0.50	0.63	0.50	0.46	0.53	0.61	0.54	0.54
Total	99.83	99.82	99.80	99.82	99.75	99.81	99.75	99.89
Trace and rare earth elements (ppm)								
Rb	230	228	241	235	246	231	222	233
Sr	10	12	13	12	13	11	10	12
Ba	36	40	38	40	43	34	35	44
Y	82	77	84	78	82	83	80	75
Zr	135	159	161	155	159	157	170	163
Hf	15	20	18	17	18	17	18	18
Nb	80	74	66	77	71	81	70	69
Ta	3	3	3	4	3	3	3	4
Pb	30	42	36	41	36	42	45	32
Ga	29	27	30	30	30	33	31	30
U	8.2	9.1	9.3	8.3	8.4	8.9	9.5	8.5
Th	16.3	17.3	17.4	15.5	16.2	16.5	17.4	16.1
La	40.0	45.0	32.1	41.3	43.7	44.1	45.3	42.4
Ce	97.5	107.1	99.4	110.5	114.8	91.7	94.5	101.9
Pr	20.2	19.4	21.5	19.7	18.9	24.1	26.0	22.3
Nd	27.1	26.3	26.4	22.4	19.3	24.0	23.7	21.9
Sm	7.3	6.7	7.0	5.8	6.0	6.7	7.4	6.6
Eu	0.7	0.6	0.7	0.5	1.0	0.6	0.7	0.8
Gd	6.5	5.9	6.2	7.1	5.8	6.7	6.3	6.8
Tb	1.2	1.4	1.5	1.1	1.0	1.4	1.6	1.1
Dy	27.2	28.0	30.2	29.1	27.5	29.0	30.7	26.4
Er	3.1	2.7	2.9	3.6	2.5	2.0	2.1	4.0
Yb	8.1	7.5	7.4	7.6	7.0	8.3	7.9	8.6
Lu	0.6	0.7	1.0	0.8	0.7	1.0	0.9	0.8
☐REEs	239.5	251.3	236.3	249.5	248.2	239.6	247.1	243.6
Geochemical ratios								
Eu*	0.31	0.30	0.32	0.24	0.58	0.27	0.31	0.36
L/H	4.74	4.86	4.31	4.72	5.18	4.60	4.52	4.73
Ce/Nb	1.21	1.45	1.50	1.43	1.60	1.13	1.35	1.48
Yb/Ta	2.70	2.50	2.50	1.90	2.33	2.76	2.63	2.15
Rb/Sr	23.01	19.00	18.54	19.60	18.92	21.00	22.2	19.41
K/Rb	161	140	132	139	133	115	131	150
K/Ba	848	788	843	817	767	784	835	797
Zr/Sr	13.5	13.3	12.4	13.0	12.2	14.3	17.0	13.6
Zr/Hf	9.00	8.00	9.00	9.10	8.80	9.2	9.40	9.10
Ba/Rb	0.16	0.17	0.16	0.17	0.17	0.15	0.16	0.19
Nb/Ta	26.7	24.6	22.0	19.3	23.7	27.0	23.3	17.3
Y/Nb	1.02	1.04	1.30	1.01	1.15	1.02	1.14	1.10
Th/U	1.58	1.90	1.87	1.86	1.92	1.85	1.83	1.89
A/CNK	1.74	1.68	1.70	1.60	1.61	1.86	1.79	1.55
Ga/Al*	39	36	40	41	41	43	39	42

* Ga/Al = Ga/Al x 10⁻⁵

Eu* = Eu_{CN} / (Sm_{CN} x Gd_{CN})^{1/2}

L/H =

☐LREES/☐HREEs

Table (2c): Major oxides (wt%), trace and rare earth elements of Homr El Gerigab Alkali feldspar granites.

Sample No.	17	18	19	20	21	22	23	24
Symbol	•	•	•	•	•	•	•	•
SiO ₂	75.81	74.65	75.50	74.53	74.64	74.74	74.45	74.21
TiO ₂	0.07	0.11	0.06	0.09	0.12	0.08	0.07	0.07
Al ₂ O ₃	11.96	12.83	12.42	12.94	12.70	13.76	13.27	13.09
Fe ₂ O ₃	0.93	1.06	0.88	1.01	1.04	1.16	1.09	1.03
FeO	0.88	0.48	0.86	0.57	0.37	0.41	0.55	0.63
MnO	0.04	0.03	0.03	0.05	0.04	0.02	0.05	0.04
MgO	0.35	0.47	0.30	0.29	0.21	0.27	0.32	0.29
CaO	0.51	0.55	0.51	0.41	0.51	0.61	0.51	0.56
Na ₂ O	4.00	4.25	4.11	4.31	4.53	4.20	4.23	4.41
K ₂ O	4.51	4.82	4.57	4.65	4.71	4.62	4.54	4.73
P ₂ O ₅	0.07	0.13	0.06	0.12	0.14	0.10	0.08	0.12
L.O.I.	0.69	0.62	0.58	0.81	0.75	0.61	0.73	0.68
Total	99.82	99.90	99.88	99.78	99.81	99.84	99.89	99.86
Trace and rare earth elements (ppm)								
Rb	241	240	251	236	250	244	261	260
Sr	8	9	14	11	9	16	14	13
Ba	85	90	67	74	69	80	76	78
Y	86	72	84	79	78	80	85	87
Zr	259	286	253	272	301	263	261	266
Hf	21	23	20	22	24	22	20	23
Nb	82	89	79	82	89	88	79	86
Ta	3	3	3	3	4	3	3	3
Pb	45	38	44	51	46	40	40	35
Ga	36	35	34	36	34	39	36	37
U	12.1	16.1	11.4	15.3	16.7	12.2	14.5	13.1
Th	26.2	29.4	23.5	28.5	29.4	27.5	28.1	27.5
La	51.1	49.8	50.3	53.6	54.2	55	53.7	53.5
Ce	120.7	121.9	125.2	120.4	122.5	130.1	121.7	123.5
Pr	27.5	26.9	31.2	30.8	28.6	31.1	29.8	28.8
Nd	29.8	31.7	34.7	33.5	35.5	33.7	33.8	33.7
Sm	8.5	9.5	8.7	8.9	9.2	9.3	8.9	9.0
Eu	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.4
Gd	7.5	8.1	7.8	7.7	8.3	8.1	7.6	8.5
Tb	1.5	1.3	1.4	1.4	1.6	1.4	1.5	1.6
Dy	25.4	26.3	26.7	24.1	24.7	24.5	24.0	23.9
Er	2.2	1.8	1.6	2.0	2.1	1.8	1.7	1.5
Yb	8.5	8.8	9.1	8.6	9.5	9.2	8.3	8.0
Lu	0.6	0.5	0.6	0.6	0.5	0.6	0.6	0.4
☐REEs	283.7	286.9	297.6	292.0	297.0	305.1	292.0	292.8
Geochemical ratios								
Eu*	0.28	0.11	0.28	0.27	0.13	0.12	0.25	0.14
L/H	6.30	6.20	6.27	6.77	6.66	6.90	6.92	7.00
Ce/Nb	1.47	1.51	1.49	1.47	1.53	1.47	1.53	1.44
Yb/Ta	2.83	2.93	3.00	2.87	2.37	3.07	2.77	2.67
Rb/Sr	30.1	26.7	18.0	21.5	27.7	15.2	18.6	20.0
K/Rb	155	167	151	164	157	157	144	151
K/Ba	440	445	566	521	566	479	496	503
Zr/Sr	32.3	31.7	18.1	24.7	33.4	16.4	18.6	20.5
Zr/Hf	12.3	12.4	12.6	12.4	12.5	12.0	13.0	11.6
Ba/Rb	0.35	0.38	0.27	0.31	0.28	0.33	0.29	0.30
Nb/Ta	27.3	29.7	26.3	27.3	22.2	29.3	26.3	28.6
Y/Nb	1.05	0.88	1.06	0.96	0.97	0.91	1.08	1.01
Th/U	2.16	1.83	2.06	1.86	1.76	2.25	1.93	2.10
A/CNK	1.33	1.33	1.35	1.38	1.30	1.46	1.43	1.35
Ga/Al	56	51	52	52	51	53	51	53

* Ga/Al = Ga/Al x 10⁻⁵

Eu* = EuCN / (SmCN x GdCN)^{1/2}

L/H =

☐LREES/☐HREES

Rb tends to be enriched relative to K in the strongly differentiated granites. Thus, it is quite possible to expect that the K/Rb ratio would be low in the highly differentiated granites. K/Rb ratios in igneous rocks result from upper mantle materials whose ratios range from 700 to 1500 (Heier, 1973). In the present study, the K/Rb ratio of the monzogranite ranges from 230 to 288, and ranges from 115 to 161 for syenogranites, while in alkali feldspar granites the ratio is ranging from 144 to 167. In general, the K/Rb ratio in all the studied samples is less than Heier's values. This can be attributed to the significant contribution of sialic crustal materials. The strong negative relationship between K/Rb and Rb (Fig. 4a) in the studied granites as well as the parallel trend in both monzogranites and syenogranites suggest high degree of fractionation and origin from the same magma (Ekwere, 1985).

The K/Ba ratio of granitic rocks in the crust, suggested by Chapman and Hall (1997), is 60. In the present study, the K/Ba ratio ranges from 506 to 970 for monzogranites and ranges from 676 to 848 for syenogranites, while this ratio is ranging from 440 to 566; which reflects the advanced degree of magmatic differentiation and contribution from sialic crustal materials. Figure (4b) shows the positive relation between K/Rb and K/Ba and the clear interference between the K/Rb ratios in both monzogranites and syenogranites as well as in both alkali feldspar granites and syenogranites suggesting that the all three granitic plutons were possibly formed from the same magma source.

The ratio of Ba/Rb decreases with magmatic differentiation due to crystallization of the feldspars. The average crustal ratio of Ba/Rb for granites, as given by Chapman and Hall (1997), is less than 4.1. In the present study, the Ba/Rb ratio in the monzogranites ranges between 0.32 and 0.45 and ranges between 0.15 and 0.19 for the syenogranites, but this ratio is ranging from 0.27 to 0.35 in alkali feldspar granites, suggesting that the studied younger granites were derived from crustal material. The very narrow range of Ba/Rb ratio in the studied younger granites suggests a common magma source, while the low ratio suggests that, they display a high degree of fractionation and relative enrichment in Rb in comparison to Ba in the source magma. This concept is supported by the strong negative correlation between Ba/Rb and Rb in the studied granitic rocks (Dostal and Chatterjee, 2000).

The Rb/Sr ratio increases with magmatic differentiation due to Sr depletion in liquid magmas as a result of crystallization of feldspars, while Rb is enriched in the liquid phase. Hassan and Hashad (1990) suggested that most of the younger granites have Rb/Sr ratio more than 0.703. In the present study, the average of Rb/Sr ratio in monzogranites, syenogranites and alkali feldspar granites is 2.3, 20.2 and 22.2, respectively. This low ratio has been interpreted by most workers to a derivation from not much older primitive crust or contamination between mantle source and sialic crust (Dostal and Chatterjee, 1995).

Niobium and tantalum are two high-field strength elements (HFSE) that have the same ionic radii, consequently, they have a very similar geochemical behaviour during various geological processes. The low Ta content of these rocks is due to the absence of topaz, rutile, cassiterite and tantalite (Taylor, 1992). Linnen and Keppler (1997) suggested that crystallization of accessory phases from magma would lead to an increase of Nb/Ta ratio in residual peraluminous granitic melts. In the studied rocks, Nb increase with increasing Zr and SiO₂. In the studied rocks, Nb increases significantly with differentiation but tantalum shows a constant value in monzogranites, syenogranites and alkali feldspar granites; suggesting the same magmatic origin of the studied granitoids (Green, 1995).

The Zr/Hf ratio ranges from 7 to 13, for the studied granites. These values are much less than Zr/Hf ratio in common granites (average at 39, Erlank et al., 1978) and the chondritic ratio 38 by Anders and Grevesse (1989). Deviation of the ratio of these two

isovalent HFSE from chondritic values or in other words, this non-CHARAC behavior (CHARGE-and Radius-Controlled) of Zr and Hf suggests a highly evolved granites (Bau, 1996) or metasomatism (e.g., Dupuy et al., 1992). Hall and Walsh (1969) suggested that the Zr/Sr ratio increase with increasing differentiation, indicating advanced degree of magmatic differentiation. They also added that the uraniferous granite is characterized by a high Zr/Sr ratio (more than 1.65). This concept is in complete harmony with the geochemical data of the studied granites (Zr/Sr ratio is more than 2).

Magma type and tectonic setting

Granitoid rocks are described using Shand's index as: peraluminous ($A/CNK > 1$), metaluminous ($A/NK > 1$ and $A/CNK < 1$) and peralkaline ($A/NK < 1$) using molar ratios ($A = Al_2O_3$, $C = CaO$, $N = Na_2O$ and $K = K_2O$). On the studied granites, the A/CNK ratio is more than 1 suggesting the peraluminous affinity for the studied granitoids. Ragab and El-Gharbawi (1989) suggested that most of peraluminous Egyptian younger granites have been formed from crustal materials.

On the $SiO_2 - (K_2O/MgO)$ diagram (Rogers and Greenberg, 1981), the monzogranites plot in the calc - alkaline granite field (Fig. 4c), but the syenogranites plot near the alkali granite field which could be attributed to their high K_2O and low MgO contents as well as high silica contents (>72%). This is supported petrographically by the rare of ferromagnesian minerals in the syenogranites. On the other hand, the alkali feldspar granitic samples were plotted in the alkali granite field.

Maniar and Piccoli (1989) variation diagrams used to discriminate between the different tectonic settings. Figure (4d) shows that the studied granitic samples are mainly plot in the POG field. This interpretation could be supported by the field relationships and observations because the younger granites intrude all the pre-existing rock types exposed in the area and also they do not show any sign of large scale metamorphism or even foliation.

On the normative Q - Ab - Or ternary diagram (Tuttle and Bowen, 1958), the studied syenogranites and alkali feldspar granites plot between 1 and 2 kb water vapour pressure, on the other hand the monzogranites plot between 2 and 3 kb water vapour pressure. Their plots lie near or at the centre of the diagram suggesting that crystallization occurred at temperatures ranging from $800^\circ C$ to $850^\circ C$ (Winkler et al., 1975) and hence they could be considered as mesozonal granites (Fig. 4e). Bown (1967) concluded that the closeness to the normative (Q- Ab- Or) proportions as well as the low water vapour pressure, indicate their genesis by selective melting followed by crystallization at low water vapour pressure. The Rb - Sr variation diagram (Condie, 1973) may explain the crustal thickness during the emplacement of any rock. Both alkali feldspar granites and syenogranites have been intruded in a crust of a thickness greater than 30 km, but monzogranites were intruded in a crust of thickness between 20 and 30 km (Fig. 4f).

Chapman and Hall (1997) suggested that the S-type granites are characterized by the following: 1) peraluminous leucogranite, 2) collision granite (syn-collision or post collision), 3) crustal type granite, and 4) crystallized at low pressure (less than 2.5 kb). All these criteria are in complete harmony with the data of the studied granites.

Geochemistry of rare earth elements (REEs)

The REEs are a useful geochemical tool to supply valuable information about rock genesis. From the REEs data (Table 2) and chondrite normalized patterns (Fig. 5) of monzogranites, syenogranites and alkali feldspar granites, important inferences can be summarized:

1- The REE chondrite patterns (Fig. 5) of the three types of granite exhibit similar patterns

and concentrations as well as roughly parallel trends, which emphasize that monzogranites and syenogranites are from common source (Henderson, 1996).

2-The close similarity in Ce/Nb, Y/Nb, and Yb/Ta ratios is also good evidence for a common origin (Henderson, op.cit.).

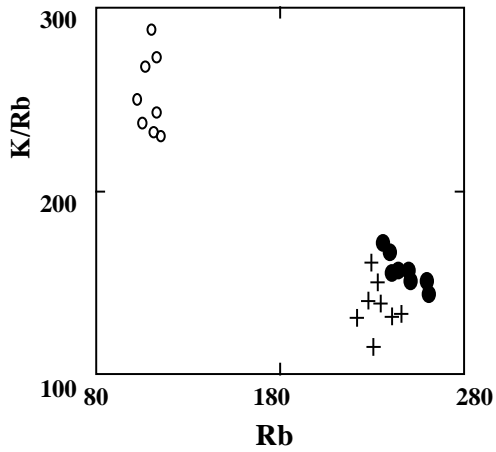


Fig. (4a): K/Rb-Rb variation diagram

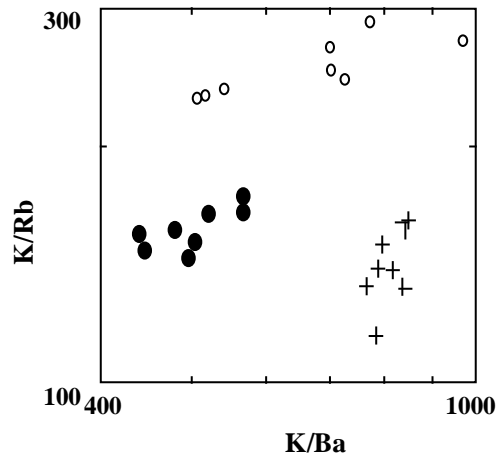


Fig. (4b): K/Rb-K/Ba variation diagram

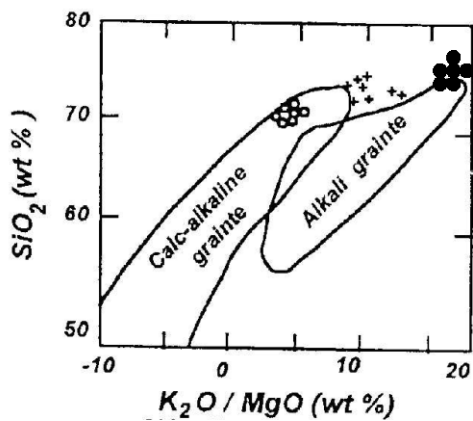


Fig. (4c): SiO₂ – K₂O/MgO variation diagram

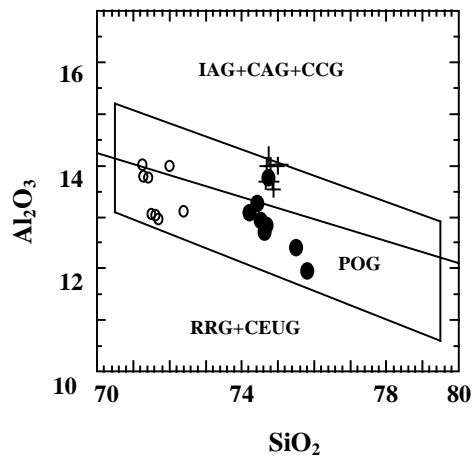


Fig. (4d): SiO₂ – Al₂O₃ variation diagram

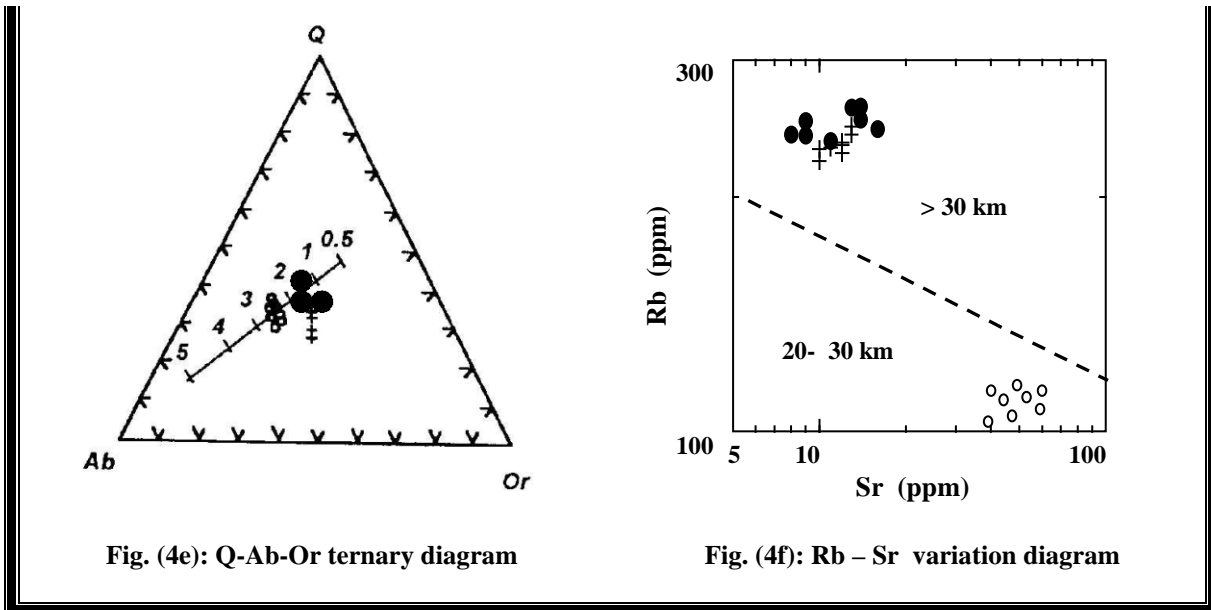


Fig. (4e): Q-Ab-Or ternary diagram

Fig. (4f): Rb – Sr variation diagram

- 3-The chondrite patterns of both monzo- and syenogranite show decisive irregularities (often referred to as tetrads or lanthanide tetrad effect which is shown by two concave – upward segments (t1 : La to Nd and t3: Gd to Ho), (Henderson, 1996).
- 4- These tetrad effect with the non-CHARAC behavior of Zr and Hf and the low Zr/Hf ratio are indication of highly evolved granites (e.g. Bau, 1996 and Irber, 1999).
- 5-The syenogranites are more enriched in CHREEs than monzogranites, while HREEs behave as immobile elements. So, there was nearly no difference in the content of HREEs .
- 6-The monzogranite is characterized by moderately positive Eu anomaly ($\text{Eu}/\text{Eu}^* = 1.1-1.7$, av. 1.3) and lower LRE (La/Ce). The positive Eu anomaly together with high Ca and Sr contents indicate the role of plagioclase accumulation or the enrichment of the source rock in Eu content (Sawyer, 1998).
- 7-The chondrite normalized pattern of syenogranites and alkali feldspar granites is distinguished by strong negative Eu anomaly and higher La/Ce and Hf/Zr . The marked deficiency of Eu in the syenogranites and alkali feldspar granites is an immediate expression of increasing alkalinity. The development of negative Eu anomaly with increasing in K content must be due to the progressive separation of plagioclase at low pressure and crystallization of K-feldspars. The higher (La/Ce and Hf/Zr) increasing in Si and K and incompatible elements content is another evidence that alkali feldspar granites is of more differentiated stage and/or differentiated from syenogranites and monzogranites.
- 8- The depletion of Er and Lu in syenogranites may signal to the fractionation of garnet that manifested petrographically by the presence of garnet in monzogranites only and by the -strong positive correlation between Er and Lu (Michard, 1989).

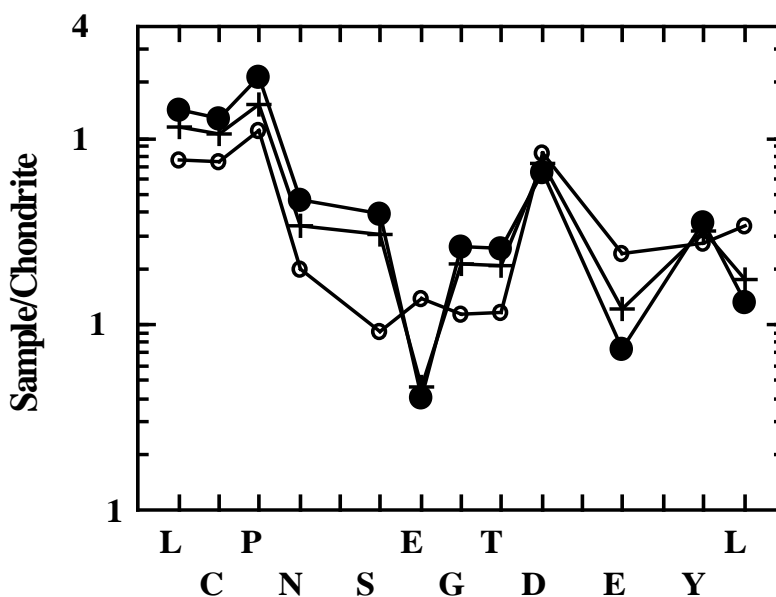


Fig. (5): The average concentrations of the chondrite - normalized rare earth elements patterns of the monzogranites, syenogranites and alkali feldspar granites.

RADIOACTIVITY

The natural radioactivity of rocks mainly stems from their contents of U, Th and K^{40} . Generally, during magmatic differentiation, U and Th increase from basaltic to low Ca-granitic rocks, but the Th/U ratio remains constant. Cambon (1994) stated that, the U content of the different rock types is variable. The types, which contain most of the U, are the post-orogenic granitic rocks. Generally, in granitoid rocks, the uranium content is mainly controlled by the amount and type of accessory minerals (Darnley, 1982 ; Moharem, 2002 and Gouda, 2007).

In the present work, the field background radioactivity level of the younger granites is much higher than the surrounding rocks. The quantitative determination of U and Th (ppm) were chemically determined using U-laser analyzer and spectro-photometer techniques respectively. The obtained results of the U and Th analyses as well as the Th/U ratio are given in table (3). The alkali feldspar granites have higher U and Th contents and lower Th/U ratio than those of syenogranites and monzogranites.

From tables (2 a, b and c), the uranium content in the studied monzogranites ranges from 5.3 to 6.5 ppm averaging 5.8 ppm and the Th content varies from 15.1 to 17.6 ppm with an average 16.4 ppm. The Th/U ratios are ranging from 2.73 to 3 with an average of 2.83. On the other hand, the uranium content in the syenogranites ranges from 8.2 to 9.5 ppm with an average 8.8 ppm and the Th content varies from 15.5 to 17.4 ppm with an average 16.6 ppm. The Th/U ratio is ranging from 1.58 to 1.92 with an average 1.84. While the uranium content in the alkali feldspar granites ranges from 11.4 to 16.7 ppm with an average 14 ppm and the Th content varies from 23.5 to 29.4 ppm with an average 27.5 ppm. The Th/U ratio is ranging from 1.76 to 2.25 with an average 2. Although the average

U contents is higher than normal granites, the studied granites could not be considered as fertile (carrying uranium mineralization) granites according to the significance of the three statistical parameters (X' , S and C.V.) suggested by Yanting et al. (1982) that divided granites into four essential groups according to U dispersion (Table 3).

Accordingly, from the study of the statistical parameters of the studied granitoid rocks (table 4), the monzogranites can be classified as group I, where (X') is low ($\cong 5.8$), C.V. is very low ($\cong 0.8$) and (S) is 0.45. On the other hand, the studied younger syenogranites granites and alkali feldspar granites can be classified as group II, where (X') values are ($\cong 8.8$ and 13.9 respectively), C.V. is low ($\cong 9$) and (S) is 3.06. The uranium content of these rocks is syngenetic and is not favorable for mineralization, due to the missing late remobilization. This assumption is also witnessed by the strong correlation between Th and U and very narrow range in the values of Th/U in the three granitic rock types.

U displays a narrow range of concentration in monzogranites, syenogranites and alkali feldspar granites suggesting magmatic origin of uranium. Generally, alkali feldspar granites show higher values of Zr/Sr, Rb/Sr, Nb, Rb, Zr, Th and U and lower values of Ba/Rb, CaO and MgO relative to those of monzogranites and syenogranites, suggesting that the alkali feldspar granites were originated from highly fractionated U-rich magma.

Fig. (6) shows that the studied granitic samples were separated into three clear groups according to their U and Th contents. The first group (samples 1-8) represents Um Dirra monzogranites and is subdivided into two subgroups; the first one (samples (1, 4, 8, 5, 6) which represents the relatively lower U and Th contents while the second subgroup (samples 2, 3, 7) represents the relatively higher U and Th contents. The second group (samples 9-16) is representing El Esh syenogranites and is subdivided also into two subgroups; the first one (samples 9, 13, 16, 14, 12) which represents the relatively lower U and Th contents while the second subgroup (samples 10, 11, 15) is representing the relatively higher U and Th contents. Finally, the third group (samples 17-24) representing Homr El Girgab alkali feldspar granites and is subdivided into two subgroups; the first subgroup (samples 17, 22, 24, 19) representing the relatively lower U and Th contents while the second subgroup (samples 18, 21, 20, 23) is representing the relatively higher U and Th contents.

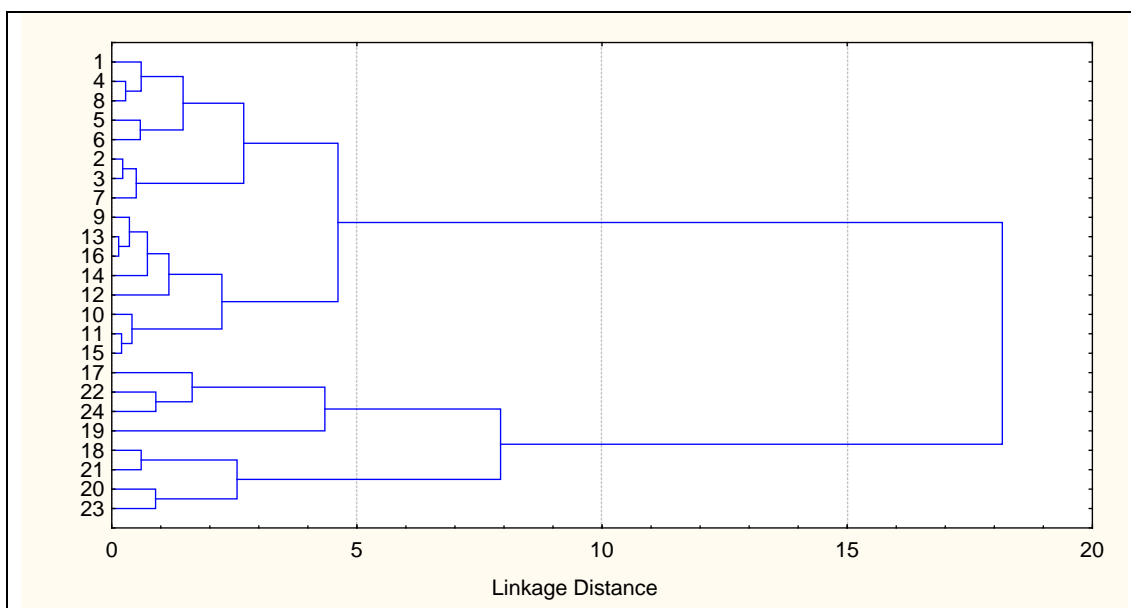


Fig. (6): R-mode cluster analysis for the studied granitic samples according to their U and Th contents.

Radio-element relationships

U, Th, REEs, Zr and Nb behave incompatibly in a granitic melt so that, where U concentration is controlled by magmatic processes, these elements would be expected to increase (Cuney, 1984). The relation between U and Th may indicate the enrichment or depletion of U because Th is chemically stable. Normally, thorium is three times as abundant as uranium in all rock types (Darnley, 1982). When this ratio is disturbed, it indicates either depletion or enrichment of uranium. The granites of the studied area show positive relationship between U-Th on the constructed diagram (Fig. 7a) as well as positive correlation between U, Th, Nb, Rb and Zr (table 2). These relationships indicate that uranium enrichment was mainly controlled by primary magmatic processes. This concept is supported by the strong negative correlation between U and Th/U (table 2).

Figures (7b and 7c) show strong positive relationship between U-Zr and U- P₂O₅ in monzogranites, syenogranites and alkali feldspar granites. This indicates that U enrichment is only related to magmatic processes and supports the concept that U was mainly trapped in the accessory minerals as zircon, sphene and apatite. The strong positive correlation between Th and Nb (Fig. 7d) indicates that the granitic magmas were emplaced at shallow depths (Briqueu et al., 1984).

From the previous discussions and relationships, it can be concluded that magmatic differentiation plays the main role in uranium enrichment. The alkali feldspar granites concentrate much more uranium than the monzogranites and syenogranites due to larger quotient of radioactive accessory minerals (e.g. zircon, fluorite, apatite and sphene) in alkali feldspar granites than those in syenogranites and monzogranites.

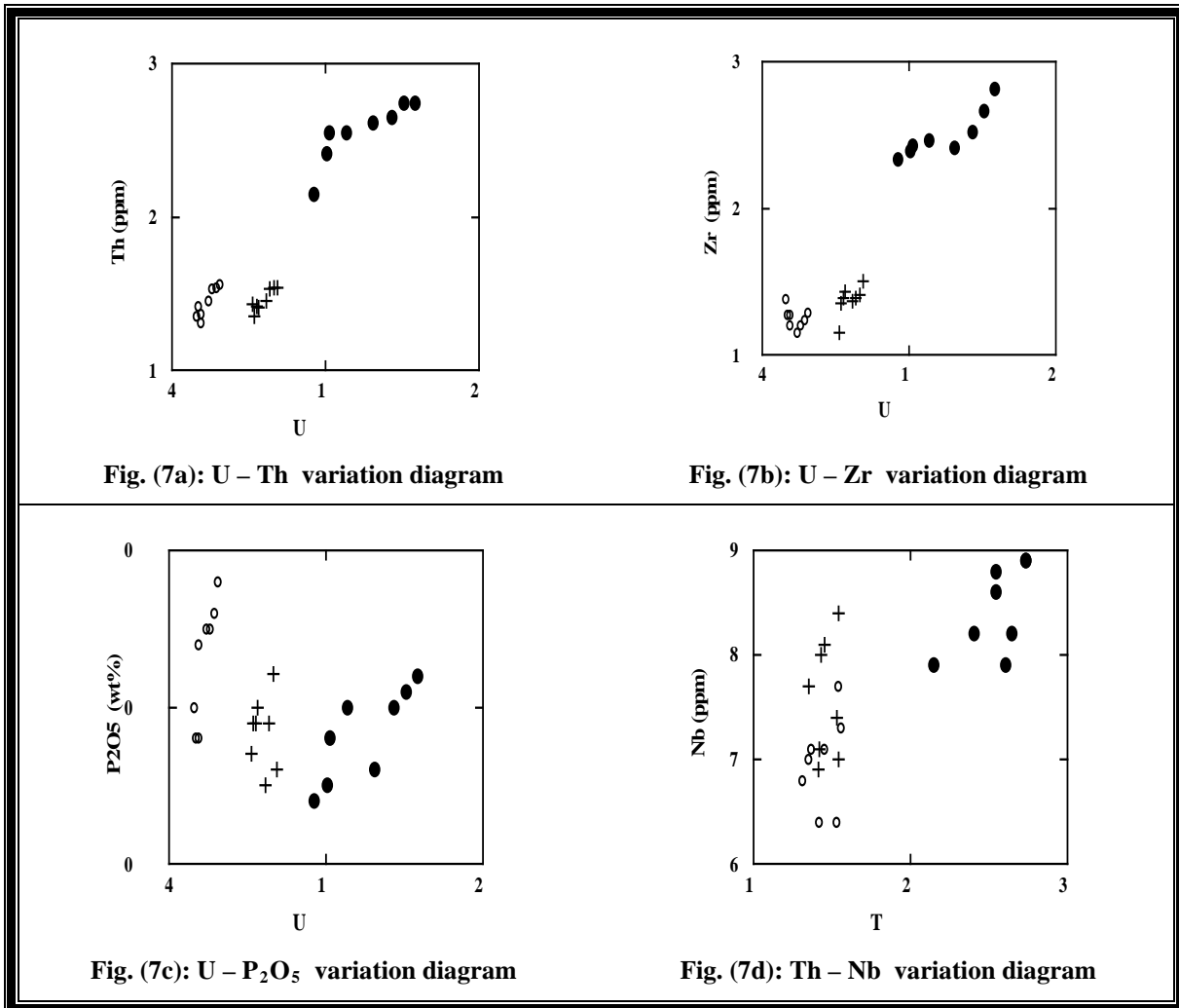
Table (3): Classification of the uraniumiferous characteristics of the granites (Yanting et al. (1982).

Group	X̄	S	C.V.%	Characters
I	4.0-10.4	0.4-1.6	0.1-1.6	Not favorable for uranium mineralization and its difficult to find any anomaly in their.
II	8.5-16.3	0.3-3.6	1-10	In this group, the uranium content is syngenetic, but not favorable for uranium mineralization.
III	8.0-21.4	2.3-3.6	23-31	Not favorable for uranium mineralization, but and its possible to find anomaly in it.
IV	10.5-38.6	1.9-8.6	7-32	In this group, the uranium content is syngenetic and /or epigenetic, and favorable for uranium mineralization.

X̄ = average uranium content, S = standard deviation, and C.V.% = coefficient of variation

Table (4): Statistical parameters (X̄, S and C.V.) for the studied granitoid rocks

Statistical parameters Rock type	X̄	S	C.V.%	Yanting et al. (1982) Group
Monzogranites	5.8	0.45	0.8	Similar to Group I (X̄ = 4-10.5, S = 0.4 –1.6, C.V.= 0.1 – 1.6)
Syenogranites	8.8	0.5	0.24	They are similar to Group II (X̄ = 8.5-16.3, S = 0.3 –3.6, C.V.= 0.1 – 1.6)
Alkali feldspar granites	13.9	2.02	4.1	



CONCLUSION

Esh El-Mallaha area represents a part of the north western extension of the Arabo-Nubian shield. It forms an elongated ridge parallel to the Gulf of Suez, running in NW-SE direction. In Esh El-Mallaha range, the younger granites crop-out in the form of three plutons. These younger granites are mostly represented by Gabal Um Dirra monzogranites, Gabal El-Esh syenogranites and Gabal Homr El-Gerigab alkali feldspar granites.

The monzogranites of G. Um Dirrah are medium- to coarse-grained, equigranular, hypidiomorphic rocks and are composed of orthoclase perthite, quartz, plagioclase, biotite and hornblende as essential minerals and sphene, apatite, zircon, garnet, epidote muscovite and opaques as accessory and secondary minerals. Both syenogranites (G. El-Esh) and alkali feldspar granites (G. Homr El-Gerigab) are medium- to coarse-grained, hypidiomorphic rocks, and are essentially composed of perthites, quartz, plagioclase, muscovite and biotite. The accessory and secondary minerals are zircon, sphene, apatite, epidote, fluorite and iron oxy-hydroxides. Alkali feldspar granites show high perthites (reach up 58%), the increase in perthites is accompanied by increase in quartz and decrease in the plagioclase contents. They show high contents of deep violet fluorite and metamict zircon as well as higher contents of iron oxides than those of syenogranites.

Geochemically, these granites were originated from peraluminous ($A/CNK > 1$) calc-alkaline highly fractionated magma. This magma is also rich in Rb and depleted in Ba indicating low pressure condition. They intruded in a crust of thickness greater than 20 km

at water vapour pressure between 1 and 3 kb and crystallized at temperatures ranging from 800° to 850° C. They originate in post-orogenic environment and could be considered as mesozonal granites. The parallel trends of K/Rb-Rb, Ba/Rb-Rb, K/Rb-Nb/Ta, Zr/Hf-Zr and the REEs chondrite patterns are indication of the common source, although the alkali feldspar granites are relatively more differentiated.

The rare earth elements show weak to moderate relative enrichment of LREE ($\frac{La}{Ce} > \frac{Nd}{Sm}$) and clear +ve Eu anomaly for the monzogranites. Higher enrichment of the LREE ($\frac{La}{Ce} > \frac{Nd}{Sm}$) and strong -ve Eu anomaly is recorded for the syenogranites and alkali feldspar granites. The REEs chondrite normalized patterns and geochemical ratios suggest that syenogranites and alkali feldspar granites are differentiated from monzogranites or at least originated from similar magma and tectonic setting. The remaining zigzag effect of the chondrite-normalized patterns of monzogranites, syenogranites and alkali feldspar granites can be interpreted to possible “tetrad-effect”. The similarity in the “tetrad-effect”, except for Eu, can be interpreted to common source and possibly similar fractionation processes. The development of lanthanide tetrad effect and the non-CHARAC behavior of Zr and Hf indicate that the studied peraluminous monzogranite can be modelled as a crustal contaminated fractionate of a basaltic magma and syenogranites and alkali feldspar granites are a partial melt extracted from the monzogranites.

Although the average U contents (X%) is higher than normal granites and the geochemical markers (e.g. felsic index, Rb/Sr, Th, Nb, Rb and Zr) of the studied granites, especially in alkali feldspar granites, match well with those of the uraniferous granites. The studied granites can not be considered as fertile granites according to the statistical parameters (S and C.V.). The low S and C.V. values means that the uranium content of these rocks is syngenetic and are not favorable for mineralization, because of missing late remobilization. This assumption is also witnessed by the strong correlation between Th and U.

Accordingly, the studied younger granites are considered as uraniferous granites originated from highly fractionated U-rich magma with trapping high concentrations of uranium in accessory minerals. The syenogranites and alkali feldspar granites show higher U and Th contents and lower Th/U ratios than those of monzogranites; due to the higher quotient of the radioactive accessory minerals (e.g. zircon, apatite and sphene) in the syenogranites with addition of fluorite in alkali feldspar granites.

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