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GEOLOGY

PETROGENETIC MODELING OF SOME GRANITIC MASSES IN THE CENTRAL EASTERN DESERT, EGYPT

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Abstract: Three granitic masses, namely Gabal Delihimmi (140 km^2), Gabal Abu Tiyur (30 km^2) and Gabal Um Shaddad (17 km^2) are located in the central Eastern Desert, intruded older metavolcanics and metasediments. They were studied petrographically, geochemically and rare earth elements were applied for petrogenetic modeling.

Petrographically, Delihimmi granites are composed of orthoclase perthites, quartz, plagioclase and biotites whereas Abu Tiyur and Um Shaddad granites are composed of microcline perthites, quartz, plagioclase and minor biotites.

Geochemically, Delihimmi, Um Shaddad and Abu Tiyur are classified as granites. All granites have characteristics of group I younger granites. Delihimmi granite has a normal calc-alkaline strongly peraluminous characters as well as characters of unfractionated M-, I- and S-types. On the other hand, Abu Tiyur and Um Shaddad granites exhibit highly fractionated A-type characters. Spider diagrams reflect enrichment in LILE and HFSE except Zr and Yb depletion for Abu Tiyur and Um Shaddad granites while Delihimmi granite reflects enrichment in LILE and depletion in HFSE except Nb and Ce. The studied Delihimmi, Abu Tiyur and Um Shaddad granites were emplaced in a post orogenic tectonic environment.

Rare earth elements normalized patterns for the studied granites reflect a fractionated enriched LREE and depleted HREE patterns with small to moderate negative Eu anomaly. Using REE petrogenetic modeling Delihimmi granite can be produced from 40% non-modal partial melting for the bulk continental source materials followed by 35% crystal fractionation but the Abu Tiyur (type 1) and Um Shaddad granites can be produced from 30% non-modal partial melting for the upper continental source materials followed by 40% crystal fractionation. On the other hand, Abu Tiyur granite (type 2) can be produced from granitic source materials by 50% partial melting followed by 60% crystal fractionation.

Introduction

The Egyptian basement rocks comprise a wide variety of gneisses, dismembered ophiolites, island arc metavolcanics, metasediments, metagabbros and unmetamorphosed volcanics, and extensively intruded by various granitoid plutons (El Gaby *et al.*, 1988; Hassan and Hashad, 1990). The Egyptian granitoids were classified according to their color into gray, red and pink; to their type locality into Shaitian and Gattarian; to their relative age into older and younger, to their relation to orogeny into syn-, late- and post-orogenic; and to their tectonic setting into subduction-related (G1), suture and crustal thickening (G2) and intraplate anorogenic (G3) (Hussein *et al.*, 1982).

Delihimmi and Abu Tiyur granites were reported as alkali-feldspar granite type by Ragab *et al.* (1993). Rb/Sr whole- rock dating yielded an age of 548±17 Ma for the granite of Abu Tiyur (Abd El Wahed *et al.*, 2002).

Rare earth elements modeling calculations have been used successfully in the study of the petrogenesis and origin of basaltic rocks which may have been derived by partial melting of upper mantle source materials and modified by differentiation or reaction with the crust. On the other hand, granitic rocks may have been derived by partial melting of the mantle, or the subducted oceanic crust or lower continental crust. The melt may be modified by differentiation, mixing with other melts, or reaction with crustal rocks of different composition during its ascent over a wide range of P, T and P_{H2O} conditions

The present study deals mainly with the petrography, geochemistry and petrogenetic modeling using REE of Delihimmi, Um Shaddad and Abu Tiyur granites located in the environs of Gabal El-Sibai, Central Eastern Desert of Egypt.

GEOLOGIC SETTING

The studied granites are located between longitudes 34° 13' and 34° 23' E and latitudes 25° 37' and 25° 47'N. Delihimmi granite occupies an oval-shaped pluton that covers ~140 km^2 (Fig. 1) and exhibits low to moderate relief (528 m.a.s.l.). Delihimmi granite exhibits exfoliation and spheroidal weathering. It encloses a large number of granodioritic xenoliths near the contact. It is highly jointed with close spacing and cut by dyke swarm. The pluton has sharp intrusive contacts against the older country rocks, viz serpentinites, metagabbros, metavolcanics and metasediments.

Abu Tiyur granite is a ring shaped intrusion located in the western part of the study area and covering ~30 km^2. It is of high relief (1099 m.a.s.l.) and composed of medium- to coarse-grained granitic rocks. The contacts against the metavolcanics and metasediments are sharp. The pluton exhibits exfoliation.

Um Shaddad pink to red granite pluton (775 m. a.s.l.) is located in the southern part of the study area covering about 17 km^2 and forming an irregular intrusion. It is intruded into the surrounding metasediments with sharp intrusive contacts.

PETROGRAPHIC CHARACTERISTICS

Delihimmi granites are medium- to coarse- grained rocks composed essentially of quartz (~42%), K-feldspars (~35%), plagioclase (~15%) and biotite (~6%) (Fig.2a). Accessories (~0.8) comprise wedge shaped sphene crystals (Fig.2b), apatite (Fig.2c), xenotime, allanite and zircon. The K-feldspars are represented by orthoclase perthites of patchy and flame types.

Plagioclase (An17) occurs as euhedral crystals of variable sizes with carlsbad and albite twinning (Fig.2a).

Abu Tiyur granite is medium- to coarse- grained and composed mainly of K-feldspars (~63%), quartz (~33%) and plagioclase (~2%) with minor biotite (~1%). Zircon and opaques (0.3%) represent the accessory minerals (0.4%). The K-feldspars are represented by microcline and orthoclase-perthite of the string (Fig.2d) and patchy types (Fig.2e). The alkali amphiboles (riebeckite and arfvedsonite) are only found near the periphery of the pluton due to the action of faulting and intensive alteration (Ragab *et al.*, 1993 and Abd El Wahed *et al.*, 2002).

Um Shaddad granite is medium- to coarse- grained and consists mainly of K-feldspar (~56%), quartz (~37%) and plagioclase (~3%) with minor biotite (~1%). Accessories (~1%) are zircon and opaques (~1.5%). It displays porphyritic texture with quartz and perthite phenocrysts. The K-feldspars are represented by microcline perthites of the patchy (Fig.2f) and string types. Plagioclase crystals (Fig.2g) are present as euhedral crystals along the mutual contacts between the quartz and K-feldspars.

GEOCHEMICAL CHARACTERISTICS

Twenty-five samples (11 from Delihimmi, 6 from Um Shaddad and 8 from Abu Tiyur granites) have been analyzed for their major, trace and RE elements and presented in table (1). The analyses were carried out at the laboratories of the Nuclear Materials Authority, using wet chemical techniques (Shapiro and Brannock, 1962) for major oxides and XRF spectrometer technique for trace elements. The REE were analyzed by the ICP-MS in the ACME Labs.Vancouver, Canada for 24 samples. In the following paragraphs, the geochemical characteristics, magma type and tectonic setting of the studied granites are discussed.

Comparing the average of the studied granites (Table 1) shows that Delihimmi granites exhibit high contents of MgO, CaO and Sr and low contents of SiO2, Nb, Zr, Y and ΣREE compared with Abu Tiyur and Um Shaddad granites. Also, the samples of Abu Tiyur exhibit high Zr and low Sr, compared with other granitic rocks.

Cox *et al.* (1979) proposed a chemical classification of igneous rocks using the relationship between Na_2O+K_2O and SiO_2 as shown in (Fig.3a). The figure shows that the studied granites plot within the granite field. The figure also shows that the studied granites plot in the subalkalic field of Miyashiro (1978).

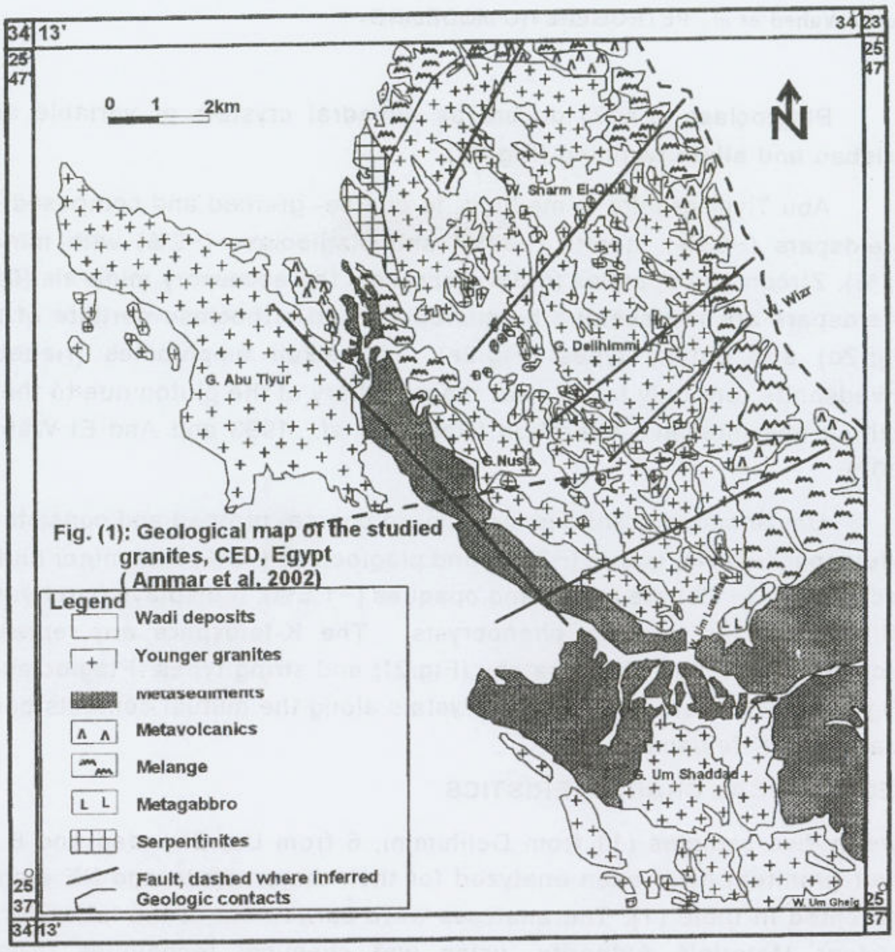

Fig. (1): Geological map of the studied granites, CED, Egypt (Ammar et al. 2002)

The binary relationship between Eu/Eu*-Sr (Fig.3b) exhibit increasing behavior from Abu Tiyur, Um Shaddad to Delihimmi granite indicating that they are magmatically related.

Sylvester (1989) diagram (Fig.3c) indicates the alkalic to highly fractionated nature of the studied Um Shaddad and Abu Tiyur granites but a normal calc-alkaline nature is observed for the granites of Delihimmi.

Whalen *et al.* (1987) discriminated between two groups of granitoids with different tectonic settings by utilizing the relation diagram between (Zr+Nb+Ce+Y) and (K_2O+Na_2O)/CaO (Fig.3d). It is noted that most of the studied Delihimmi granites plot in the (M-, S-, and I-types) field while the Um Shaddad and Abu Tiyur granitic rocks plot mainly in the A-type granite field.

The spider diagram of the studied granitoids normalized to a hypothetical oceanic ridge granite (Pearce *et al.*, 1984), Fig. (3e) indicates enriched LILE and HFSE for Abu Tiyur and Um Shad dad granites except Zr and Yb which are depleted. On the other hand, Delihimmi granites exhibit enriched LILE (K_2O, Rb and Ba) and depleted HFSE except Nb and Ce which show enriched behaviors.

The tectonic setting under which the studied granites were formed can be detected from the relationship between (Nb+Y) and Rb (Pearce *et al.*, 1984) (Fig. 3f) which shows that the Delihimmi granites plot in the VAG field while Um

Shaddad and Abu Tiyur granitic rocks plot in the WPG field, while they lie in the field of post-orogenic tectonic environment of Pearce (1996) suggesting cogenetic relationship.

RARE EARTH ELEMENTS PETROGENETIC MODELING

The origin and evolution of igneous rocks using REE is based on Kd (distribution coefficient) in quantitative models indicating differentiation and/or partial melting. The Kd`s for a given element are dependent on the temperature and composition of the mineral and melt. Gast (1968) and Shaw (1970) suggested the theoretical derivations of quantitative modeling of trace elements for differentiation and partial melting of igneous rocks. Two models are commonly considered for partial melting: batch melting and fractional melting. In either model melting is assumed to occur under equilibrium conditions.

The calculations of the following models for the origin of the studied granites were carried out using the basic computer program (NEWPET 1994); the mineral/melt partition coefficients of the REE were taken from Arth (1976) for dacites and rhyolites quoted in Rollinson (1993) (Table 2).

In the following models calculations, the average REE contents of the Continental Crust (Taylor and McLennan, 1985) were used as the parent materials involved in the generation of the studied granites. The continental crust is composed of 20 km upper granitic crust overlying 10 km dioritic middle crust above a 10 km gabbroic crust (Jackson *et al.*, 1984).

The patterns of the rare earth elements normalized to chondrites using the values of Boynton (1984) are shown in (Figs. 4a, b and c) for the studied Delihimmi, Um Shaddad and Abu Tiyur granites. They reflect a fractionated magma enriched in LREE and depleted in HREE patterns with a small to moderate negative Eu anomaly. Abu Tiyur granites reflect two patterns (two types); the first exhibits more enriched LREE with more or less flat HREE and with small to moderate Eu anomaly, while the other type reflects smaller fractionated LREE than HREE with moderate to large Eu anomaly.

A-Petrogenesis of Delihimmi granites from the bulk Continental Crust source materials

The suggested modal mineralogy of the source is: 60% plagioclase, 15% hornblende, 8% biotite , 5% quartz, 5% potash feldspar, 3% clinopyroxene and 2% ilmenite, and it has the REE abundance similar to that of the average of the bulk Continental Crust (Taylor and McLennan, 1985). At 40% degree of non-modal partial melting with major contribution of plagioclase and hornblende to the liquid composition followed by 35% crystal fractionation involving separation of biotite, k-feldspar and quartz will give a best fit to the observed REE pattern of this type of granites as shown in (Fig. 4d), (Table 3). The calculated remaining source compositions after 40% partial melting is: 60% plagioclase, 11.3% biotite; 9.6% hornblende, 6.3% for potash-feldspar and quartz, 5% clinopyroxene, 1.3% ilmenite and 0.5% apatite)

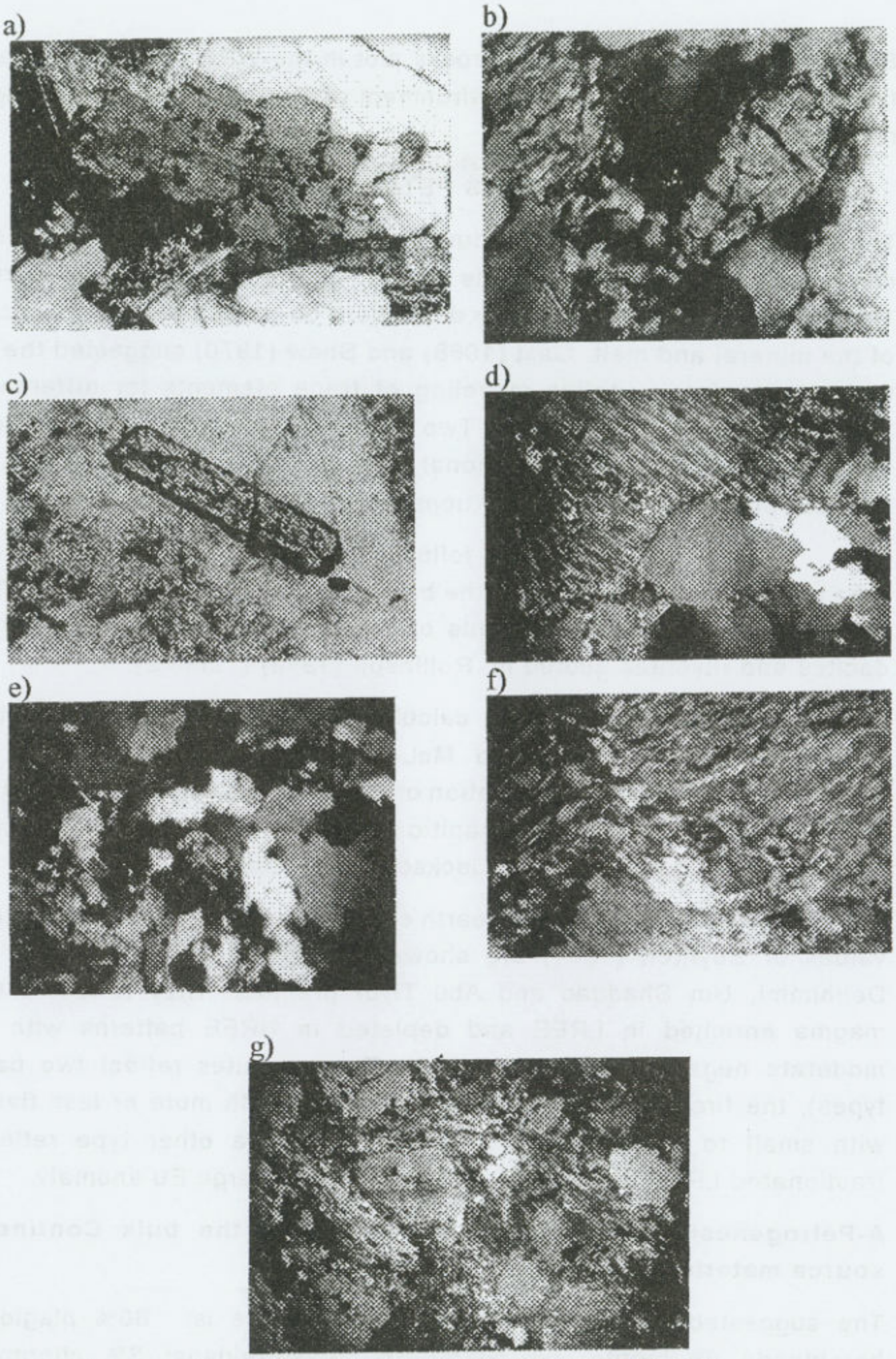

Fig.(2): a-Biotite flakes associated with Qz and plagioclase, Delihimmi granite,C.N.,X=60; b-Euhedral sphene crystal associated with Qz and micas, Delihimmi granite,C.N.,X=120 ; c-Well developed apatite crystal, Delihimmi granite,C.N.,X=120 ;d-String perthites associated with Qz, Abu Tiyur granites,C.N.,X=60; e-Zircon crystal enclosed in Qz, Abu Tiyur granites,C.N.,X=120; f-Patchy perthites associated with Qz and zircon, Um Shaddad granite,C.N.,X=60; g-Plagioclase crystal in between Qz and potash feldspar ,Um Shaddad granite, C.N.,X=60.

TABLE (1): MAJOR OXIDES (WT%), TRACE AND RARE EARTH ELEMENTS (PPM) OF THE STUDIED GRANITES

Sample no.	1	2	3	4	5	6	7	8	9	10	11	Ave.Del N=11
SiO_2	74.51	74.20	73.85	73.79	72.11	74.46	74.38	74.17	74.01	73.83	73.55	74.34
TiO_2	0.21	0.27	0.27	0.26	0.26	0.21	0.23	0.21	0.23	0.23	0.24	0.21
Al_2O_3	12.98	12.74	13.17	13.05	14.01	12.98	12.90	12.93	13.04	12.64	12.96	12.97
$Fe_2O_3^t$	1.92	2.45	2.17	2.56	2.35	2.10	2.34	2.12	2.39	2.33	2.50	2.12
MnO	0.05	0.04	0.04	0.05	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.04
MgO	0.42	0.43	0.44	0.36	0.53	0.29	0.28	0.25	0.29	0.28	0.30	0.31
CaO	1.36	1.20	1.63	1.21	1.74	0.98	1.58	1.26	1.32	1.23	1.34	1.21
Na_2O	3.71	3.44	3.70	3.73	4.10	3.51	3.89	3.43	3.61	3.68	3.60	3.71
K_2O	3.95	3.79	3.94	3.53	3.54	4.46	3.41	4.64	4.31	4.52	4.44	4.04
P_2O_5	0.05	0.08	0.07	0.05	0.06	0.07	0.03	0.03	0.06	0.05	0.05	0.05
L.O.I.	0.80	0.80	0.70	1.00	1.00	0.70	0.80	0.70	0.50	1.20	0.90	0.84
Total	100.00	99.51	100.04	99.71	99.83	99.87	99.95	99.85	99.85	100.10	99.99	
Trace Elements (ppm)												
Nb	13.20	10.60	15.30	15.50	14.50	11.30	11.90	11.10	11.80	11.10	12.80	13.10
Rb	146.70	81.40	137.90	67.00	150.50	93.00	73.90	89.50	88.10	89.20	90.90	116.30
Sr	92.90	121.60	115.70	127.50	95.50	95.10	113.10	105.40	102.70	102.90	113.60	93.90
Zr	135.00	177.60	135.50	222.10	126.70	208.30	223.50	190.90	222.40	208.50	201.00	175.50
Ba	324.00	526.00	424.00	953.00	299.00	696.00	465.00	583.00	560.00	578.00	540.00	474.15
Y	25.00	22.20	43.60	34.70	36.90	28.80	31.60	30.30	30.00	30.10	33.30	32.12
REE (ppm)												
La	23.50	31.10	24.60	32.40	17.40	61.90	42.80	47.70	51.60	45.10	73.70	41.07
Ce	45.00	86.40	55.30	67.40	39.70	127.20	90.90	101.30	106.50	96.30	155.00	88.30
Pr	5.84	7.35	6.20	7.51	4.42	13.21	9.87	10.72	11.56	10.56	16.92	9.50
Nd	22.80	27.80	24.80	28.50	17.90	47.60	37.70	39.30	42.30	39.40	60.50	35.30
Sm	5.20	5.10	6.00	6.40	4.70	8.00	7.00	7.20	7.60	7.60	10.20	6.82
Eu	0.66	1.03	0.69	1.57	0.62	1.33	1.39	1.35	1.28	1.23	1.44	1.15
Gd	5.19	4.25	5.98	5.70	4.95	5.50	5.74	5.49	5.73	5.61	6.81	5.50
Tb	0.87	0.66	1.06	0.94	0.82	0.85	0.91	0.87	0.88	0.87	1.09	0.90
Dy	6.00	4.24	7.29	6.07	5.75	5.38	5.92	5.69	5.80	5.82	6.74	5.90
Ho	1.24	0.79	0.41	1.21	1.18	0.96	1.09	1.05	1.06	1.04	1.18	1.02
Er	4.06	2.57	4.48	3.73	3.85	3.09	3.34	3.24	3.24	3.25	3.69	3.50
Tm	0.59	0.34	0.65	0.51	0.55	0.39	0.43	0.41	0.41	0.42	0.45	0.47
Yb	4.54	2.57	4.88	3.79	4.18	2.97	3.22	3.09	3.12	3.10	3.28	3.50
Lu	0.73	0.40	0.75	0.60	0.69	0.44	0.48	0.47	0.48	0.49	0.49	0.60

Note: Total iron as $Fe_2O_3=Fe_2O_3^t$

samples from 1-11=Delihimmi granites ; 12-17=Urn Shaddad;
18-20 Abu Tiyur type (1) and 21-25 Abu Tiyur (type 2) granitic rocks.

Table (1, cont.): Major oxides(wt%), trace and rare earth elements (ppm) of the studied granites

sample no.	12	13	14	15	16	17	Ave. shad N=6	18	19	20	Av1 N=3	21	22	23	24	25	Av2 N=5
SiO_2	77.47	77.44	77.31	77.14	77.12	75.77	77.04	78.69	78.31	76.69	77.90	77.90	77.58	77.08	76.63	75.97	77.03
TiO_2	0.17	0.17	0.14	0.14	0.10	0.15	0.15	0.13	0.17	0.19	0.16	0.06	0.07	0.07	0.08	0.08	0.07
Al_2O_3	11.24	11.26	11.52	11.76	11.31	11.68	11.46	10.66	10.49	11.39	10.85	11.46	11.78	11.58	11.76	12.05	11.73
$Fe_2O_3^t$	2.68	1.90	1.85	1.67	1.99	2.13	2.04	1.78	2.54	2.45	2.26	1.25	1.26	1.42	1.66	1.43	1.40
MnO	0.01	0.03	0.02	0.02	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.01	0.01
MgO	0.04	0.02	0.05	0.04	0.02	0.04	0.04	0.03	0.09	0.04	0.05	0.03	0.03	0.01	0.02	0.05	0.03
CaO	0.12	0.27	0.36	0.39	0.24	0.76	0.36	0.15	0.19	0.11	0.15	0.26	0.24	0.26	0.28	0.33	0.27
Na_2O	3.12	3.79	3.28	2.99	3.79	3.35	3.40	3.32	3.27	3.71	3.43	4.14	4.20	4.17	4.06	4.27	4.17
K_2O	4.72	4.66	4.59	4.85	4.11	4.54	4.58	4.35	3.88	4.28	4.17	4.20	4.33	4.02	4.12	4.41	4.22
P_2O_5	0.01	0.01	0.04	0.03	0.06	0.04	0.03	0.02	0.01	0.05	0.03	0.04	0.02	0.01	0.16	0.01	0.05
L.O.I.	0.30	0.30	0.40	0.60	0.60	1.00	0.50	0.50	0.40	0.40	0.43	0.50	0.10	0.50	0.60	1.00	0.54
Total	99.96	99.90	99.66	99.74	99.38	99.59		99.76	99.48	99.50	99.58	99.86	99.63	99.13	99.42	99.63	99.53
	Trace l	elements(ppm)															
Nb	44.80	55.50	30.20	33.60	76.20	43.30	47.30	33.40	49.30	46.90	43.20	40.30	70.50	56.90	53.00	54.20	54.98
Rb	80.90	67.20	90.10	81.40	85.10	77.80	80.40	53.40	40.80	51.30	48.50	96.70	97.40	100.80	104.00	92.30	98.24
Sr	46.80	9.80	52.20	55.20	6.90	48.50	36.60	21.90	18.40	22.70	21.00	6.00	3.90	7.10	4.30	8.90	6.04
Zr	356.40	471.90	235.10	327.40	347.70	295.80	339.10	397.20	611.40	430.30	479.63	294.20	267.30	321.70	262.20	245.50	278.18
Ba	837.00	508.00	820.00	943.00	142.00	778.00	671.30	946.00	960.00	1376.00	1094.00	26.00	30.00	21.00	32.00	30.00	27.80
Y	95.50	486.70	132.90	50.80	126.50	71.60	160.70	56.70	72.90	98.50	76.03	86.90	105.20	108.90	127.50	107.10	107.12
	REE (ppm)																
La	100.90		133.00	88.80	45.40	74.70	88.56	71.20	122.40	186.70	126.77	26.00	28.70	30.70	30.40	47.20	32.60
Ce	177.20		156.50	197.30	121.70	172.20	165.00	162.60	208.50	229.10	200.07	64.20	68.70	70.70	84.20	115.70	80.70
Pr	26.44		32.59	22.06	16.22	19.55	23.37	19.15	32.48	42.80	31.48	8.18	10.40	10.18	10.19	15.13	10.82
Nd	102.90		144.10	84.60	73.40	77.20	96.24	78.70	130.00	184.60	131.10	32.10	44.70	43.50	43.90	64.30	45.70
Sm	18.20		35.40	14.70	23.00	15.20	21.30	16.90	24.40	38.50	26.60	10.30	15.40	13.90	14.80	19.90	14.86
Eu	2.80		6.36	2.29	2.01	2.17	3.13	2.59	3.19	7.68	4.49	0.59	0.91	0.77	0.88	1.16	0.86
Gd	14.31		37.01	9.58	21.70	11.27	18.77	12.50	16.05	33.11	20.55	10.90	16.19	14.35	16.79	19.18	15.48
Tb	2.57		5.78	1.60	3.93	2.04	3.18	2.05	2.56	4.46	3.02	2.20	3.08	2.66	3.33	3.42	2.94
Dy	16.29		32.13	10.23	25.46	13.50	19.52	12.82	15.81	25.55	18.06	15.69	20.01	18.22	23.41	21.33	19.73
Ho	3.17		5.45	1.84	4.92	2.54	3.58	2.27	2.65	4.03	2.98	3.15	3.92	3.58	4.53	3.83	3.80
Er	10.81		14.32	5.83	14.29	7.85	10.62	6.84	6.13	10.47	7.81	9.95	3.58	11.43	13.34	11.02	9.86
Tm	1.43		1.56	0.73	1.75	1.02	1.30	0.83	0.97	1.12	0.97	1.30	1.47	1.49	1.65	1.34	1.45
Yb	8.90		10.37	5.44	11.38	7.54	8.73	5.94	7.24	7.91	7.03	9.12	9.85	10.67	10.66	9.11	9.88
Lu	1.27		1.44	0.81	1.60	1.15	1.25	0.92	1.10	1.15	1.06	1.32	1.38	1.58	1.52	1.31	1.42

Note: Total iron as $Fe_2O_3=Fe_2O_3^t$

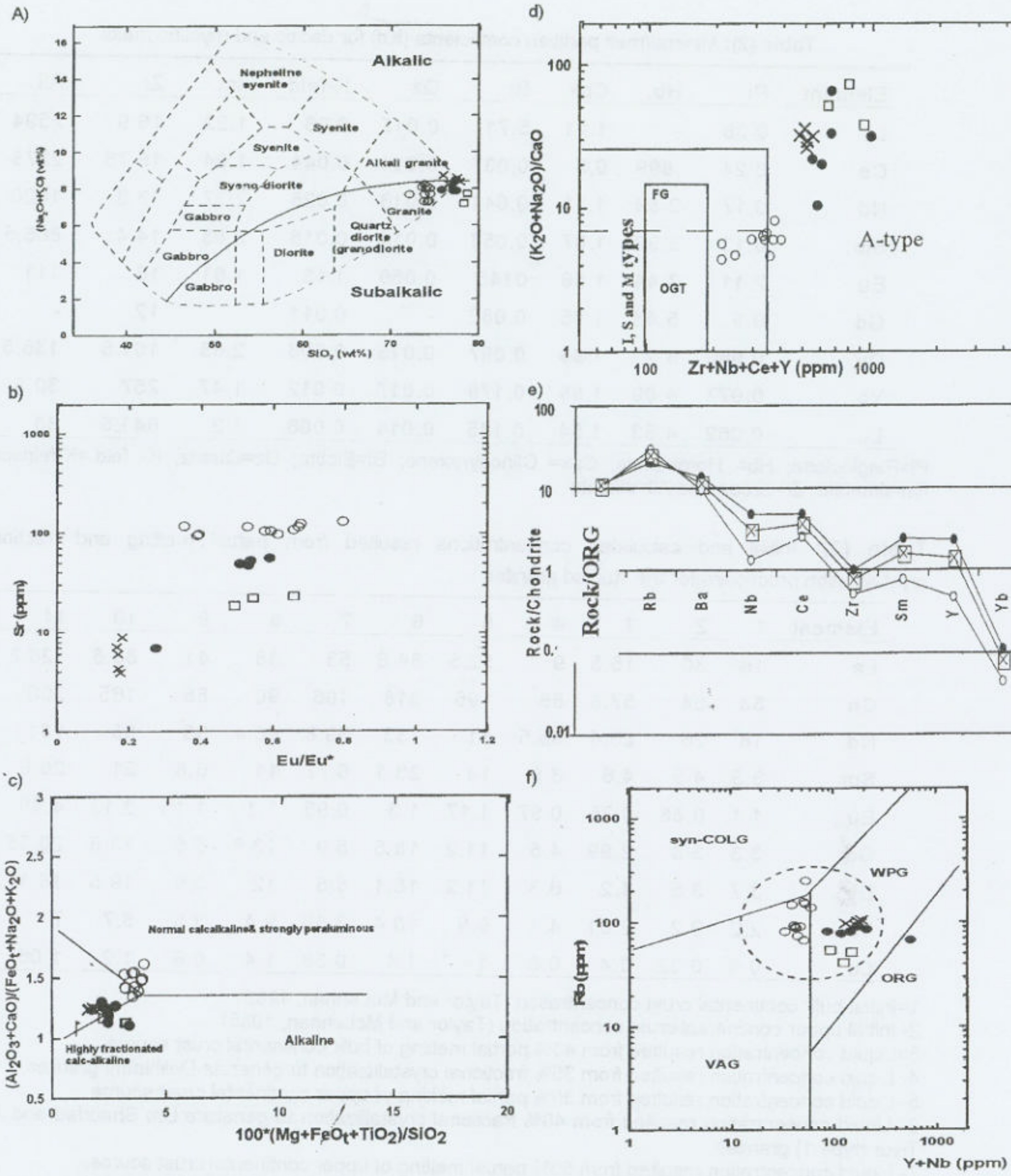

Fig.(3):

a- (Na_2O+K_2O)- SiO_2 chemical classification diagram of the studied granites (Cox et al., 1979), the curved solid line subdivides the alkalic from subalkalic rocks (Miyashiro,1978).

b-Sr-Eu/Eu* diagram.

c- Sylvester (1989) diagram of the studied granites.

d-Discrimination diagram between OGT, FG and A-type granites (Whalen et al., 1987).

e- Spider diagram normalized to ORG of the studied granites (Pearce et al., 1984).

f-Tectonic discrimination diagram of the studied granites (Pearce et al., 1984). The field delineated by dashed line includes the post collision granites (POG) based on data from Pearce (1996).

○Delihimmi granites.

●Um Shaddad granites.

□ Abu Tiyur (type 1) granites.

X Abu Tiyur (type 2) granites.

Table (2): Mineral/melt partition coefficients (Kd) for dacitic and rhyolitic melts

Element	Pl	Hb.	Cpx.	Bi	Qz	K-feld.	Ilm.	Zr	All
La	0.38	-	1.11	5.71	0.015	0.08	1.22	16.9	2594
Ce	0.24	.899	0.5	0.037	0.014	0.044	1.64	16.75	2278
Nd	0.17	2.89	1.11	0.044	0.016	0.025	2.27	13.3	1620
Sm	0.13	3.99	1.67	0.058	0.014	0.018	2.83	14.4	866.5
Eu	2.11	3.44	1.56	0145	0.056	1.13	1.01	16	111
Gd	0.9	5.48	1.85	0.082	-	0.011	-	12	-
Dy	0.086	6.2	1.93	0.097	0.015	0.006	2.63	101.5	136.5
Yb	0.077	4.89	1.58	0.179	0.017	0.012	1.47	257	30.8
Lu	0.062	4.53	1.54	0.185	0.014	0.006	1.2	641.5	33

Pl=Plagioclase; Hb= Hornblende; Cpx= Clinopyroxene; Bi=Biotite; Qz=Quartz, K- feld.=K-feldspar, Ilm=ilmenite; Zr=zircon and All=allanite

Table (3): Initial and calculated concentrations resulted from partial melting and fractional crystallization processes for the studied granites

Element	1	2	3	4	5	6	7	8	9	10	11	12
La	16	30	16.5	9	52.5	84.8	53	38	41	88.8	126.8	32.6
Ce	33	64	57.8	88	195	318	106	90	88	165	200	80.7
Nd	16	26	23.4	35.5	81	133	39.8	46.4	35	96	131	45.7
Sm	3.5	4.5	4.6	6.9	14	23.1	6.77	11	6.8	21	26.6	14.9
Eu	1.1	0.88	0.75	0.97	1.17	1.3	0.95	1.1	1.15	3.13	4.49	0.86
Gd	3.3	3.8	2.99	4.5	11.2	18.5	5.9	13.8	5.5	18.8	20.55	15.48
Dy	3.7	3.5	4.2	6.3	11.2	18.1	5.5	12	5.9	19.5	18.1	19.7
Yb	2.2	2.2	2.81	4.1	6.9	10.4	3.88	9.4	3.5	8.7	7	9.88
Lu	0.3	0.32	0.4	0.6	1	1.4	0.58	1.4	0.6	1.2	1.06	1.42

1=Initial bulk continental crust concentration (Taylor and McLennan, 1985).
2- Initial upper continental crust concentration (Taylor and McLennan, 1985).
3=Liquid concentration resulted from 40% partial melting of bulk continental crust source.
4- Liquid concentration resulted from 35% fractional crystallization to generate Delihimmi granites.
5- Liquid concentration resulted from 30% partial melting of upper continental crust source.
6- Liquid concentration resulted from 40% fractional crystallization to generate Um Shaddad and Abu Tiyur (type 1) granites.
7- Liquid concentration resulted from 50% partial melting of upper continental crust source.
8-Liquid concentration resulted from 60% fractional crystallization to generate Abu Tiyur (type 2) granite.
9-Average of studied Delihimmi granites.
10- Average of studied Um Shaddad granites.
11- Average of studied Abu Tiyur (type 1) granites.
12- Average of studied Abu Tiyur (type 2) granites.

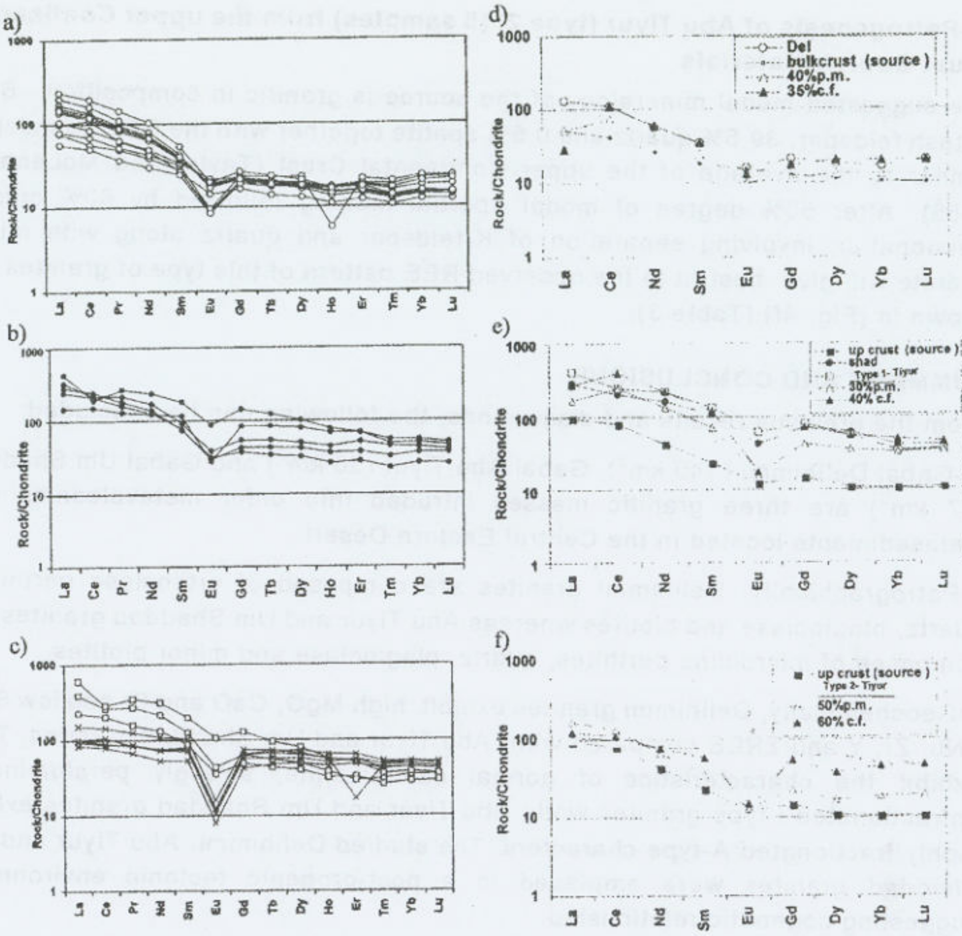

Fig.(4):

a- Chondrite normalized REE pattern for Delihimmi granites.
b- Chondrite normalized REE pattern for Um Shaddad granites.
c- Chondrite normalized REE pattern for Abu Tiyur granites.
d- REE petrogenetic modeling of Delihimmi granites from 40% non-modal partial melting of the bulk continental source materials followed by 35% crystal fractionation.
e- REE petrogenetic modeling of Um Shaddad and Abu Tiyur (type 1) granites from 30% non-modal partial melting of upper continental source materials followed by 40% crystal fractionation.
f- REE petrogenetic modeling of Abu Tiyur (type 2) granites by 50% partial melting of upper continental source materials followed by 60% crystal fractionation.
Symbols as in figure 3

B-Petrogenesis of Um Shaddad (5 samples) and ABU TIYUR (TYPE 1) (3 samples) granites from the upper Continental Crust Source Materials

The suggested modal mineralogy of the source is: 45% potash feldspar, 40% quartz, 10% biotite and 5% plagioclase together with the REE abundance similar to the average of the upper Continental Crust (Taylor and McLennan, 1985). At 30% degree of non-modal partial melting with major contribution of K-feldspar and quartz to the liquid composition followed by 40% crystal fractionation involving separation of k-feldspar and quartz along with minor zircon will give a best fit to the observed REE pattern of this type of granites as shown in (Fig. 4e)

(Table 3). The calculated remaining source composition after 30% partial melting is: 45% K-feldspar, 44.3% quartz, 5% plagioclase and 5.7% biotite.

C -Petrogenesis of Abu Tiyur (type 2) (5 samples) from the upper Continental Crust Source Materials

The suggested modal mineralogy of the source is granitic in composition: 60% potash feldspar, 39.5% quartz and 0.5% apatite together with the REE abundance similar to the average of the upper Continental Crust (Taylor and McLennan, 1985). After 50% degree of modal partial melting followed by 60% crystal fractionation involving separation of K-feldspar and quartz along with minor allanite will give best fit to the observed REE pattern of this type of granites, as shown in (Fig. 4f) (Table 3).

SUMMARY AND CONCLUSIONS

From the previous results and discussions, the following can be concluded:

1-Gabal Delihimmi (140 km^2), Gabal Abu Tiyur (30 km^2) and Gabal Um Shaddad (17 km^2) are three granitic masses intruded into older metavolcanics and metasediments located in the Central Eastern Desert.

2-Petrographically, Delihimmi granites are composed of orthoclase perthites, quartz, plagioclase and biotites whereas Abu Tiyur and Um Shaddad granites are composed of microcline perthites, quartz, plagioclase and minor biotites.

3-Geochemically, Delihimmi granites exhibit high MgO, CaO and Sr and low SiO2 , Nb, Zr, Y and ΣREE compared with Abu Tiyur and Um Shaddad granites. They exhibit the characteristics of normal calc-alkaline, strongly peraluminous; unfractionated I-type granites while Abu Tiyur and Um Shaddad granites exhibit highly fractionated A-type characters. The studied Delihimmi, Abu Tiyur and Um Shaddad granites were emplaced in a post-orogenic tectonic environment suggesting cogenetic relationship.

4-The normalized REE patterns of Abu Tjyur and Um Shaddad granites indicate a more fractionated pattern compared with Delihimmi granites.

5-Rare earth elements petrogenetic modeling indicates that Delihimmi granites can be produced by 40% non-modal partial melting of bulk continental source materials followed by 35% crystal fractionation. Abu Tiyur granite (type 1) and Um Shaddad granite can be produced by 30% non-modal partial melting of upper continental source materials followed by 40% crystal fractionation. On the other hand, the granite of Abu Tiyur (type 2) can be produced from granite source materials by 50% partial melting followed by 60% crystal fractionation.

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نمزجه الاصل الصخرى لبعض الكتل الجرانيتيه وسط الصحراء الشرقيه- مصر

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تشمل المنطقه على 3 متداخلات من الصخور الجرانيتية (جبل دلهيمى/ أبو الطيور , أم شداد) فى وسط الصخور البركانية المتحولة و الرسوبية المتجولة.

أوضحت الدراسة البتروجرافية أن جبل الدليهيمى صنف كجرانيت بيوتيتى بينما جرانيتتات أبو الطيور و أم شداد كجرانيت الفاتح.

تنتمى الجرانيتات إلى الجرانيتات الحديثة (المجموعة I) فجبل الدليهمى له خصائص كلس قلوى ,فوق الومينى بينما أبو الطيور أم شدادة له صفات ال A- type. يعكس جبل الدليهمى إثراء فى العناصر LILE وإنخفاض فى العناصر HESE فيما عدا عنصر النوبيبوم والسريوم بينما يعكس جرانيتات أبو الطيور وأم شداد إثراء فى العناصر LILE و HESE فيما عدا الزوركونيوم والانتريوم. نشأت الجرانيتات للدهليمى فى بيئه قوس بركانى بينما جرانيتات أبو الطيور وأم شداد فى بيئه داخل اللوح.

تم دراسه النموذج الموديل للعنلصر الارضيه النادره. وأوضحت دراسه الموديل أن جرانيت الدلهيمى يتكون من 40% انصهار جزئى للمصدر القارى متتبعا ب 35 % تبلور بللورى بينما جرانيتات أبو الطيور وأم شداد من 30% انصهار جزئى للمصدر القارى متتبعا بواسطه 40 % تبلور بلورى, فى حين الجرانيت القلوى لابو الطيور من مصدر جرانيتى بواسطه 50% انصهر جزئى متتبعا ب 60% تبلور بلورى.