International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-8,August 2016
ISSN: 2395-3470
www.ijseas.com

Geochemistry and Petrotectonic studies of the Extensional I- and A-types Neoproterozoic granitic rocks of continental arc assemblage on Gabal Gassuss area, Central Eastern Desert, Egypt

Abdellah Sadek Tolba
Geology Department, Faculty of Science, Al Azhar University, Assiut branch
Email: abdellah.tolba@yahoo.com

Abstract:

The Neoproterozoic basement rocks of Gabal Gassuss is a part of the Central Eastern Desert of Egypt, at the northern part of the Arabian–Nubian Shield (ANS), the granitic rock in the study area is comprised of two different granite suites, the oldest one is granodiorite and related to synextensional orogenic suit, while the second type is represented by monzogranite and syenogranite, which both are related to late to post extensional orogenic suit. Granodiorite is calc-alkaline, magnesian, metaluminous in nature and belonging to I-type granite, with high Sr contents, and depleted in Rb, Nb, Y and REE. Both monzogranite and syenogranite are mainly high-K calc-alkaline, alkaline to peralkaline affinities and belonging to A-type granites. The A-type granites are mainly enriched in Ga, Y, HFSE and REE elements, and depleted in the LILE elements Ba, Sr and Rb. The emplacement of the synextensional orogenic suite took place similarity of the granitic rocks of I-type of Whalen et al. 1987, while the late to post extensional orogenic suites are mainly similar to the granitic rocks of A-type of Whelan et al. 1987.

1- Introduction:

The crystalline rocks of the Egyptian Eastern Desert that represent a part of Arabian-Nubian Shield (ANS) of Neoproterozoic Era. The study area is a part of the Central Eastern Desert, it has been previously described and investigated by many authors (e.g; El Ramly and Akaad, 1960; El Shazly, 1964; El-Mezayen, 1978; Akaad and Noweir, 1980; Dardir et al., 1982 ; Sims & James 1984, El Gaby et al., 1988 & 1990; Kroner & Stern 2004; Stern et al. 2006 and Tolba & Kamel 2014). Recently some authors deduced a new assumptions of Neoproterozoic based on age dating for almost all the basement rocks of the Eastern Desert (e.g: Collins, 2006; Collins, and Pisarevsky, 2005; Johnson, 2003; Johnson et al., 2011). Whereas the Late Cryogenian–Ediacaran events (650–542 Ma) cased creating of ANS continental crust due to of interacting depositional, magmatic, and structural events.

The study area covers about 155 Km^2, which is a part of Central Eastern Desert, it is far from Qena-Safaga road about 14 Km at south and far from Safaga City by about 25 Km. It lies between Latitudes 26° 29' and 26° 36' N and Longitudes 33° 47' and 33° 57' E (Fig.1). The investigated area is characterized by its low to moderate topographic relief, G. Gassuss is the main pluton of the study area, which it is reached about 610 m, on the other hand the mapped area is mainly traversed by two main Wadis; Wadi Safaga has crossed E-N direction, whereas Wadi Gassuss NE-SW direction and turned west of the mapped area to W direction (Fig.1).

2- Geology and petrography:

The study rock units are related to island arc and continental arc assemblages, the Island arc assemblage rocks (metavolcanics and schist) are represented the Early orogeny, and they are intruded directly by continental arc assemblage rocks (granodiorite, dokhan volcanic, gabbro, monzogranite, hammamat sediments and syenogranite), that are represented the late to post orogenic magmatism (Tolba & Kamel 2014). The granitic rocks of the investigated study covers about 45% (~70 Km^2) of the measured area represented by granodiorite, monzogranite and syenogranite, which these rocks are related to East African orogen (Post amalgamation) of continental arc assemblage. The granodiorite is present the synextensional orogeny, while the monzogranite is late extensional orogeny, and syenogranite is post extensional orogeny of the continental arc.

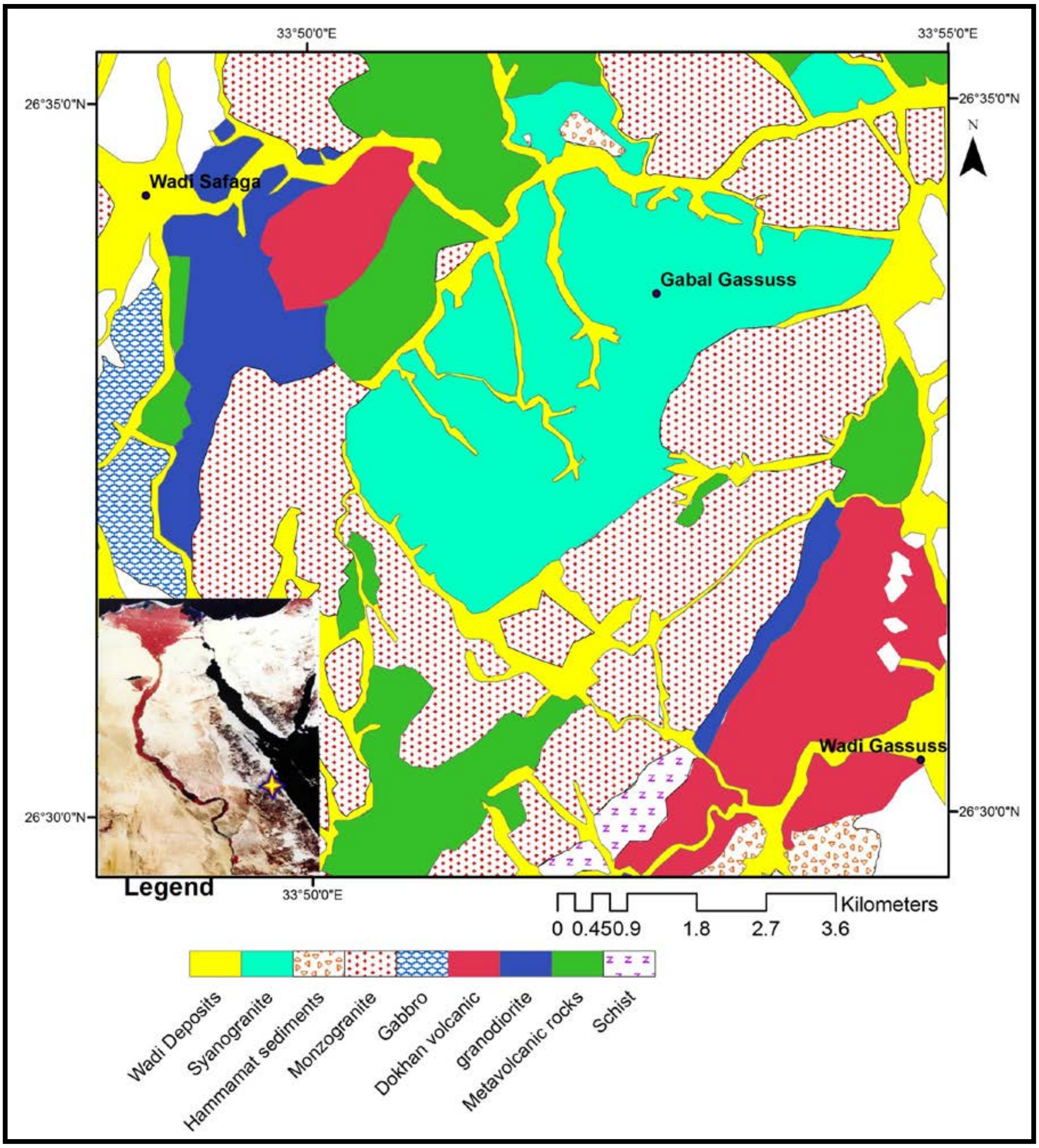
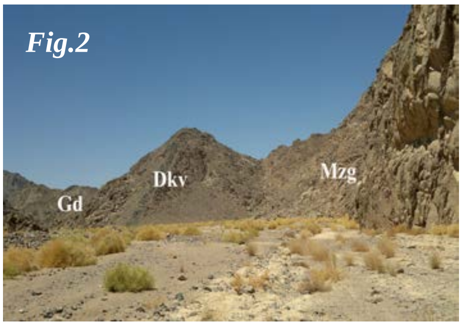
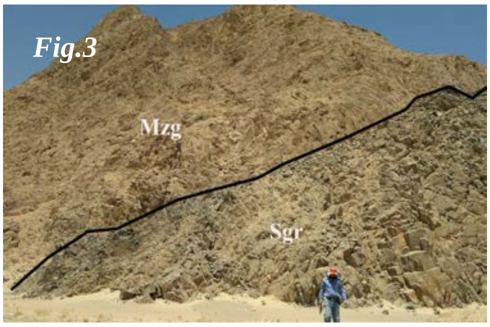


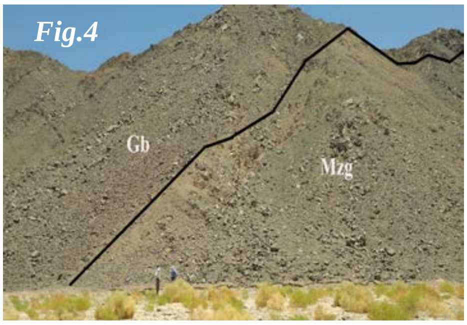
Fig. 1: Geologic map of Gabal Gassuss modified after Tolba & Kamel (2014).

The granodiorite is the oldest granitic rocks in the study area and characterized by medium to coarse grained, generally grayish-white color and covers about 5.5 % of the total mapped area. They are low to moderate relief and restricted in south part of the area and characterizing by highly weathered, jointed, exfoliated and xenoliths, which are mostly abundant, the granodiorite is extruded by dokhan volcanics and intruded directly by monzogranite in many locations of the study area (Fig.2). Monzogranite is medium to moderately fine grains, and it is ranging in color from gray to pink. It is present in middle part of mapped area, covers about 25.16 % of the rock constituents, and formed as moderate to low relief, moderately weathered and highly jointed, this rock exhibits a sharp intrusive contact against the older surrounding rocks (granodiorite, Dokhan volcanics and gabbro), as well as it is intruded by syenogranite and some dikes swarms (Figs. 2, 3&4). Syenogranite is the youngest rock unit in the study area, which is present by medium to fine grained of red to pink color. It covers about 14.16 % of the total mapped area, and characterized by moderately relief of massive rock with highly jointed and rarely weathered rock. It exhibits a sharp contact, and intruded in all old rock units of the investigated area.

Petrographically, the granitic rocks of the investigated study are classified into granodiorite, monzogranite and syenogranite (Fig.5), they are mainly course to medium grain and exhibiting predominant texture is the perthitic texture in all, in these granitic rocks show quite different in the mineral constituents (as shown in appendix 1) of decreasing of quartz content (22.6%) in monzogranite, followed by granodiorite (23.2%) and syenogranite (33.1%), while the plagioclase ranging in composition from oligoclase to andesine (An_{20} to An_{30}) in granodiorite, oligoclase to albite (An_{12} to An_{25}) in monzogranite and albite in composition (An_{10} to An_{15}) for syenogranite with an average 34.4%, 23.3% and 16.6% respectively, on the other hand the granodiorite represent subsolvus granite, whereas, monzogranite is related to transolvus granite, therefore the syenogranite is of frequency texture between hypersolvus and transolvus granite. As well as the alkali feldspar descending present from syenogranite to granodiorite passing by monzogranite (46.5%, 13.5% and 30.9% respectively). The biotite and muscovite are the important minerals present as accessories, the biotite present as large average content in granodiorite (12.9%) and smallest in syenogranite (1.2%), while the largest average content of muscovite in syenogranite (1.4%).







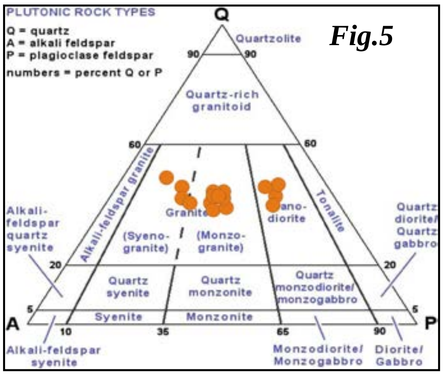


Fig. 2: Photograph showing dokhan volcanic (Dkv) extruded in granodiorite (Gd) and all intruded by monzogranite (Mzg).
Fig. 3: Photograph showing monzogranite (Mzg) intruded by syenogranite (Sgr).
Fig. 4: Photograph showing fresh Gabbro (Gb) intruded by monzogranite (Mzg).
Fig. 5: Plots of the studied granitic rock samples on Streckeisn classification modeling diagram (1976).

3- Geochemistry

The major, trace, REE and calculation of CIPW norms of sixteen representative samples from synextensional orogeny (granodiorite 4 samples) and late to post extensional orogeny (monzogranite about 8 samples and 4 samples for syenogranite) are present (Tables 1-4), respectively. The different geochemical ratios with addition some parameters are given (Table 5), on the other hand comparison of an average major, trace element concentrations and some different geochemical ratios of the investigated granitoide rock with some average compositions of the various genetic I & A type's granite of Whalen et al. (1987) and continental crust of Rudnick and Fountain (1995) shown in table 6.

3.1- Major elements ratios:

According to the major elements of the study granitic rocks, the granodiorite is varying from all oxides than the monzogranite and the syenogranite (Table 1). SiO_2 (%) is ranging from 65.4-69.6 for granodiorite, while 71.5-76.2 for monzogranite and 74.5-77.6 for syenogranite, Na_2O is ranging from 4.3-5.4 for granodiorite, 4.9-5.9 for monzogranite, while syenogranite is ranging from 5.1-5.6, as well as K_2O is ranging from 2.5-2.6 for granodiorite, 1.5-2.7 for monzogranite, while syenogranite is ranging from 2.7-3.9, on the other hand the percentage of total iron Fe_2O_3* from 1.9-3.1 for granodiorite, while is ranging from 0.7-2 for monzogranite and 0.5-1.1 for syenogranite, as well as CaO is ranging from 4.8-5.6 and MgO from 1.7-2.2 for granodiorite, while CaO is ranging from 3.1-4.4 for monzogranite, from 1.7-3 for syenogranite, and MgO is ranging from 0.7-2 for monzogranite and 0.6-1.1 for syenogranite. The silica and total alkali values (%) of synextensional granodiorite less than the same values (silica and total alkali) of late to post extensional orogeny of monzogranite and syenogranite, on the other hand the mafic oxides like Fe_2O_3, CaO and MgO ratios greeter in granodiorite than monzogranite and syenogranite.

Table: (1) The complete analyses of major oxides of the granites

Sample No.	SiO_2	TiO2	Al_2O_3	Fe_2O_3*	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	To
Granodiorite											
1	69.6	0.1	12.4	1.9	1.7	4.8	5.4	2.6	0.6	1	**100**
2	67.5	0.4	13.2	2.7	1.9	5.3	4.6	2.5	0.5	1.4	**100**
3	68.6	0.1	12.7	3.1	2.2	5.6	4.3	2.6	0.5	0.4	**100**
4	65.4	0.4	13.3	3.1	1.9	5.6	4.3	2.5	0.6	3	**100**
Av	**67.8**	**0.3**	**12.9**	**2.7**	**1.9**	**5.3**	**4.7**	**2.6**	**0.6**	**1.5**	**100.1**
Monzogranite											
5	71.5	0.4	12.2	2	1.6	4	5	1.5	0.6	1.2	**100**
6	72.1	0.4	12.6	1.5	1.5	4.2	5	1.5	0.5	0.8	**100**
7	76.2	0.1	11.2	0.7	0.7	3.3	5.8	1.8	0.1	0.1	**100**
8	72.1	0.5	11.6	2.1	1.5	3.1	5.8	2	0.4	1	**100**
9	71.9	0.1	12.9	1.6	1.2	3.5	5.9	2	0.2	0.6	**100**
10	72.1	0.1	11.1	2	2	3.7	5.8	2.7	0.1	0.4	**100**
11	71.5	0.2	11.5	1.3	1.7	3.9	5.5	2.7	0.6	1	**100**
12	71.5	0.4	12.5	1.7	1.1	4.4	4.9	2.5	0.4	0.6	**100**
Av	**72.4**	**0.3**	**12.0**	**1.6**	**1.4**	**3.8**	**5.5**	**2.1**	**0.4**	**0.7**	**100.0**
Syenogranite											
13	74.5	0.1	10.8	0.6	0.6	3	5.2	3.9	0.3	1.1	**100**
14	77.6	0.1	9.8	0.6	0.6	2.5	5.4	2.7	0.1	0.8	**100**
15	77.1	0.1	9.4	1.1	1.1	2.4	5.6	2.7	0.1	0.5	**100**
16	77.3	0.1	9.2	0.5	0.6	1.7	5.1	3.7	0.2	1.6	**100**
Av	**76.6**	**0.1**	**9.8**	**0.7**	**0.7**	**2.4**	**5.3**	**3.3**	**0.2**	**1.0**	**100.1**

Fe_2O_3* = mean that total Iron

Table: (2) The complete analyses of trace elements of the investigated granites

Sample No.	Cr	Ni	Cu	Zn	Zr	Rb	Y	Ba	Pb	Sr	Ga	V	Nb
						Granodiorite							
1	15	9	77	30	100	55	10	370	2	340	14	101	2
2	22	9	30	49	93	49	7	460	2	777	15	106	2
3	17	21	39	49	100	37	6	371	2	878	14	116	2
4	15	10	30	31	107	153	13	475	6	344	18	39	45
Av	**17.3**	**12.3**	**44**	**39.8**	**100**	**73.5**	**9**	**419**	**3**	**584.8**	**15.3**	**90.5**	**12.8**
						Monzogranite							
5	27	8	10	37	162	154	30	263	5	164	16	8	8
6	35	9	9	100	829	46	47	194	2	25	20	4	47
7	34	7	11	8	89	167	27	51	3	29	13	2	17
8	30	10	10	103	839	53	48	194	2	24	21	4	46
9	30	10	10	104	820	53	48	190	2	24	19	2	48
10	33	13	9	57	156	163	56	137	2	44	18	3	29
11	31	9	8	101	839	50	43	194	2	25	18	3	46
12	24	8	10	38	162	120	27	264	7	191	15	9	9
Av	**30.5**	**9.3**	**9.6**	**68.5**	**487.0**	**100.8**	**40.8**	**185.9**	**3.1**	**65.8**	**17.5**	**4.4**	**31.3**
						Syenogranite							
13	20	2	5	50	160	690	20	262	56	13	47	1	70
14	18	1	12	24	205	301	48	526	52	42	22	2	77
15	9	2	10	28	214	303	31	590	50	44	19	2	70
16	6	1	12	35	250	287	30	560	60	50	20	2	70
Av	**13.3**	**1.5**	**9.8**	**34.3**	**207.3**	**395.3**	**32.3**	**484.5**	**54.5**	**37.3**	**27.0**	**1.8**	**71.8**

Table: (3) The complete analyses of Rare Earth elements of the investigated granites

Sample No.	La	Ce	Nd	Sm	Eu	Gd	Tb	Er	Yb	Lu	∑REE	Eu/Sm	La/Sm	Gd/Yb
						Granodiorite								
1	21	51	33	2	0.6	6	1.2	1	0.2	0.4	116.4	0.3	10.5	30.0
2	21	52	33	2	0.5	6	1	0.5	0.3	0.5	116.8	0.3	10.5	20.0
3	20	52	32	3	0.8	7	1	0.5	0.4	0.4	117.1	0.3	6.7	17.5
4	19	51	32	2	0.9	5	1.2	0.9	0.2	0.4	112.6	0.5	9.5	25.0
Av	**20.3**	**51.5**	**32.5**	**2.3**	**0.7**	**6**	**1.1**	**0.7**	**0.3**	**0.4**	**115.7**	**0.4**	**9.3**	**23.1**
						Monzogranite								
5	27	80	15	6	1	8	1.5	1	6	1	146.5	0.2	4.5	1.3
6	28	70	16	6	1	8	1.5	1	6	1	138.5	0.2	4.7	1.3
7	30	70	16	7	2	9	1.5	1	5	1	142.5	0.3	4.3	1.8
8	31	77	22	5	0.9	7	1	0.2	3	0.8	147.9	0.2	6.2	2.3
9	31	70	22	5	0.8	7	1	0.2	3	0.8	140.8	0.2	6.2	2.3
10	40	66	18	4	0.8	8	2	0.2	2	1	142	0.2	10.0	4.0
11	32	55	20	6	0.7	8	1.9	0.8	2	0.9	127.3	0.1	5.3	4.0
12	32	89	28	6	0.7	6	1.8	1	3	0.9	168.4	0.1	5.3	2.0
Av	**31.4**	**72.1**	**19.6**	**5.6**	**1**	**7.6**	**1.5**	**0.7**	**3.8**	**0.9**	**144.2**	**0.2**	**5.8**	**2.4**
						Syenogranite								
13	40	96	38	6	1	8	2	3	4	1	199	0.2	6.7	2.0
14	56	122	43	9	2	9	2	3	3	1	250	0.2	6.2	3.0
15	50	124	50	6	0.8	8	2	3	3	1	247.8	0.2	8.3	2.7
16	53	128	50	8	1	9	2	1	3	1	256	0.1	6.6	3.0
Av	**49.8**	**117.5**	**45.3**	**7.3**	**1.2**	**8.5**	**2**	**2.5**	**3.3**	**1**	**238.2**	**0.2**	**7**	**2.7**

Table: (4) The complete analyses of CIPW Norm of the investigated granites

Sample No.	Q	Or	Ab	An	Di wo	Di en	he(F)	ap	ac	ns	Hy en	T
						Granodiorite						
1	22.6	15.5	46.1	1.9	5	4.3	1.9	1.3	-	-	-	98.6
2	22.4	15	39.4	8.1	5.6	4.8	2.7	1.1	-	-	-	99.1
3	23.9	15.4	36.5	7.7	6.4	5.5	3.1	1.1	-	-	-	99.5
4	21.7	15.2	37.4	9.9	5.7	4.9	3.2	1.4	-	-	-	99.3
Av	**22.7**	**15.3**	**39.9**	**6.9**	**5.7**	**4.9**	**2.7**	**1.2**	**-**	**-**	**-**	**99.1**
						Monzogranite						
5	29.8	9	42.8	6.5	4.2	3.6	2	1.3	-	-	0.4	99.6
6	29.8	8.9	42.6	7.5	4.4	3.8	1.5	1.1	-	-	-	99.6
7	30	15.7	40.5	5.5	2	1.8	0.2	-	2	2	-	99.7
8	28.9	10.7	41	8	3.5	3	0.9	-	1.7	1.9	-	99.6
9	25.4	11.9	50.2	2.8	3.5	3	1.6	0.4	0.4	0.4	-	99.7
10	27	12	49	3	4	3.5	0.9	-	-	-	0.5	99.9
11	29.8	16.2	40.8	3.2	3	2.3	1.5	0.9	0.8	0.9	0.5	99.9
12	28.3	14.9	42.7	4.7	3.2	2.8	1.7	0.9	0.2	0.2	0.2	99.8
Av	**28.6**	**12.4**	**43.7**	**5.2**	**3.5**	**3**	**1.3**	**0.6**	**0.6**	**0.7**	**0.2**	**99.7**
						Syenogranite						
13	32.5	23.9	36.5	3.5	0.2	0.2	1.8	0.7	0.2	0.2	-	99.7
14	33	25.2	36.3	4.2	0.2	0.3	0.2	0.6	-	-	-	100
15	32.2	23.8	36.9	4.2	0.2	0.3	1	0.7	0.3	0.3	-	99.8
16	31	22.2	37.9	4.8	0.3	0.3	1	0.8	0.7	0.8	-	99.8

Av	**32.2**	**23.8**	**36.9**	**4.2**	**0.2**	**0.3**	**1**	**0.7**	**0.3**	**0.3**	**-**	**99.8**

Table: (5) The complete different geochemical ratios and some calculated parameters

	Nk	NKC	A/NK	A/CNK	K/N	F/M	F/(F+M)	NK/C	AC	C/N	Rb/Sr	Y/Nb	Zr/Rb	Ba/Nb	Zr+Nb+Ce+Y
							Granodiorite								
1	8	12.8	1.6	1.0	0.5	1.1	0.5	1.7	17.2	0.9	0.16	5.0	1.8	185	163
2	7.1	12.4	1.9	1.1	0.5	1.4	0.6	1.3	18.5	1.2	0.06	3.5	1.9	230	154
3	6.9	12.5	1.8	1.0	0.6	1.4	0.6	1.2	18.3	1.3	0.04	3.0	2.7	185	160
4	6.8	12.4	2.0	1.1	0.6	1.6	0.6	1.2	18.9	1.3	0.44	0.3	0.7	10.6	216
Av	**7.3**	**12.6**	**1.8**	**1.0**	**0.6**	**1.4**	**0.6**	**1.4**	**18.2**	**1.1**	**0.2**	**3**	**1.8**	**152.7**	**173.3**
							Monzogranite								
5	6.5	10.5	1.9	1.2	0.3	1.3	0.6	1.6	16.2	0.8	0.9	3.8	1.1	32.9	280
6	6.5	10.7	1.9	1.2	0.3	1.0	0.5	1.5	16.8	0.8	1.8	1.0	18.0	4.1	993
7	7.6	10.9	1.5	1.0	0.3	1.0	0.5	2.3	14.5	0.6	5.8	1.6	0.5	3.0	203
8	7.8	10.9	1.5	1.1	0.3	1.4	0.6	2.5	14.7	0.5	2.2	1.0	15.8	4.2	1010
9	7.9	11.4	1.6	1.1	0.3	1.3	0.6	2.3	16.4	0.6	2.2	1.0	15.5	4.0	986
10	8.5	12.2	1.3	0.9	0.5	1.0	0.5	2.3	14.8	0.6	3.7	1.9	1.0	4.7	307
11	8.2	12.1	1.4	1.0	0.5	0.8	0.4	2.1	15.4	0.7	2.0	0.9	16.8	4.2	983
12	7.4	11.8	1.7	1.1	0.5	1.5	0.6	1.7	16.9	0.9	0.6	3.0	1.4	29.3	287
Av	**7.6**	**11.4**	**1.6**	**1.1**	**0.4**	**1.1**	**0.5**	**2.0**	**15.8**	**0.7**	**2.4**	**1.8**	**8.7**	**10.8**	**631.1**
							Syenogranite								
13	9.1	12.1	1.2	0.9	0.8	1.0	0.5	3.0	13.8	0.6	53.1	0.3	0.2	3.7	346
14	8.1	10.6	1.2	0.9	0.5	1.0	0.5	3.2	12.3	0.5	7.2	0.6	0.7	6.8	452
15	8.3	10.7	1.1	0.9	0.5	1.0	0.5	3.5	11.8	0.4	6.9	0.4	0.7	8.4	439
16	8.8	10.5	1.0	0.9	0.7	0.8	0.5	5.2	10.9	0.3	5.7	0.4	0.9	8.0	478
Av	**8.6**	**11.0**	**1.1**	**0.9**	**0.6**	**1.0**	**0.5**	**3.6**	**12.2**	**0.5**	**18.2**	**0.4**	**0.6**	**6.7**	**428.8**

Table (6): The comparison of an average major, trace element concentrations and some different geochemical ratios of the study granitic rocks with some average compositions of the various genetic I & A type's granite of Whalen et al. (1987) and continental crust of Rudnick and Fountain (1995)

	Study area			Whalen et al. (1987)			Rudnick and Fountain (1995)
	synextensional	Late-post extensional					
	Granodiorite	Monzogranite	Syenogranite	I-type	Felsic I-type	A-type	Continental Crust
No. of Sample	**4**	**8**	**4**	**991**	**421**	**148**	**-**
SiO_2	67.8	72.4	76.6	69.17	73.39	73.81	59.1
TiO_2	0.3	0.3	0.1	0.43	0.26	0.26	0.7
Al_2O_3	12.9	12.0	9.8	14.33	13.43	12.4	15.8
Fe_2O_3*	2.7	1.6	0.7	3.33	1.92	2.82	6.6
MgO	1.9	1.4	0.7	1.42	0.55	0.2	4.4
CaO	5.3	3.8	2.4	3.2	1.71	0.75	6.4
Na_2O	4.7	5.5	5.3	3.13	3.33	4.07	3.2
K_2O	2.6	2.1	3.3	3.4	4.13	4.65	1.9
P_2O_5	0.6	0.4	0.2	0.11	0.07	0.04	0.2
N+K	7.3	7.6	8.6	6.53	7.46	8.72	5.1
F/M	1.4	1.1	1	2.35	3.49	14.1	1.5
Ba	419	185.9	484.5	538	510	352	390
Rb	73.5	100.8	395.3	151	194	169	58
Sr	584.8	65.8	37.3	247	143	48	325
Pb	3	3.1	54.5	19	23	24	12.6
Zr	100	487	207.3	151	144	528	123
Nb	12.8	31.3	71.8	11	12	37	12
Y	9	40.8	32.3	28	34	75	20
Ce	51.5	72.1	117.5	64	68	137	42
Sc	-	-	-	13	8	4	22
V	90.5	4.4	1.8	60	22	6	131
Ni	12.3	9.3	1.5	7	2	<1	51
Cu	44	9.6	9.8	9	4	2	24
Zn	39.8	68.5	34.3	49	35	120	73
Ga	15.3	17.5	27	16	16	24.6	16
Rb/Sr	0.2	2.4	18.2	0.61	136	3.52	0.18
Rb/Ba	0.2	0.5	0.8	0.28	0.38	0.48	0.15
Zr/Nb	7.8	15.6	2.9	13.73	12	14.27	10.25

Y/Nb	3	1.8	0.4	16.92	16.92	16.92	1.67
Zr/Rb	1.8	8.7	0.6	1	0.3	3.1	2.1
Ba/Nb	152.7	10.8	6.7	48.9	42.5	9.5	32.5

3.2- Trace elements ratios:

The trace elements values are varying from granodiorite to syenogranite passing by monzogranite in most trace elements as shown in table (2). Generally the synextensional orogeny (granodiorite) are increasing in Ba, Sr and Cu values (ppm) than the late to post extensional orogeny values (monzogranite and syenogranite) (~ 370-475, ~ 340-878 and ~ 30-77 respectively), while decreasing in values (ppm) of Rb, Zr, Y, Nb and Ga (~ 55-153, ~ 93-107, ~ 7-13, ~ 2-45 and ~ 14-18 respectively) than the same trace elements ratios of the late to post extensional orogeny (monzogranite and syenogranite). Occasionally, the monzogranite increasing in the values (ppm) of all Zr, Y, Sr, Cr and Ni (~88-839, ~ 27-56, ~ 24-191, ~ 24-35 and ~8-13 respectively) than the values of the same traces of the syenogranite (~160-250, ~ 20-48, ~ 13-50, ~ 6-20 and ~1-2 respectively), while the values (ppm) of all Rb, Ba, Ga and Nb are increasing in syenogranite (~ 287-690, ~ 262-590, ~ 19-47 and ~ 70-77 respectively) than the same elements of monzogranite (~ 46-167, ~ 51-264, ~ 13-21 and ~ 8-48 respectively).

According to some relationship parameters of some trace elements (Table 5), showing that the study synextensional orogenic granite exhibits large content ratio of Ba/Nb (10.5-230 ppm) comparable than the late to post extensional orogenic granites (~ 3-32.9 ppm), on the other hand the synextensional orogenic granite exhibits less content ratio of Rb/Sr (0.06-0.44 ppm) comparable than the late to post extensional orogenic granites (~ 0.6-53.1 ppm). Generally both of Y/Nb and Z/Rb ratios are recorded moderately values in synextensional granite (~0.3-3.5 and ~0.7-2.7ppm respectively), which these are moderate to high ratios value in late to post orogenic granites (~ 0.3-3.8 and ~ 0.2-18ppm respectively).

According to some comparison of an average major, trace element concentrations and some different geochemical ratios of the study granitic rocks (synextensional granite and late to post extensional granites) with some average compositions of the various genetic I & A type's granite of Whalen et al. (1987) and continental crust of Rudnick and Fountain (1995) as given in Table (6), showing that the investigated granodiorite (synextensional orogeny) mainly as the same investigation of the I-type granite examined of Whalen et al. (1987), on the other hand the study monzogranite and syenogranite (late to post extensional orogeny) mainly as the same investigation of A-type granite examined of Whalen et al. (1987).

3.3-Magma type:

The geochemical classification using total alkali (Na_2O+K_2O) vs silica (SiO_2) TAS diagram of plutonic rocks according to Middlemost, (1994) as shown in fig. (6). The all samples of granodiorite (synextensional orogenic) plotted in granodiorite field, while the study monzogranite and syenogranite samples plotted in the field of granite. According to K_2O and SiO_2 diagram of Peccerillo and Taylor, 1976 (Fig. 7), the study synextensional granite (granodiorite) inclosing in the field of calc alkaline series, on the other hand the late to post extensional orogenic granites are subdivided into two groups, where the lower in SiO_2 and K_2O granites (monzogranite) plots in the calc-alkaline series field and the other one is higher in SiO_2 and K_2O (syenogranite) plots mainly between calc-alkaline to high-K calc-alkaline series fields.. In terms of alumina saturation index diagram of Maniar and Piccoli (1989), the synextensional orogenic granite is dominantly metaluminous in nature, while the study late to post extensional orogenic granites are mainly varying from metaluminous (some monzogranite ~ higher content of CaO comprising with total alkalis, these are commonly instead contain normative diopside Table 4: index of Shand, 1947) to peralkaline in nature (some other monzogranite and all samples of syenogranite) (Fig. 8).

International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-8,August 2016
ISSN: 2395-3470
www.ijseas.com

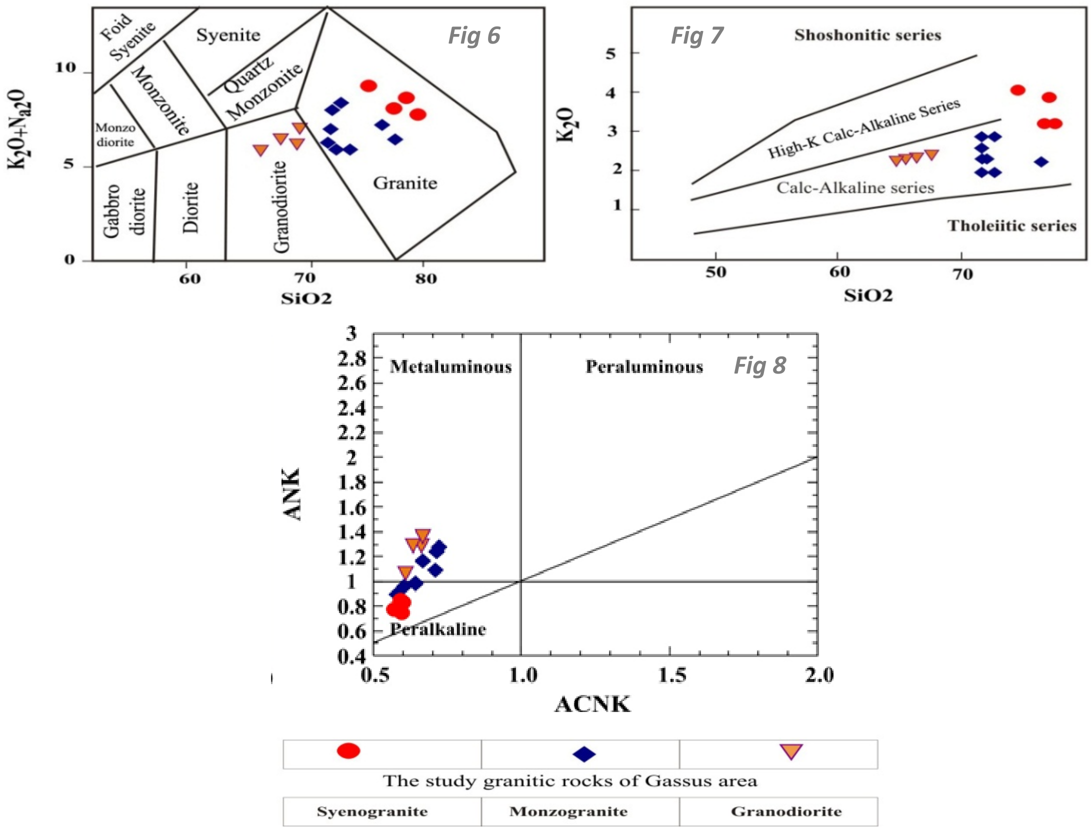


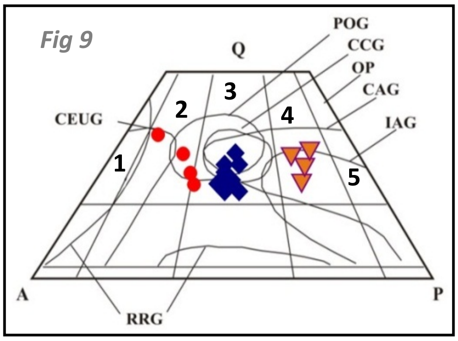
Fig. 6: Plots of the study granitic rocks on the total alkalis vs. silica (TAS) diagram (Middlemost, 1994).
Fig. 7: The K2O –SiO_2 diagram (after Peccerillo and Taylor, 1976).
Fig. 8: The A/CNK vs. A/NK plot of (Maniar and Piccoli, 1989)

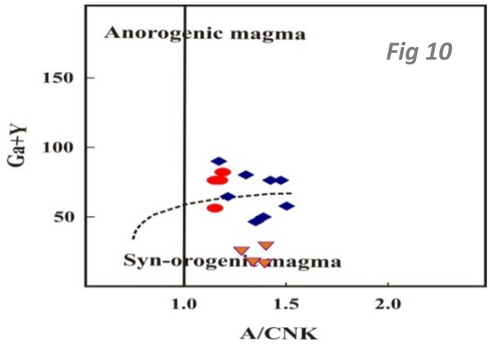
4- Petrotectonic

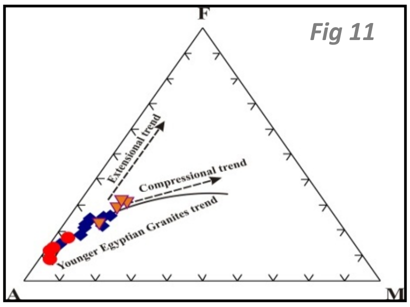
4.1- Granitic Suite type:

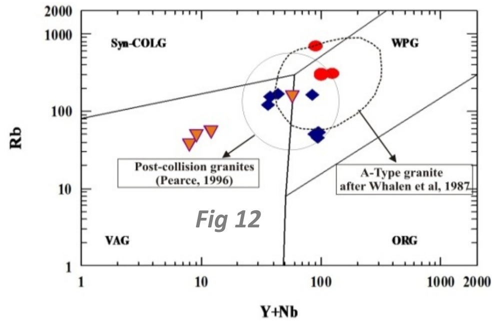
According to the normative composition diagram of Maniar and Piccoli (1989) the granodiorite is mainly plotted in the overlapped fields of calc alkaline granite (CAG) and island arc granite (IAG), on the other hand the majority of syenogranite is plotted in the field of post orogenic granite, while the monzogranite is inclosing mainly overlapped fields of post orogenic and continental collision granites (Fig.9). Generally, the investigated syenogranite and monzogranite are clearly strongly enriched in Ga+Y relative to granodiorite, so that the majority of monzogranite and syenogranite samples plotted in the field of anorogenic magma, whereas the granodiorite samples are plotted in the field of syn-orogenic magma (Fig. 10).

In the AFM diagram of Petro et al. (1979) all of the investigated granitic rocks are coinciding with the trend of Egyptian younger granites as well as tends to extensional trend (Fig. 11). On the other hand, the binary diagram of Pearce et al. (1984) showing that the granodiorite is plotted in the field of volcani arc granite, while the monzogranite is plotted in the post collision granite (line after Pearce 1996), whereas the syenogranite is plotted in the A-type (after Whalen et al., 1987) of within the plate (Fig. 12).









1= Alkali feldspar granite, 2= Syenogranite, 3= Monzogranite, 4= Granodiorite & 5= Tonalite
IAG= island arc granite - **CAG**= continental arc granite - **OP**= oceanic plagiogranite - **CCG**= continental collision granitoids - **POS**= post orogenic granite - **CEUG**= continental epi-orogenic uplift granitoids - **RRG**= rift related granitoids
WPG= Within the Plate granite – **VAG**= Volcanic Arc granite – **ORG =** Oceanic ridge granite

Fig. 9: Modal Q-A-P ternary diagram of Maniar and Piccoli (1989).
Fig.10: plot the variation diagram of Ga+Y vs.A/CNK (Al2O3/(CaO+Na_2O+K_2O)(mol.%) of Damm et al. (1990).
Fig. 11: AFM ternary diagram of Petro et al. (1979).
Fig. 12: Yb + Nb vs. Rb (Pearce et al., 1984)

Generally, Chappell and White, 1974 assume that I-type granite have relatively high sodium, Na_2O greater than 3.2% in felsic varieties, decreasing to more than 2.2% in mafic types, as well as have been determined to have a Mol $Al_2O_3/(Na_2O+K_2O+CaO)$ ratio of less than 1.1. Whereas A-type granites were originally defined, by Loiselle and Wones (1979), as anhydrous, reduced, anorogenic, high in Fe/(Fe + Mg), K_2O and K_2O/Na_2O and containing high incompatible trace element concentrations (e.g. REE, Zr, Nb and Ta).Moreover, although A-type granites typically have higher FeO⁄MgO than I-type granites (Table 1-3).

According to Collins et al., 1982 and Whalen et al., 1987 variation diagrams (Fig. 13) showing that some variation binary diagrams between some trace elements (Ga, Nb, Zn, Zr, Ce and Y) versus some major oxides (SiO_2, FeO*, MgO, K_2O, Na_2O, CaO) to showing the discrimination between I and A type granites. Zr + Nb + Ce + Y vs. FeO*/MgO and (K_2O + Na_2O)/CaO discrimination diagrams of Whalen et al. (1987) (Fig. 13 a&b) showing that the samples of granodiorite are plotted in the field of unfractionated I-type granite, on the other hand the syenogranite and some monzogranite mainly are related to A-type granite. Occasionally, according to Collins et al., (1982) and Whalen et al., (1987) as shown in figure 13 (c,d,e and f) the granodiorite samples plotted in the I-type granite, while the majority of monzogranite and all samples of syenogranite are mainly A-type granite.

Eby (1990) found that the Y/Nb average ratio is relatively constant for each A-type suite and thus it can serve as a useful parameter for chemical discrimination. He stated that A-type suites with Y/Nb < 1.2 are derived from sources chemically similar to those of oceanic island basalts while suites with Y/Nb > 1.2 are derived from sources chemically similar to island arc or continental margin basalts. The average of Y/Nb ratio of the investigated granodiorite is ~ 0.3-5 with an average 3 (table 5) that is more than 1.2 so that is related to continental arc (I-type granite), on the other hand the syenogranite (~0.3-0.6 with an average 0.4) and some samples of monzogranite less than 1.2 (~0.9-1.00 about 4-sample) to indicate derivation from sources chemically similar to those of anorogenic magma suite of A-type granite.

The investigated granite of late to post extensional orogeny according to the ternary diagrams of Eby (1992) as shown in figure 14, showing that the syenogranite and some samples of monzogranite are plotted in the field of anorogenic sitting of within the plate, on the other hand some samples of monzogranite (Y/Nb more than 1.2) related to post collision sitting. Accordingly, it is postulated that the Gassuss area A-type granites were formed during late to post extensional orogeny of the Arabian–Nubian Shield (ANS) evolution after the collision between the juvenile ANS crust and the pre-Neoproterozoic continental blocks of west Gondwana (Saharan Metacraton; Abdelsalam et al., 2002).

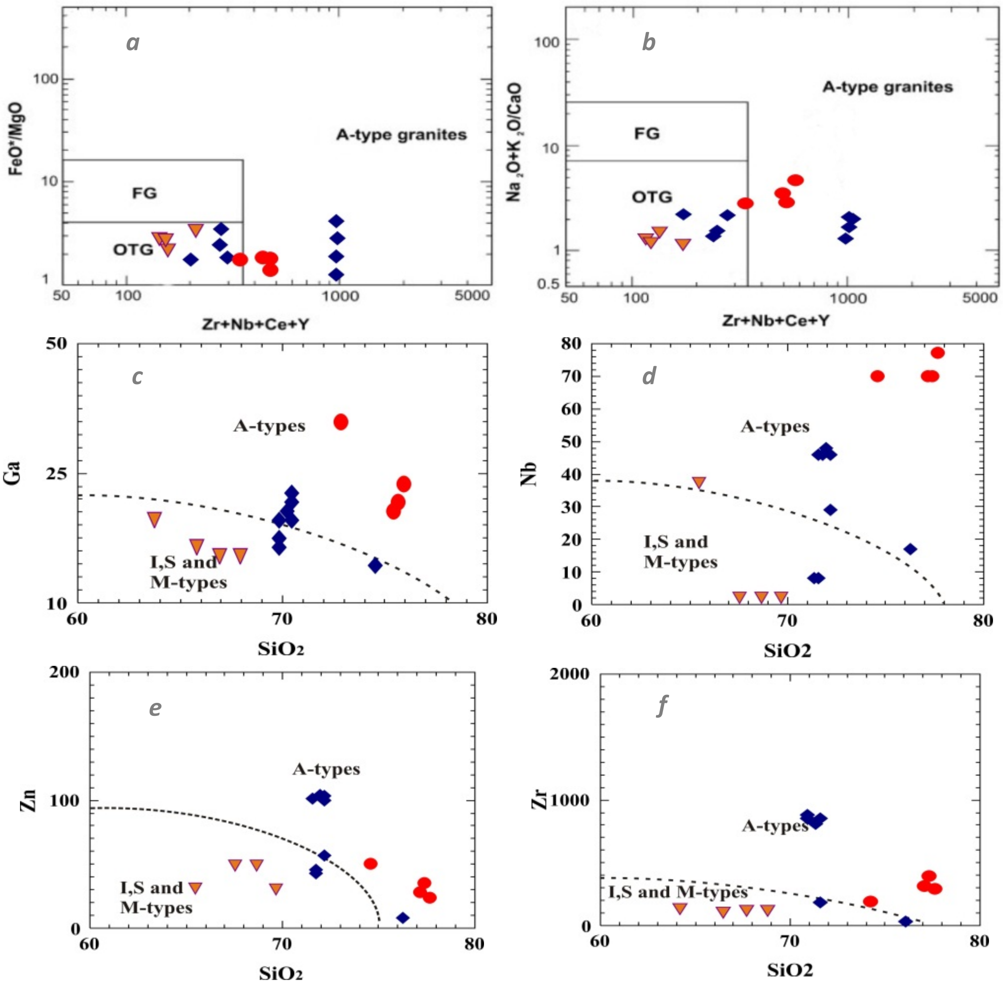
4.2- Normalized spider diagram

Incompatible normalized spider diagrams of some multi-element to MORB composition (Sun and McDonough, 1989) and ORG (oceanic ridge granite) of Pearce et al. (1984) for the Gassuss area granitic rocks suites are shown in figures. 15 and 16.

In the MORB normalized spider diagram the samples of each granitic rocks suites (synextensional orogeny and late to post extensional orogeny) show comparable patterns. Both group of patterns have fairly steep slopes with evident tilting of the patterns up to left due to selective enrichment of the incompatible elements LILE (Rb, Ba and Sr) with high steep slopes in K at the left-hand side over the more compatible elements (HFSE, HREE and LREE) to the right (Nb, Zr, Y & La-Sm & Eu-Lu) and represented slow slopes. Although the granodiorite are less enriched in incompatible LILE and HFSE relative to the monzogranite and syenogranite (Fig. 15c), they mainly exhibit slowly steeper patterns owing to slightly smooth depletion in HREE.

The synextensional orogeny suite patterns are characterized by minor positive spikes at Ba and Sr, and they are oppositely a markedly deep negative Nb anomaly. Also, Y and HREE exhibit extensive depletion, with concentrations reaching levels which are even lower than MORB. The coexistence of deep negative Nb anomalies on primitive-source spider diagrams are characteristic of magmatic rocks formed in subduction zones and indicates incorporation of crustal material (e.g. Zartman and Doe, 1981; Saunders et al., 1991). The relative enrichment of the fluid mobile element Ba (~40–90- MORB Fig. 15a), suggests the involvement of fluids released from the subducted slab because Ba is the most mobile and riched element in such fluids (Pearce, 1983; Wilson, 1989; Rollinson, 1993).

In spite of their exceedingly high Nb content with an average = 31.3-71.8 ppm for the monzogranite and syenogranite respectively, the patterns of the late to post extensional orogeny suites show moderate to slightly high negative Nb anomaly (Fig. 15b). In contrast to the positive Ba spike shown by the granodiorite suite, Ba in the late to post granitic suites patterns shows markedly deep negative anomalies than other behavior pattern of granodiorite. Furthermore, major depletions in the right-hand segment of the pattern are exhibited by a very deep Sr anomaly (Fig. 15 b&c). These depletions in Ba and Sr are likely attributed to fractionation of plagioclase and apatite, respectively during magmatic evolution. However, this strong depletion and low abundances of Ba and Sr, which sometimes drop below those of MORB, require an advanced fractionation of these minerals under upper crustal conditions. The negative Ba anomaly can be considered as an indication of high temperature fractionation of feldspar rather than hornblende or biotite (cf. Ilbeyli et al., 2004; Arslan and Aslan, 2006; Mansouri Esfahani et al., 2010).



FeO* total Iron

Fig. 13: Zr + Nb + Ce + Y vs. FeO*/MgO (a) and (K_2O + Na_2O)/CaO (b) discrimination diagrams of Whalen et al. (1987) FG: fractionated felsic granites; OGT: unfractionated I- and S-type granites and showing SiO_2 versus Ga, Nb, Zn and Zr variation diagrams (c,d,e and f respectively) of Collins et al., 1982 and Whalen et al., 1987.

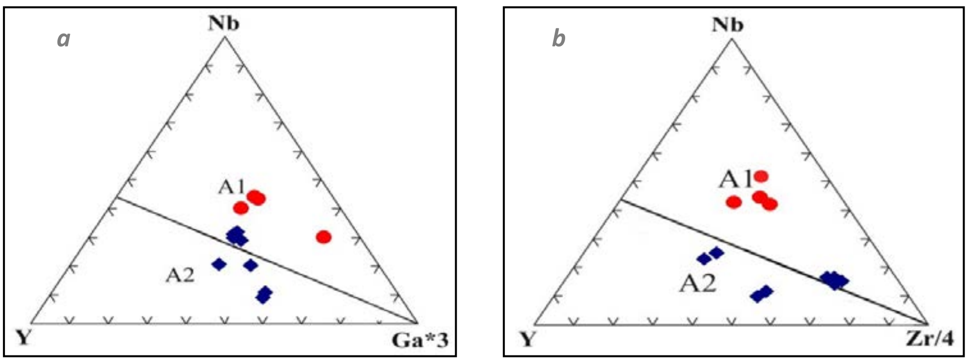


Fig. 14: (a) Nb-Y-Ga*3 ternary diagram and (b) Nb-Y-Zr/4 ternary diagram after Eby (1992): A1 (Anorogenic setting of within the plate) and A2 (Post collision setting).

International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-8,August 2016
ISSN: 2395-3470
www.ijseas.com

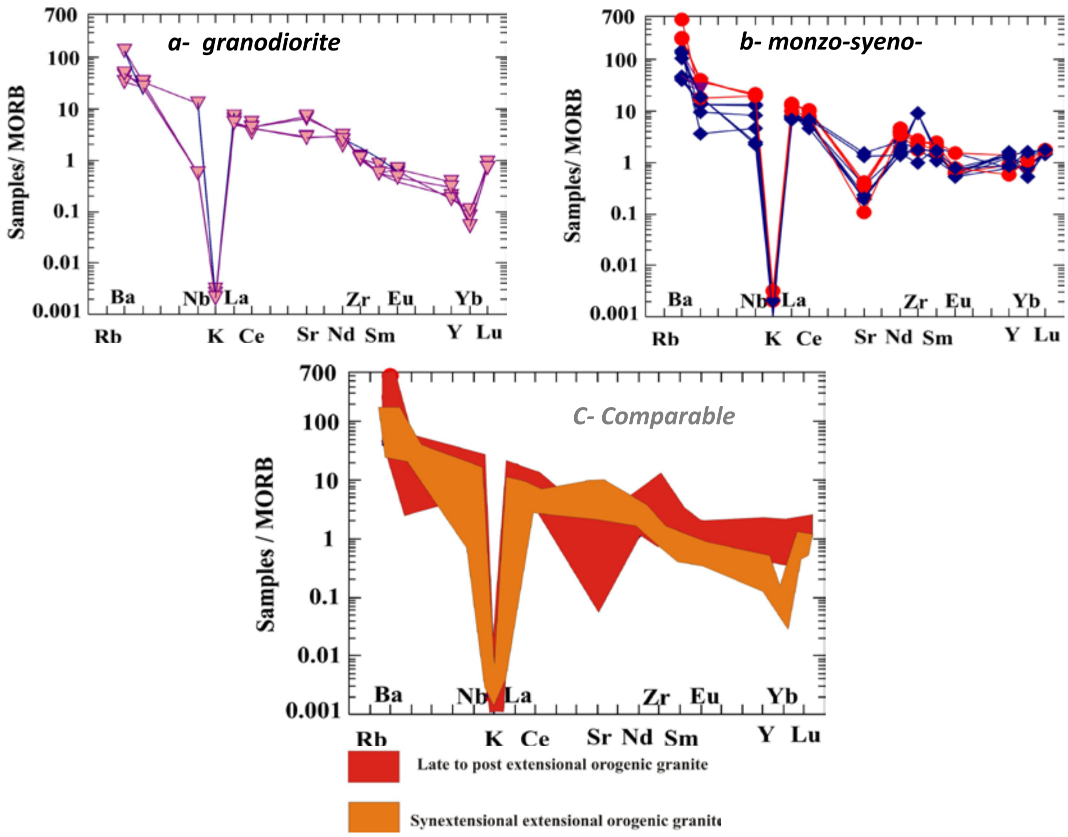


Fig. 15: MORB-normalized some multi-element spider diagrams for G. Gassus Granites. Normalization values are from Sun and McDonough (1989).

In the some multi-element abundance spider diagram are effective means for discriminating the tectonic setting of the Egyptian granitoid rocks (e.g. Moghazi, 2002;Farahat et al., 2007). The ORG-normalized patterns of the examined granodiorite (synextensional orogeny) and monzogranite - syenogranite (late to post extensional orogeny) of Gassuss area are showing in figure 16. However, the granodiorite samples pattern are exhibit slightly low to moderate variation of the incompatible elements Rb, Nb, Zr and Y as well as they are high of some incompatible elements Ba (Fig. 16 a), particularly these granodiorite has been demonstrated to be correlated with the degree of arc maturity (Brown et al., 1984; Jin, 1986).

On the other hand the ORG-normalized patterns of the examined monzogranite & syenogranite (late to post extensional orogeny) samples (Fig. 16b) are negative Ba anomaly and more enrichment Nb, Zr and Y, in particularly these monzogranite and syenogranite have been dominated to be correlated with continental arc maturity (Brown et al., 1984; Jin, 1986) as well as that concluded that the behavior of anorogenic of younger granite suite (Eby 1992).

4.3- Rear earth elements (REE):

The concentrations of rare earth elements (REE) for all of the studied granitic suites are given in Table 3. In the synextensional granite suite (granodiorite), La concentrations range about 19 to 21ppm, while Lu varies between 0.4 to 0.5 ppm with total REE varies between 112.6 and 117.1 ppm. On the other hand, the late extensional granite suite (monzogranite) is obviously more REE enriched relatively than granodiorite, with La and Lu values between about 27–40 ppm and 0.8–

1 ppm respectively with total REE 127.3-168.4 ppm, whereas the post extensional granite suite (syenogranite) is relatively more REE enriched than monzogranite and granodiorite (Table 3), which it is range concentration of La between 40 and 56 ppm, Lu reaches 1 ppm with high total of REE between 199 and 256 ppm.

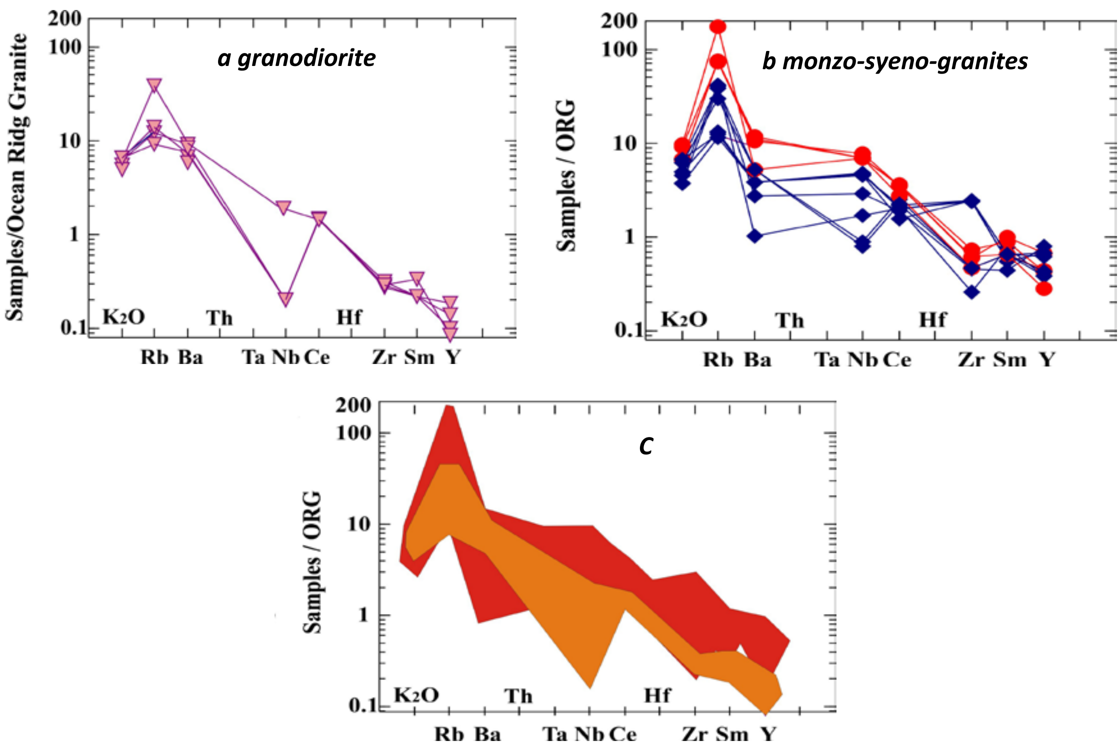


Fig. 16: ORG-normalized multi-element spider diagrams G. Gassus Granites. ORG (ocean ridge granite) normalization values are from Pearce et al. (1984).

The examined samples of the study granitic rocks have comparatively moderate abundance of ∑REE averages for granodiorite (synextensional orogeny) (average: 115.7 ppm) to high abundances of ∑ REE averages for monzogranite (late extensional orogeny) (average: 144.2 ppm) and ∑ REE averages for syenogranite (post extensional orogeny) (average: 238.2 ppm), being comparable to or even more REE-enriched than other A-type granites elsewhere in the Arabian–Nubian Shield (e.g. Abdel-Rahman and El-Kibbi, 2001; Moghazi et al., 2004, 2011; Katzir et al., 2007; Jarrar et al., 2008; Mohamed and El-Sayed, 2008; Be'eri-Shlevin et al., 2009a; El-Bialy, Streck, 2009; Eyal et al., 2010; Ali et al., 2012 and El-Bialy & M. Omar 2015).

Particularly, the average of Eu/Sm ratio and Eu anomaly are variable from the all types of the examined granitic rocks Cullers and Graf (1984), which the average concentration of Eu/Sm ratio and Eu for the examined late to post extensional orogenic granitic rocks are mainly moderate to small Eu negative anomalies (~0.2) (Table 3), on the other hand they are little to no Eu negative anomaly (~0.4) for the examined synextensional orogeny (Table 3).

According to C1-chondrite-normalized REE's ratios of McDonough and Sun, 1995, the granodiorite exhibits LREE-enriched patterns (La – Sm) with rather steep and mild negative Eu anomalies (average Eu= 0.7) (Fig.17 & Table3). The LREE segments (La–Nd), have parallel to sub-parallel arrangement, while the HREE segments (Eu-Lu) are noticeably less concordant (Fig. 17a). On the other hand, the monzogranite and syenogranite displays enriched, parallel to sub-parallel REE patterns, characterized by moderate slopes which are due to fair enrichment of the LREE (La-Sm) relative to HREE (Eu-Lu). These patterns also exhibit deeper negative Eu troughs with an average Eu= 1-1.2 relative to those of the granodiorite (Fig. 17b and c). The degree of LREE fractionation in the granodiorite (average(La/Sm) = 9.3) is higher relative to monzogranite and syenogranite (average (La/Sm) = 5.8 and 7 respectively). The situation is analogous with regard to the HREE of the granodiorite samples are slowly fractionated with remarkably steep patterns with an average (Gd/Yb) = 23.1, as well as they are relatively very high ratio to monzogranite and syenogranite (average (Gd/Yb) = 2.4 and 2.7 respectively), which they are weakly fractionated with almost flat pattern.

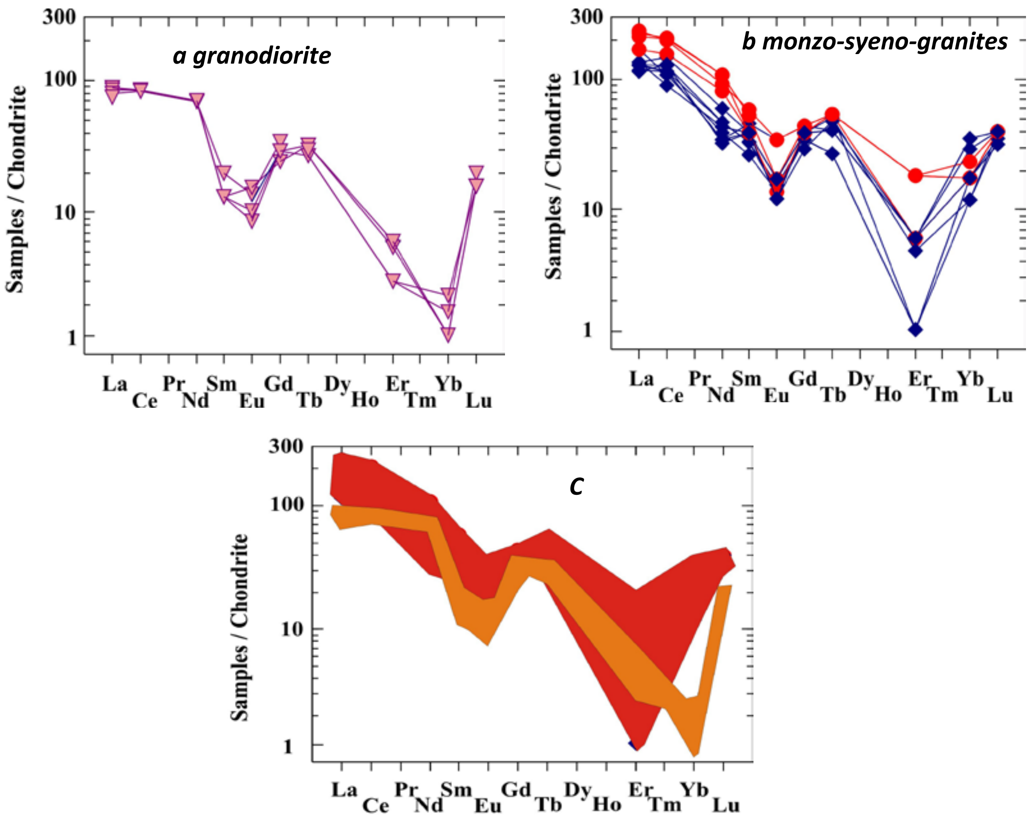


Fig. 17: C1-Chondrite-normalized REE diagrams of McDonough and Sun (1995) for the investigated granitic rocks of G. Gassuss area.

4.4- Comparative normalized:

The different comparatives of an average major, trace element concentrations and some different geochemical ratios of the examined granitic rocks with some average compositions of the various genetic I & A type's granite of Whalen et al. (1987) and continental crust of Rudnick and Fountain (1995) shown in table 6. According to some normalized spider average diagrams MORB of Sun and McDonough, (1989), ORG (oceanic ridge granite) of Pearce et al. (1984) and C1-chondrite-normalized REE's ratios of McDonough and Sun, (1995) (Fig. 18). Generally showing that the investigated granodiorite (synextensional orogeny) of I-type granite similar behavior patterns of I-type granite of Whalen et al (1987) in most normalized diagrams in all LILE, LREE and HREE patterns, on the other hand the investigated monzogranite and syenogranite (late to post extensional orogeny) of A-type are similar behavior patterns of both A-type granite and relatively felsic I-type of Whalen et al (1987) in most normalization diagrams.

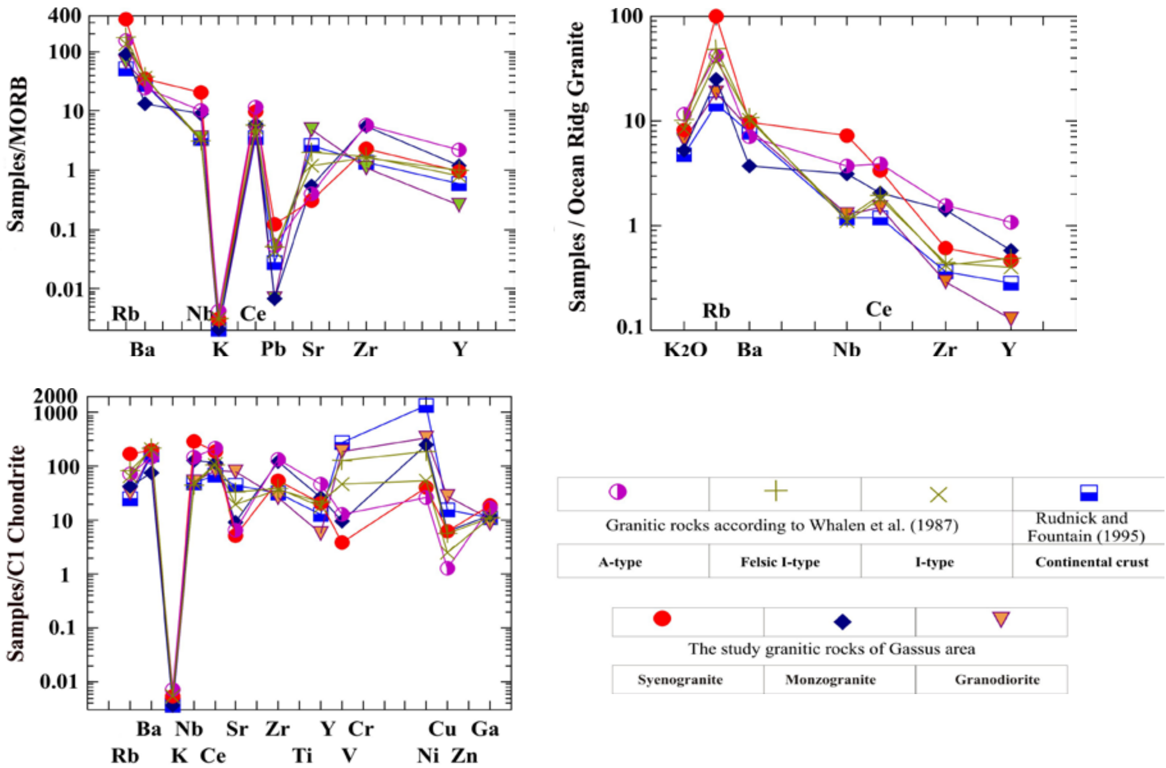


Fig. 18: Normalized spider diagrams of (a) MORB McDonough and Sun (1995), (b) ORG (ocean ridge granite) normalization values of Pearce et al. (1984) and (c) C1-Chondrite-normalized REE of McDonough and Sun (1995) for the investigated granitic rocks and some fumes granitic rocks of Whalen et al. (1987) and continental crust of Rudnick and Fountain (1995).

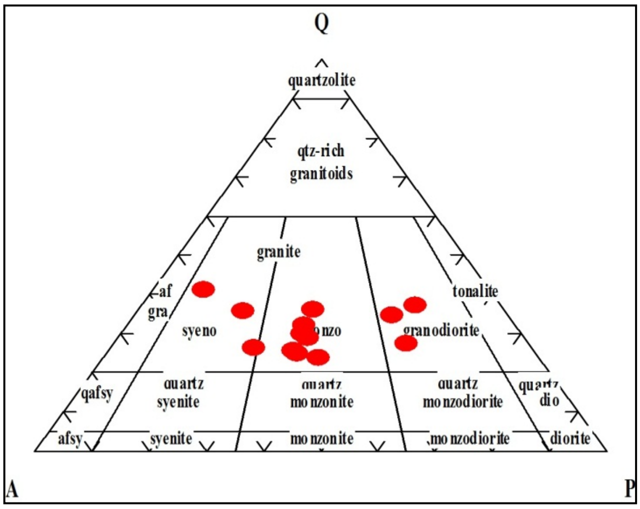
5- Conclusion:

The study area is a part of Arabian Nubian Shield of Neoproterozoic, that is cover about 155 Km^2, it is a part of Central Eastern Desert of Egypt, and it lies between Latitudes 26° 29' and 26° 36' N and Longitudes 33° 47' and 33° 57' E. The granitic rocks of the present study are divided into granodiorite, monzogranite and syenogranite, according to the geochemical and petrotectonical parameters, theses rocks are produced of I-type and A-type granites of continental arc assemblages. Particularly, the granodiorite is related to synextensional orogeny of calc-alkaline and metaluminous in nature, which is relatively low values of total alkali (with an average 7.3), on the other hand the granodiorite mainly high in LILE (Rb, Ba and Sr) and low in HFSE (Nb, Zr, Y), HREE (La-Sm) and LREE (Eu-Lu). Tectonically, that is described as synorogenic suite and due to I-type granite, which is similar to the I-type granite of Whalen et al 1987. On the other hand, the other type of granitic rock suites (monzogranite and syenogranite) are related to the late to post extensional orogeny of calc alkaline (monzogranite) to high-K of calc-alkaline (syenogranite) and mainly alkaline to peralkaline in natures, these rocks mainly highest in the values of total alkali with an average about 8.6, and that are high in HFSE (Nb, Zr, Y), HREE (La-Sm) and LREE (Eu-Lu) relative to the granodiorite and lowest in LILE elements than granodiorite. The monzogranite and syenogranite are mainly tectonically related to anorogenic granites of A-type granite, which are mostly similar to the A-type granite of Whalen et al 1987.

(Appendix)

Appendix (1): The modal composition and classification diagram of Streckeisn (1976) of the investigated granitic rocks of G. Gassuss (Tolba & Kamel 2014). (Table App.1 & Fig App. 1)

							Granodiorit								
	Qz	**Pl**	**A-Fld**	**Bio**	**Hb**	**Pyx**	**Mus**	**Ir**	**Sp**	**Zr**	**Ep**	**Ap**			**T**
C7	22.2	41.4	17.3	11	1.2	0	0.3	2	2	1.3	1	0.3			**100**
C11	26	33.4	10.4	16	4.8	5.2	0.3	3	0.6	0.1	0.1	0.1			**100**
C18	21.4	27.7	12.7	11.8	5.5	8.5	0	10	1.2	0.6	0.4	0.2			**100**
Av	**23.2**	**34.2**	**13.5**	**12.9**	**3.8**	**4.6**	**0.2**	**5**	**1.2**	**0.7**	**0.5**	**0.2**			**100**
							Monzogranite								
	Qz	**Pl**	**K-F**	**Bi**	**Hb**	**Pyx**	**Sp**	**All**	**Ir**	**Cl**	**Mu**	**Zr**	**Ep**	**Ap**	
C8	18.5	20	28	11.5	4.2	3	3	0	5.5	3.7	0	0.8	1	0.8	**100**
C13	17.5	21	27.5	11	4.7	3.5	3.3	0	5.2	3.7	0	0.8	1	0.8	**100**
C19	33.3	28.1	30.9	3.6	0	0	0	0	2.2	0	1.7	0	0	0	**100**
C21	27	21	36	6	1	0	1	0	3	2	3	0	0	0	**100**
C23	20	22	37	10	2	0	1	0	3	2	3	0	0	0	**100**
C24	25.2	26.7	32.2	7.9	1.5	0	0	0	4	1.6	1	0	0	0	**100**
C26-2	16.5	24	24.5	9.5	4.2	3	4	3	5	3.7	0	0.8	1	0.8	**100**
Av	**22.6**	**23.3**	**30.9**	**8.5**	**2.5**	**1.4**	**1.6**	**0.4**	**4**	**2.4**	**1.2**	**0.3**	**0.4**	**0.3**	**99.8**
							Syenogranite								
	Qz	**Pl**	**K-F**	**Bi**	**Mu**	**Ir**	**Ep**								
C6-1	25.2	24	46.5	1.3	2.2	0.8	0								**100**
C22	34.2	17.7	44	1.4	0.9	1.1	0.7								**100**
C25-1	40	8	49	1	1	1	0								**100**
Av	**33.1**	**16.6**	**46.5**	**1.2**	**1.4**	**1**	**0.2**								**100**



REFERENCES

Abdel-Rahman, A.M., El-Kibbi, M.M., 2001. Anorogenic magmatism: chemical evolution of the Mount El-Sibai A-type complex (Egypt), and implications for the origin of within-plate felsic magmas. Geol. Mag. 138, 67–85.

Abdelsalam, M.G., Li'egeois, J., Stern, R.J., 2002. The Saharan Metacraton. J. Afr. Earth Sci. 34, 119–136.

Ali, K.A., Moghazi, A.M., Maurice, A.E., Omar, S.A., Wang, Q., Wilde, S.A., Moussa, E.M., Manton, W.I., Stern, R.J., 2012. Composition, age, and origin of the _620 Ma Humr Akarim and Humrat Mukbid

A-Type granites: no evidence for pre-Neoproterozoic basement in the Eastern Desert, Egypt. Int. J. Earth Sci. 101, 1705–1722.

Arslan, M., Aslan, Z., 2006. Mineralogy, petrography and whole-rock geochemistry of the Tertiary granitic intrusions in the Eastern Pontides, Turkey. J. Asian Earth Sci. 27, 177–193.

Akaad, M. K., Noweir, A. M., 1978. Geology and lithostratigraphy of the Arabian Desert orogenic belt of Egypt between latitudes 25° 35' and 26° 30' N. In "Evolution and Mineralization of the Arabian-Nubian Shield Symposium IAG Jaddah, Abstract Precambrian Research, 6, A 6.

Akaad M. K., Noweir, A. M., 1980. Geology and lithostratigraphy of the Arabian Desert orogenic belt of Egypt between Latitudes 25˚ 35' and 26˚ 30' N. King Abdel Aziz Univ., Inst. App. Geol. Bull., V. 4 No. 3, P. 127-135.

Be'eri-Shlevin, Y., Katzir, Y., Whitehouse, M.J., 2009a. Post-collisional tectono-magmatic evolution in the northern Arabian-Nubian Shield (ANS): time constraints from ionprobe U-Pb dating of zircon. J. Geol. Soc. Lond. 166, 71–85.

Brown, G.C., Thorpe, R.S., Webb, P.C., 1984. The geochemical characteristics of granitoids in contrasting arcs and comments on magma sources. J. Geol. Soc. Lond. 141, 413–426.

Chappell, B.W., White, A.J.R., 1974. Tow constricting granite types. Pacific Geol. V. 8, P.173-174.

Collins, W.J., Beams, S.D., White, A.J., Chappell, B.W., 1982. Nature and origin of A-type granites with particular reference to Southeastern Australia. Contrib. Min. Petrol., V. 80, P. 189-220.

Collins, A.S., Pisarevsky, S.A., 2005. Amalgamating eastern Gondwana: the evolution of the Circum-Indian Orogens. Earth Science Reviews 71, 229–270.

Collins, A.S., 2006. Madagascar and the Amalgamation of Central Gondwana. Gondwana Research 9, 3–16.

Cullers, R.L., Graf, L., 1984. Rare earth elements in igneous rocks of the continental crust, intermediate and silicic rock-ore petrogenesis. In: Henderson, P.(Ed.), Rare earth element geochemistry. Elsevier, Amsterdam, P. 275-316.

Dardir, A.A., Awadallah, M.F., Abu Zid, K.M., 1982. A new contribution to the geology of Gabel Dokhan, Eastern Desert, Egypt. Ann. Geo. Surv. Egypt, V. 12, 19-27.

Damm, K.W., Pichowiak, S., Harmon, R.S., Todt, W., Kelley, S., Omarini, R., Niemeyer, H., 1990. Pre-Mesozoic evolution of the central Andes; the basement revisited In Kay, S. M., and Repela C. W., eds, plutonism from Antarctica to Alaska: Boulder, Colorado, Geol. Soc. Of Amer. Spe., 241 P.

Eby, G.N., 1992. Chemical subdivision of the A-type granitoids: petrogenetic and tectonic implications. Geology 20, 641–644.

El-Bialy, M.Z., 2004. Petrologic, geochemical and petrogeneticcharacterization of the old granites of Sinai, Egypt. Ph.D. Thesis, Suez Canal University, Ismailia, Egypt, 230 pp.

El-Bialy, M.Z , Omar, M.M. 2015. Spatial association of Neoproterozoic continental arc I-type and post-collision A-type granitoids in the Arabian–Nubian Shield: The Wadi Al-Baroud Older and Younger Granites, North Eastern Desert, Egypt. African Earth Sciences J. 103., 1–29

El-Bialy, M.Z., Streck, M.J., 2009. Late Neoproterozoic alkaline magmatismin the

Arabian-Nubian Shield: the postcollisional A-type granite of Sahara-Umm Adawi pluton, Sinai, Egypt. Arab. J. Geosci. 2, 151–174.

EL-Gaby, S., List, F. K., Tehrani, R., 1988. Geology, evolution and metallogenesis of the Pan-African belt in Egypt. In: El-Gaby S., Greiling R.O., (eds.). The Pan-African belt of northeast Africa and adjacent areas. ViewegSohn, Braunschweig/Wiesbaden, 17-68.

EL-Gaby, S., List, F. K., Tehrani, R., 1990. The basement complex of the Eastern Desert and Sinai. In Said, R., (ed.). The Geology of Egypt.Balkema, Rotterdam, 175-184.

El-Mezayen, A. M., 1978. Petrographical and Petrochemical studies of Gabal Gasus granitic rocks, Eastern Desert, Egypt M.Sc. Thesis, Faculty of Science, Al-Azhar University, Egypt, 155 pp.

El Ramly, M, F., Akaad, M. K., I960. The basement complex in the Eastern Desert of Egypt between latitudes 24° 30' and 25° 40'. Geol. Surv. Egypt, paper No. 8.

El Shazly, E.M., 1964. On the classification of the Precambrian and other rocks of magmatic affiliation in Egypt. In: Proceedings of the 22nd International Geological Congress, New Delhi, 10, pp. 88–101.

Eyal, M., Litvinovsky, B., Jahn, B.M., Zanvilevich, A., Katzir, Y., 2010. Origin and evolution of post-collisional magmatism: coeval Neoproterozoic calc-alkaline and alkaline suites of the Sinai Peninsula. Chem. Geol. 269, 153–179.

Farahat, E.S., Mohamed, H.A., Ahmed, A.F., El Mahallawi, M.M., 2007. Origin of I- and A-type granitoids from the Eastern Desert of Egypt: implications for crustal growth in the northern Arabian-Nubian Shield. J. Afr. Earth Sci. 49, 43–58.

Jarrar, G., Manton, W.I., Stern, R.J., Zachmann, D., 2008. Late Neoproterozoic A-type granites in the northernmost Arabian-Nubian Shield formed by fractionation of basaltic melts Chem. Erde 68, 295–312.

Jin, M.S., 1986. Ca, Na, K, Rb, Zr, Nb and Y Abundances of the Cretaceous to Early Tertiary Granitic Rocks in Southern Korea and Their Tectonic Implications. Memoir for Prof. S.M. Lee 60th Birthday, pp. 195–209.

Johnson, P.R., 2003. Post-amalgamation basins of the NE Arabian Shield and implications for Neoproterozoic tectonism in the northern East African Orogen.Precambrian Research 123, 321–337.

Johnson, P.R., Andresen, A., Collins, A.S., Fowler, A.R., Fritz, H., Ghebreab, W., Kusky, T., Stern, R.J., 2011. Late Cryogenian–Ediacaran history of the Arabian–Nubian Shield: A reviewof depositional, plutonic, structural, and tectonic events in the closing stagesof the northern East African Orogen.Journal of African Earth Sciences 61, 167–232

Katzir, Y., Eyal, M., Litvinovsky, B.A., Jahn, B.M., Zanvilevich, A.N., Valley, J.W., Beeri, Y., Pelly, I., Shimshilashvili, E., 2007. Petrogenesis of A-type granites and origin of vertical zoning in the Katherina pluton, Gebel Mussa (Mt. Moses) area, Sinai, Egypt. Lithos 95, 208–228.

Kroner, , A., Stern, R. J., 2004. Pan-African Orogeny. Encyclopedia of Geology, 1:1-12. LASCELLES, D. F. 2006. The Mt Gibson banded iron formation hosted magnetite deposit: two distinct processes for the origin of high grade iron ore deposits. Economic Geology, 101: 651-666.

Loiselle, M.C., Wones, D.R., 1979. Characteristics and origin of anorogenic granites. Geol. Soc. Am. Abstr. Progr. 11, 468.

Maniar, P.D., Piccoli, P.M., 1989. Tectonic discrimination of granitoids. Geol. Soc. Am. Bull. 101, 635–643.

Mansouri Esfahani, M., Khalili, M., Kochhar, N., Gupta, L.N., 2010. A-type granite of the Hasan Robat area (NW of Isfahan, Iran) and its tectonic significance. J. Asian Earth Sci. 37, 207–218.

McDonough, W.F., Sun, S., 1995. The composition of the Earth. Chem. Geol. 120, 223–253.

Middlemost, E.A.K., 1994. Naming materials in the magma/igneous rock system. Earth Sci. Rev. 37, 215–224.

Moghazi, A.M., 2002. Petrology and geochemistry of Pan-African granitoids, Kab Amiri area, Egypt—implications for tectonomagmatic stages of the Nubian Shield evolution. Mineral. Petrol. 75, 41–67.

Moghazi, A.M., Hassanen, M.A., Mohamed, F.H., Ali, S., 2004. Late Neoprotero-zoic strongly peraluminous leucogranites, South Eastern Desert, Egypt -petrogenesis and geodynamic significance. Mineral. Petrol. 81, 19–41.

Moghazi, A.M., Harbi, H.M., Ali, K.A., 2011. Geochemistry of the Late Neoproterozoic Hadbadh Dayheen ring complex, Central Arabian Shield: implications for the origin rare-metal-bearing post-orogenic A-type granites. J. Asian Earth Sci. 42, 1324–1340.

Mohamed, F.H., El-Sayed, M.M., 2008. Post-orogenic and anorogenic A-type fluorite bearing granitoids, Eastern Desert, Egypt: petrogenetic and geotectonic implications. Chem. Erde 68, 431–450.

Pearce, J.A., 1983. The role of sub-continental lithosphere in magma genesis at destructive plate margins. In: Hawkesworth, C.J., Norry, M.J. (Eds.), Continental Basalts and Mantle Xenoliths. Shiva, Nantwich, pp. 230–249.

Pearce, J.A., Harris, N.B.W., Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. J. Petrol. 25, 959–983.

Pearce, J.A., 1996. Sources and settings of granitic rocks. Episodes 19, 120–125.

Pearce, J.A., Gale, G.E., 1977. Identification of ore deposition environment from trace element geochemistry. Geol. Soc. Lond. Spec. Publ. 7, 4–24.

Peccerillo, A., Taylor, S.R., 1976. Geochemistry of Eocene calcalkaline volcanic rocks from the Kastasmonu area, north Turkey. Contrib. Miner. Petrol. 58, 63–81.

Petro, W.L., Vogel, T.A., Wilband, J.T., 1979. Major element chemistry of plutonic rock suites from compressional and extensional plate boundaries. Chem. Geol., V. 26, P. 217-235.

Rollinson, H.R., 1993. Using Geochemical Data; Evaluation, Presentation, Interpretation. Longman Group Ltd., London.

Rudnick, R.L., Fountain, D.M., 1995. Nature and composition of the continental crust: a lower crustal perspective. Rev. Geophys. 33, 267–309.

Saunders, A.D., Norry, M.J., Tarney, J., 1991. Fluid influence on the trace element compositions of subduction zone magma. Philos. Trans. R. Soc. Lond. A 335, 377–392.

Shand, S.J., 1947. Eruptive Rocks: Their Genesis, Composition, Classification, and Their Relation to Ore-deposites, third ed. John Wiley & Sons, New York.

Sims, M. A., James, H. L., 1984. Banded iron ore formation of Late Proterozoic age in the CentralEastern desert, Egypt: geological and tectonic setting. Economic Geology, 79, 1777-1784.

Stern, R. J., Avigad, D., Miller, N. R, Beyth, M., 2006. Evidence for snowball earth hypothesis in the Arabian-Nubian Shield and the East African orogen.Journal of African Earth Sciences, 44, 1-20.

Sun, S.S., McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders, A.D., Norry, M. (Eds.), Magmatism in Ocean Basins. Geological Society of London Special Publication 42, pp. 313–345.

Tolba, A. S., Kamel, M. 2014. Lithological Discrimination of Neoproterozoic basement rocks based on Landsat ETM+ Image Processing Techniques and Petrographic studies of Gabal Gassuss, Central Eastern Desert, Egypt. Al-Azhar Bull. of Scie. V. 25 No. 1, June, 9-28

Whalen, J.B., Currie, K.I., Chappell, B.W., 1987. A-type granites: geochemical characteristic, discrimination and petrogenesis. Contrib. Mineral. Petrol. 95, 407–419.

Wilson, M., 1989. Igneous Petrogenesis. Unwin Hyman Ltd., London.

Zartman, R.E., Doe, B.R., 1981. Plumbotectonics – the model. Tectonophysics 75, 135–162.