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Petrology and Geochemical Characteristic of the Younger Gabbros of Wadi Shianite Area, Southeastern Desert, Egypt

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Abstract

The present work is a petrological study of the gabbroic rocks of wadi Shianite Southeastern Desert of Egypt. Chemical analyses for major and trace elements showed that there are 3 main gabbro types. These are: 1) pyroxene hornblende gabbronorite; 2) hornblende gabbro; and 3) anorthosite. The opaque minerals study of the gabbroic rocks showed that they composed mainly of ilmenite, magnetite and sulphides. The present gabbroic rocks work are related to calc-alkaline magma type, similar to the younger gabbros in other areas in the Eastern Desert.

Keywords

Pyroxene Hornblende Gabbronorite, Hornblende Gabbro and Anorthosite

1. Introduction

The gabbroic rocks represent major rock units in the Pre-Cambrian shield. Several studies were carried out dealing with the general geology and the petrology of these rocks. Recent studies indicated two types of gabbros, older gabbros (Takla 1971 [1], Basta and Takla 1974 [2], Takla *et al*., 1981 [3] and Ghoneim *et al*. 1991 [4]), or metagabbro (Akaad and Neweir, 1980 [5], and Mansi, 1996 [6]), and younger gabbros (Takla 1971 [1], Ghoneim *et al*. 1991 [4]) Mohamed & Hassanen (1996) [7] El Gaby *et al*., (1988) [8] referred the older metagabbro of the Pan African belt in Egypt as member of the ophiolite sequence and have a tholeiitic composition. They considered the metagabbros as belonging to the weakly metamorphosed calc-alkaline island arc rocks. They could be intruded after the over thrusting of the younger metavolcanics.

El Gaby *et al*. (op. sit), classified the younger gabbros as intrusive, mantle derived rocks composed commonly of fresh peridotites, gabbro diorite and intruded at the late Cordilleran stage (655 - 570 Ma). The present work

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deals with the petrological and mineral chemistry to identify and detect the magma type and tectonic setting of the younger gabbroic rocks of Wadi Shianite.

2. General Geology and Petrography

The studied area is located between longitude 34˚15' - 34˚25'E and latitude 23˚00' - 23˚10'N. It covers by Precambrian rocks represented by massive granodiorite, deformed granodiorite, younger gabbro, hornblende granite, and perthitic leucogranite (**Figure 1**).

The exposed late neoproterozoic rocks in the study area are classified according to Takla (2002) [9] into:

V—Intraplate Magmatism and Sediments Youngest

c) perthitic leucogranites

b) hornblend granites

a) younger gabbro

VI—Subduction-Related Granitoids (Arc Granites)

b) deformed granodiorites

a) massive granodiorites

Intraplate Magmatism and Sediments. The **younger gabbros** form arched outcrop within the hornblende monzogranite and separated from them by wadi alluvium. They form low hills with gentle slope (**Figure 1**). These rocks are homogenous in composition usually massive and have characteristic boulder-shape weathering at the outer parts. These gabbros are slightly fractured and they classified into: 1) pyroxene hornblende gabbronorite; 2) hornblende gabbro and 3) anorthosite. The modal composition of these gabbros are given in **Table 1** and graphically represented on plagioclase-pyroxene-hornblende diagram (Streckeisen, 1976) [10]. On this diagram (**Figure 2**) the studied gabbroic rocks plot within the pyroxene hornblende gabbro norite, hornblende gabbro and anorthosite fields. **The pyroxene hornblende gabbronorite** composed mainly of plagioclase, ortho- and clino-pyroxene, hornblende and opaques. The plagioclases (An_{50-65}), are euhedral prismatic crystal (**Plate I(a)**) generally fresh, twinned according to albite pericline, and Carlsbad laws (**Plate I(b)**). Sometimes plagioclase crystals are partially sericitized especially at the contact with the hornblende granites. The clino-pyroxene represented by titanaugite and hypersthene. The augite occurs as anhedral basal section and short prisms (**Plate I(c)**), while hypersthene occurs as subhedral to anhedral crystals (Plat I(d)) strong pleochroic from pale green to pale brown. **The hornblende gabbro** is coarse- to medium-grained, orthocumulate, composed essentially of plagioclase as cumulate phase enclosed in intercumulus hornblende and biotite (**Plate I(e)**), opaque, titanite and apatite are accessories and quartz is secondary mineral constituent.

The anorthosite composed mainly plagioclase (An_{50-65}) as the cumulus phase together with small amount of

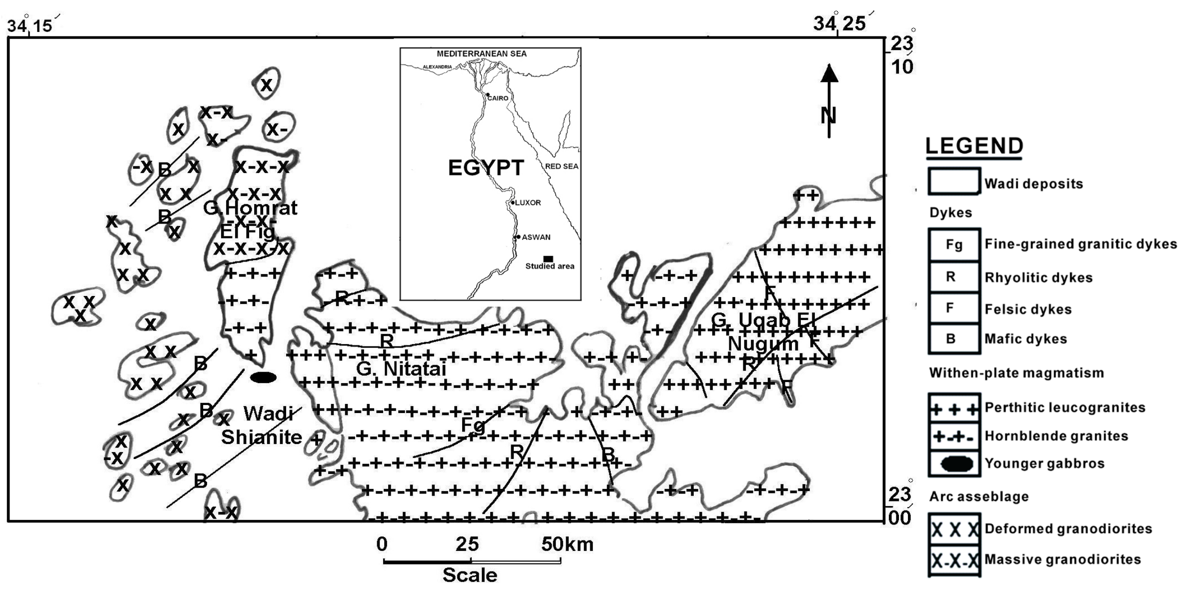

Figure 1. Lithlogical map of Wadi Shianit area, South Eastern Desert, Egypt.

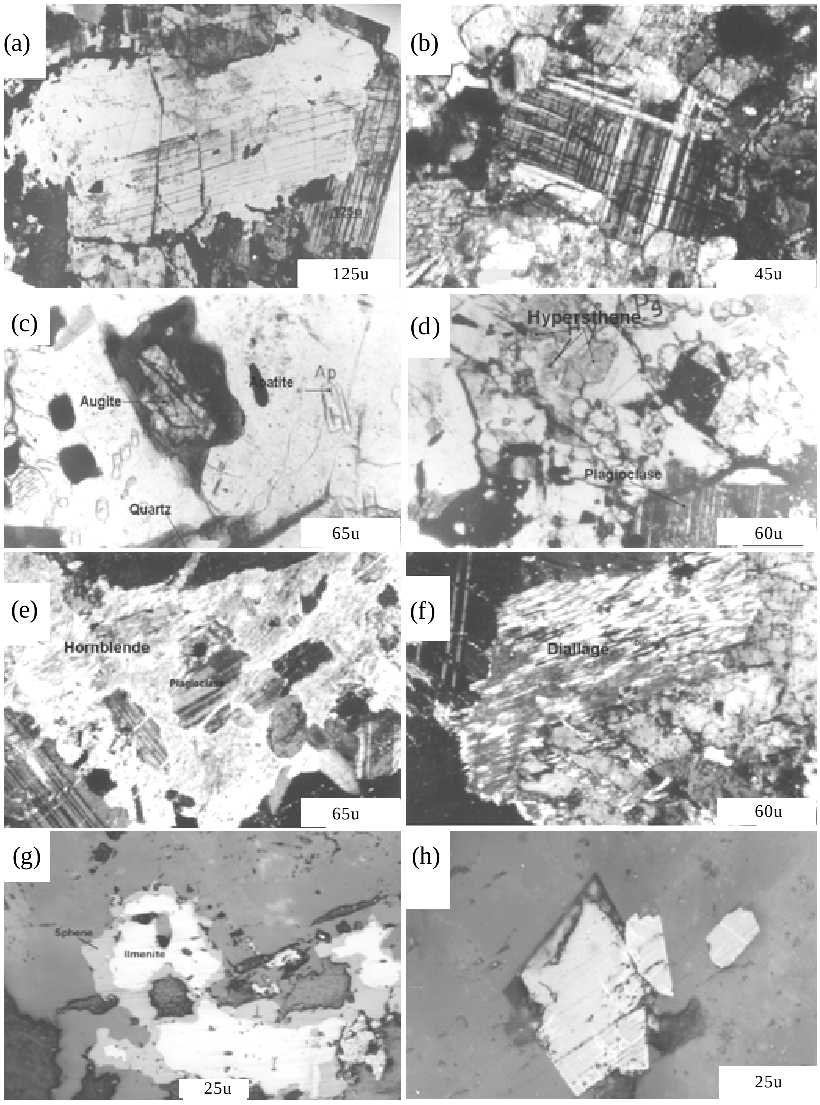

Plate I. (a) Euhedral prismatic plagioclase C.N.; (b) pericline twining in plagioclase C.N.; (c) short prism augite crystal PPL; (d) hypersthene crystal C.N.; (e) cumulus plagioclase enclosed in intercumulus hornblende C.N.; (f) diallage crystal as intercumulus C.N.; (g) ilmenite grain replaced by titanite along peripheries; and (h) pyrite inclusion in ilmenite are extensively to completely replaced by gothite.

Table 1. Mineral composition for the younger gabbros of Wadi Shianite area.

Rock types	Pyroxene hornblende gabbronorite				Hornblende gabbro				Anorthosite			
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Plagioclase	55	51	52	53	55	58	48	56	88	85	90	89
Brown hornblende	7	12	11	10	36	28	34	33	1	0.5	1.5	1
Clino-pyroxene	19	20	17	19	--	--	3	1	7	10	4	7
Orth-pyroxene	8	5	9	8	--	--	--	--	--	--	--	--
Opaques	4	3	3	3	4	6	11	7	2	4	1	1
Accessory	2	3	3	2	1	2	1	2	1	1	1	1
Quartz*	5	6	3	5	6	6	3	4	2	--	3	1

*Secondary quartz.

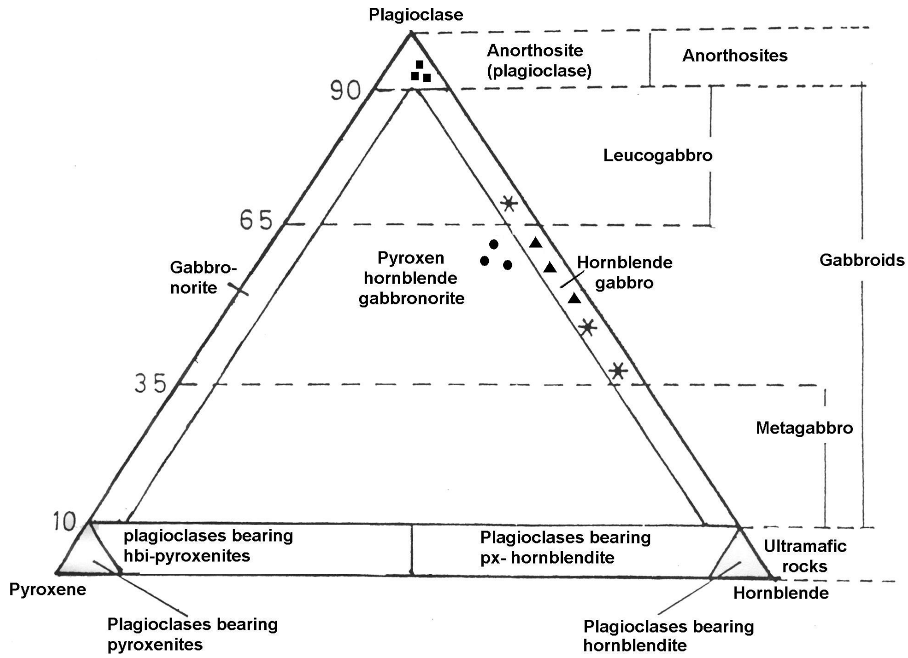

Figure 2. Modal plagioclase-pyroxene-hornblende diagram for younger gabbros (Streckeisen, 1976). ▲ hornblende gabbros, ● pyroxene hornblende, ■ gabbronorite anorthosite.

diallage as the intercumulus phase (**Plate I(f)**). The opaque minerals in the studied younger gabbros are mainly represented by ilmenite, magnetite and sulphides. The ilmenite is subhedral homogenous prismatic fresh crystals, sometimes replaced by titanite along grain peripheries (**Plate I(g)**). Magnetite occurs as discrete subhedral to euhedral grains slightly martitized along (111) plane. Sulphides occur in very small amount as pyrite and pyrrhotite inclusions. Pyrite inclusions in ilmenite are extensively to completely replaced by goethite (**Plate I(h)**).

Subduction-Related Granitoids (Arc Granites), represented by massive granodiorite and deformed granodiorite. The massive granodiorite rocks occupy as few masses in the central part (**Figure 1**). They are massive and less weathered, grayish green to green color and cut by acidic dykes and quartz veins.

Under the microscope, They are coarse- to medium-grained, composed of plagioclase (An$_{20}$-An$_{27}$), potash feldspar and hornblende as essential minerals. Accessory minerals represented by quartz, biotite, sphene, rutile, apatite, zircon and opaque minerals. Calcite, chlorite and saussurite are the main secondary minerals. The textures of the massive granodiorites are holocrystalline, The porphyritic textures. Hypidiomorphic and granular textures are also recorded.

The deformed granodiorites occur in the eastern part of the study area along Gebal Shianite (**Figure 1**). These rocks form high hills cutting by acidic dykes. The deformed granodiorites are fine to medium-grained rocks that are highly weathered to boulders (**Plate I(f)**) and show exfoliation structure.

Under the microscope, they are composed of plagioclase (An$_{18-22}$), showing percline twining. Alkali feldspar (orthoclase and microcline), quartz (undulatory extinction) are the essential minerals. Biotite, muscovite, sphene, zircon, apatite and opaque minerals are the accessory minerals. Chlorite, saussurite and clay minerals are found as secondary minerals. The granodiorites are holocrystalline, porphyritic with hypidiomorphic textures.

3. Geochemistry of the Younger Gabbros

Five samples were analyzed for major oxides and trace elements analyses and two samples for rear earth element (REEs) analyses of the studied younger gabbros as given in **Table 2**.

Table 3 shows the average chemical composition of the studied gabbros and similar rocks from different localities in the Eastern Desert of Egypt. From **Table 3** it is clear that the pyroxene hornblende gabbronorite is more rich in SiO_2 than the other types, while the hornblende gabbro is more rich in TiO_2 than the other types. All the types of younger gabbros have similar contents of the other major oxides. From **Table 3** it is evident that the pyroxene hornblende gabbronorite of the study area is similar to the younger gabbro of El Bakria (El Mansi,

Table 2. Major oxides, trace elements, CIPW norms and some REE for the studied younger gabbros of Wadi Shianite area.

Rock types	Pyroxene hornblende gabbronorite	Hornblende gabbros			Anorthosite
S. No.	1	2	3	4	5
		Major oxides wt%			
SiO_2	48.91	47.01	45.89	46.98	45.99
TiO_2	00.44	01.54	00.98	01.19	00.82
Al_2O_3	11.92	13.05	12.52	13.81	12.11
Fe_2O_3	05.05	04.69	05.55	05.95	05.09
FeO	05.03	0.520	06.01	06.58	04.93
MnO	00.20	00.12	00.14	00.12	00.18
MgO	11.91	14.01	13.10	13.01	13.05
CaO	12.51	11.20	12.05	11.80	13.55
Na_2O	02.05	02.43	01.90	01.70	01.94
K_2O	00.38	00.33	00.57	00.20	00.26
P_2O_5	0.59	0.39	00.16	00.29	00.34
L.O.I	00.69	01.77	00.69	00.38	01.09
Total	99.77	100.71	100.44	100.11	99.91
		Trace elements ppm			
Cr	172	195	188	379	212
Ni	175	48	196	201	182
Co	41	133	45	61	52
V	191	130	160	130	150
Cu	192	54	162	72	53
Pb	33	26	36	22	27
Zn	58	63	23	49	51
Rb	33	29	63	23	29
Ba	305	204	28	170	255
Sr	310	290	270	275	240
Ga	25	24	285	19	28
Nb	28	19	17	26	50
Hf	25	18	25	18	50
Zr	38	40	25	39	45
Y	10	7	8	6	8
U	3	1.8	2.1	1.2	2.5
Th	7	4.2	5	4	6
		REE ppm			
La			4.67		4.6
Ce			8.72		7.2
Nd			8.57		7.3
Sm			2.44		2.4
Eu			1.3		1.5
Gd			2.9		2.6
Tb			0.38		0.35
Er			2.3		1.3
Yb			1.9		1.7
Lu			0.4		0.29
		CIPW norms			
Qz	01.55	02.04	01.32	02.07	02.04
Or	16.81	10.06	18.94	15.84	15.72
Ab	31.54	27.07	30.61	26.32	29.56
An	24.92	25.12	25.53	26.36	26.82

Table 3. Major oxides of younger gabbro form different localities of Egypt.

Oxides	1	2	3	4	5	6	7
SiO_2	49.2	47.25	45.60	46.12	46.72	47.58	48.34
TiO_2	00.55	01.33	00.90	01.20	00.96	00.51	0.49
Al_2O_3	11.90	12.37	12.10	12.71	19.42	08.39	21.43
Fe_2O_3	05.01	05.37	05.08	05.07	02.66	02.66	01.03
FeO	05.20	05.93	04.94	05.14	03.14	07.99	04.21
MnO	00.20	00.13	00.18	00.14	00.18	00.24	00.11
MgO	11.95	13.37	13.05	12.67	12.73	20.51	07.04
CaO	12.50	11.68	13.55	12.67	10.12	08.03	12.47
Na_2O	02.05	02.00	01.95	01.80	01.60	00.68	01.84
K_2O	00.38	00.37	00.25	00.30	00.26	00.14	00.23
P_2O_5	00.59	00.28	00.34	00.31	00.02	00.05	00.08
L.O.I	00.69	01.28	01.08	02.00	01.66	04.21	02.22

1: Data of pyroxene hornblende gabbronorite of the studied area. 2: Data of hornblende gabbro of studied area. 3: Data of anorthosite of the studied area. 4: Data after Hamimi (1992) [11]. 5: Data after Takla *et al.* (1981) [3]. 6: Data after Takla and Neweir (1980) [12]. 7: Data after El Mansi (1996) [6].

1996 [6]), while the hornblende gabbros similar to the younger gabbros of Gabal Ambat and gabbro Akarem (Takla *et al*., 1981 [3]). The anorthosites of the studied area are similar to the leucogabbro of Wadi Beitan (Hamimi, 1992) [11].

To display the trace elements distribution in the studied gabbros they are plotted on spider diagram normalized to Primitive mantle according to Wood *et al*., 1975 [13] (**Figure 3(a)**) shows that the studied gabbros are depleted in Cr, Cu, Zr and Ni and enriched in the other element. The REE pattern of the studied gabbronorite and anorthosite (**Figure 3(b)**) are very similar to each other and similar to that of calc-alkaline rocks.

3.1. Typology

The studied gabbroic rocks are chemically classified using the following relationships: On the normative Ab-An-Or diagram (**Figure 3(c)**) according to Streckeisen, (1976) [10], the studied younger gabbros plot in the gabbro diorite field. On the ($Na_2O + K_2O$) vs. SiO_2 diagram (**Figure 3(d)**) according to Wilson, 1989 [14] all the analyzed rocks plot in the field of gabbro

3.2. Magam Type

On the relation between Alk, vs. SiO_2 (**Figure 3(d)**) the gabbros plot in the sub alkaline (calc-alkaline) field. The Same conclusion is reached on plotting the analyses of the studied gabbro on Zr vs. P_2O_5 diagram (**Figure 3(e)**) according to Winchester and Floyd, 1977 [15], where they plot in sub alkaline field. In the relation between FeO vs. (FeO*/MgO), according to Miyashiro, 1975 [16] (**Figure 3(f)**) the younger gabbros plot in the calc-alkaline field. In conclusion the younger gabbro of Wadi Shianite area originated from a calc-alkaline magma source similar to other younger gabbro in different areas in the Eastern Desert of Egypt (Takla *et al*., 2002) [9].

3.3. Tectonic Setting

The tectonic setting of the studied gabbroic rocks can be predicted by using TiO_2-K_2O-P_2O_5 ternary diagram (Pearce *et al*. 1975) [17]. On this diagram the studied gabbros plot in the continental field (**Figure 4**).

3.4. Mineral Chemistry

3.4.1. Pyroxene

The mineral analyses for the clino-pyroxenes are presented in **Table 4(a)**. In relation between Q = Ca + Mg +

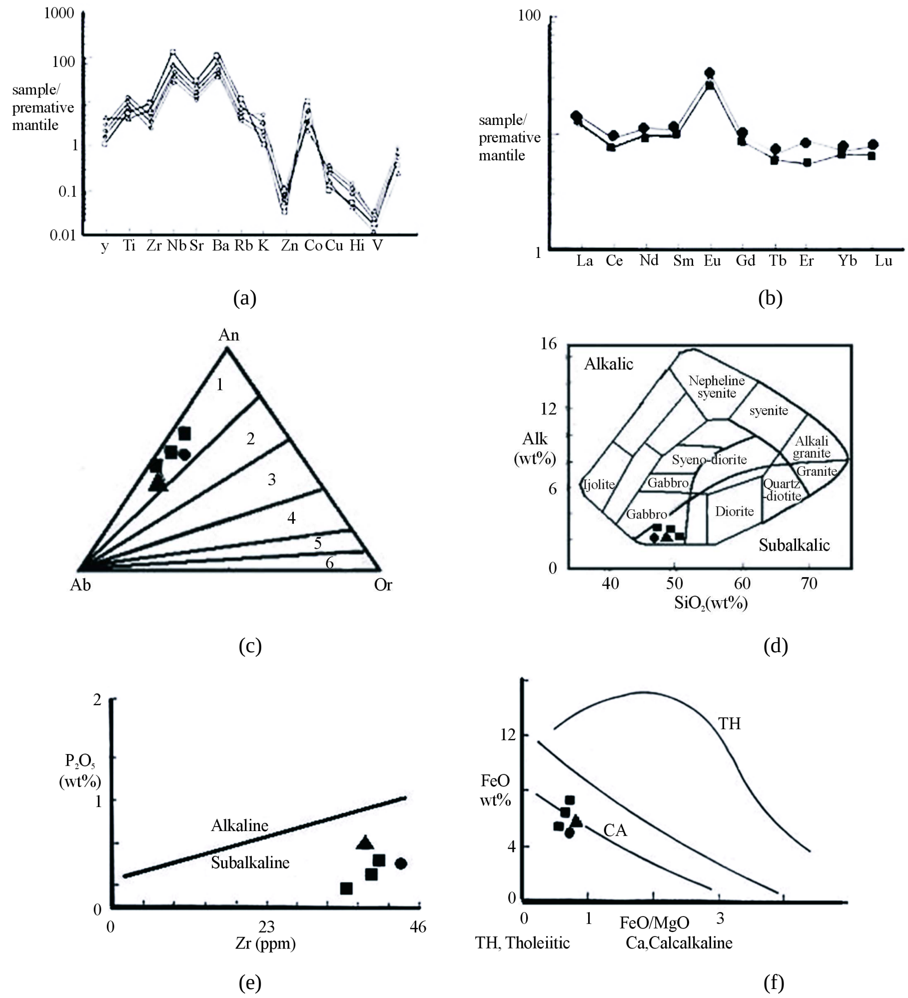

Figure 3. Geochemical characteristics of the studied younger gabbros from Wadi Shianite area. (a) Spider diagram for trace elements (b) REE pattern (c) Ab-An-Or diagram (Streckeisen, 1976) (d) (Na_2O+K_2O) vs SiO_2 (Wilson, 1989) (e) Zr-P_2O_5 diagram (Winchester and Floyd, 1977) (f) FeO/MgO-FeO* diagram (Miyashiro, 1975) (symbols as **Figure 2**).

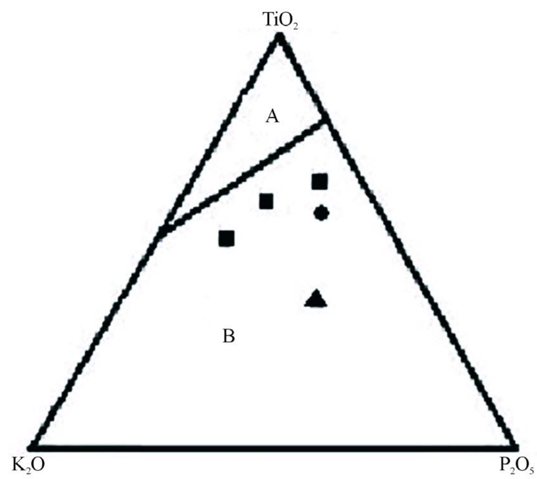

Figure 4. Tectonic discrimination plot for the studied younger gabbros. TiO_2-K_2O-P_2O_5 diagram (Pearce *et al*. 1975). (A) Oceanic field; (B) continental field (symbols as **Figure 2**).

Table 4. Chemical composition and structural formula for (a) clino-pyroxene, (b) hornblende, and (c) plagioclase of the younger gabbros of Wadi Shianit area, South Eastern Desert, Egypt.

(a)

Spot No.	1	2	3	4	5	6
Major oxides wt% recalculated to 100%						
SiO_2	48.16	48.68	50.42	47.54	51.01	49.92
TiO_2	0.72	0.54	0.29	0.59	0.24	0.62
Al_2O_3	1.06	0.78	1.58	1.79	0.94	0.92
FeO*	27.64	22.53	23.06	28.18	25.93	23.10
MnO	0.12	0.59	0.52	0.81	0.24	0.64
MgO	3.53	16.18	14.58	11.24	12.11	9.86
CaO	18.50	9.90	9.45	9.27	9.20	14.4
Na_2O	0.23	0.65	0.07	0.23	0.11	0.44
K_2O	0.04	0.15	0.03	0.05	0.04	0.1
Total	100	100	100	100	100	100
Cations on basis of 6 oxygens						
Si	1.841	1.827	1.929	1.946	1.968	1.935
Ti	0.022	0.026	0.009	0.027	0.009	0.025
Al	0.051	0.034	0.067	0.083	0.029	0.465
Al	0.051	0.039	0.009	0.055	0.029	0.015
Al	0.00	0.00	0.00	0.028	0.00	0.00
Fe	0.915	0.615	0.713	0.888	0.030	0.602
Mn	0.019	0.019	0.016	0.027	0.010	0.018
Mg	0.211	0.925	1.21	0.651	0.832	0.733
Ca	0.826	0.417	0.095	0.362	0.858	0.526
Na	0.017	0.048	0.004	0.018	0.035	0.024
K	0.002	0.080	0.00	0.003	0.002	0.021

(b)

Spot No.	1	2	3	4
Major oxides wt% recalculated to 100%				
SiO_2	32.19	30.38	38.27	30.97
TiO_2	0.011	0.002	0.18	0.002
$Al2O_3$	20.23	19.43	17.58	20.33
FeO*	27.15	30.12	25.22	28.34
MgO	18.26	16.87	16.89	16.62
CaO	0.018	0.017	0.519	0.418
Na_2O	2.24	3.21	1.32	3.32
K_2O	0.011	0.012	0.012	0.011
Total	100	100	100	100
Cations on basis of 32 oxygens				
Si	4.68	4.45	5.65	4.54
Ti	0.011	0.01	0.389	0.011
Al	3.07	2.97	2.539	3.12
Al	2.05	1.98	2.009	2.74
Al	1.05	0.98	0.531	0.48
Fe	3.44	3.69	2.74	3.57
Mg	3.98	3.68	1.72	3.69
Ca	0.001	0.001	0.08	0.07
Na	0.64	0.91	0.38	0.95
K	0.001	0.001	0.001	0.002

(c)

Spot No.	1	2	3	4
Major oxides wt% recalculated to 100%				
SiO_2	51.64	48.09	51.75	50.62
TiO_2	0.04	0.00	0.04	0.03
Al_2O_3	28.90	31.24	30.07	31.48
FeO*	0.47	0.27	0.38	0.45
MgO	0.08	0.21	0.16	0.12
CaO	13.65	16.45	13.12	12.45
Na_2O	5.01	3.57	4.29	4.65
K_2O	0.21	0.17	0.19	0.20
Total	100	100	100	100
Cations on basis of 8 oxygens				
Si	9.55	8.89	9.25	9.42
Al	6.32	6.93	0.67	6.55
Fe	0.079	0.047	0.083	0.031
Mg	0.072	0.085	0.099	0.051
Ca	1.476	0.953	1.47	1.50
Na	2.37	3.32	2.64	2.68
K	0.039	0.04	0.035	0.027
An	62.45	72.72	69.28	65.70
Ab	36.30	21.99	29.58	33.10
Or	1.24	0.96	1.13	1.70

FeO and J = 2Na (plot **Figure 5(a)**) according to Morimoto *et al*. (1988) [18], the data plot at Q + J between 1.5 - 2.00. In the $CaSiO_3$ (Wo), $MgSiO_3$ and $FeSiO_3$ triangular diagram (**Figure 5(b)**) according to Deer *et al*. (1992) [19] the clino-pyroxene fall in Fe-augite field. On TiO_2 vs. Al_2O_3 diagram (**Figure 5(c)**) according to Le Bas (1962) [20] the studied clino-pyroxene plotted in Tholeitic + Calc-alkline figure.

3.4.2. Amphiboles (Hornblende)

The mineral analyses for the hornblende are given in **Table 4(b)**, which shows that some hornblende crystals are rich in CaO and other rich in Na_2O, except one sample with high TiO_2 content (3.62 wt%). Basta (1988) [21] indicated that the primary hornblende in the younger gabbros of Sinai are rich in TiO_2 (>1.5%) while the secondary hornblende is poor in TiO_2.

On Si vs. (Na + Ka) diagram (**Figure 5(d)**) according to Leak (1978) [22], the majority of samples plot in the ferroan pargastic hornblende field and one sample plot in tschermakitic field.

3.4.3. Plagioclases

Plagioclase is ubiquitous mineral in all the studied samples. The mineral compositions are given in **Table 4(c)**. Or-Ab-An ternary diagram (**Figure 5(e)**) according to Deer *et al*. (1992) [19] shows that the studied plagioclase analyses plot in the labradorite (An 63) and bytownite (An 76) fields.

In conclusion the gabbro of the studied area are pertain to the Egyptian younger gabbros (Takla *et al*., 1981 [3]) because they contains fresh pyroxene, brown hornblende and fresh plagioclase. The younger gabbro of the studied area is produced from calc-alkaline magma in continental setting similar to the younger gabbros of Samut-Atud (El Mansi, 1996) [6].

4. Conclusions

The study of the younger gabbros in wadi Shianite area is classifieds into: pyroxene hornblende gabbronorite,

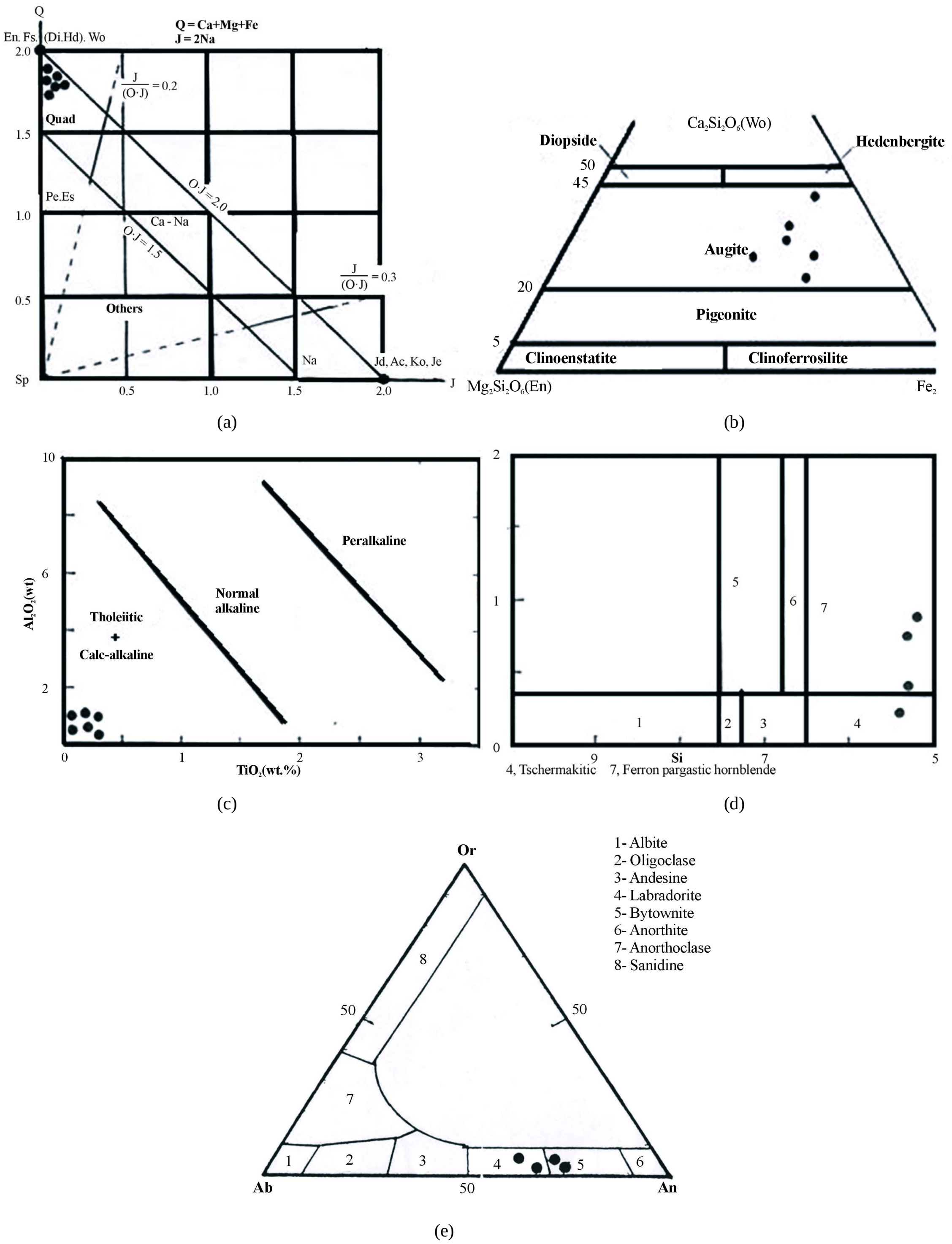

Figure 5. Mineral analyses of selected mineral phase of the younger gabbros. (a) Q-J diagram (Morimoto *et al*. 1988); (b) $CaSiO_3$-$MgSiO_3$-$FeSiO_3$ diagram (Deer *et al*. 1992); (c) Al_2O_3-TiO_2 diagram (La Bas, 1962); (d) Si – (Na + K) digram (Leak, 1978); (e) Or-Ab-An diagrame (Deer *et al*. 1992).

hornblende gabbro and anorthosite. Pyroxene hornblende gabbronorite is the predominant type; it has hypidiomorphic granular texture and less common porphyritic texture. It consists of plagioclases, pyroxenes (hypersthenes and augite), brown hornblende and biotite. Hornblende gabbro is a coarse to medium grained rock composed of plagioclase, brown hornblende and biotite. Opaque and apatite are accessories. Anorthosite is idiomorphic and granular. It is composed mainly of plagioclase and diallage.

From the study of the opaque mineralogy it is cleared that the opaque minerals in the younger gabbros range from 1% to 11%. They are composed mainly of ilmenite and magnetite. The opaque minerals indicate that they are belonging to younger gabbros of Egypt (Takla, 1971 [1]; and Basta and Takla, 1974) [2].

Geochemically, the studied gabbros are similar to the younger gabbros of Egypt (Takla *et al*., 1981 [3]). They are sub alkaline formed in a continental arc setting. The pyroxene chemistry (augite) indicates that the host rocks are sub alkaline similar to conclusion reached from the whole-rock geochemistry.

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