Geochemical Analysis of Igneous Rocks in the middle part of Katan Island, Kyunsu Township, Myeik District, Tanintharyi Region, Myanmar

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Abstract

Geology and geochemical studies were carried out on the middle part of Katan Island, west of Myeik in the Kyunsu Township, Tanintharyi Region, (Latitudes 12°24'00" N to12°30'00"N and Longitudes 98°19'00" E to 98°27'50" E) and map no.95 L/7. The total coverage is approximately 114.8 km^2. According to granite province of South East Asia, the study area lies within the western granite province. The study area is the part of the Central Granitoid Belt. The rock sequences of the study area are quartzite and mudstone intercalated with sandstone and pebbly mudstone of metasedimentary rocks (Mergui Group), and sandstone and shale alternation (Namyau Group), and igneous rocks are dacite porphyry, porphyritic biotite granite, hornblende biotite granite. All the granite bodies are parallel to the general trend of mountain ranges, approximately NNW-SSE. Sandstone and shale alteration unit (Namyau Group) occurs in the eastern part of the study area. The mudstone intercalated with sandstone unit occurs as some brachiopod fossils which indicates that Late Carboniferous to Early Permian. Pebbly mudstones or diamictites units were occurred. Geochemically, the XRF results of granitic rocks show that the SiO_2 ranges, 63.30-66.80 Wt.% corresponding to an intermediate to acidic composition and total alkali contents (Na_2O+K_2O) of 10.96-14.57 Wt. % with an average of 12.01 Wt.%. In A/NK (molecular Al_2O_3/Na_2O+K_2O) *Vs* A/CNK (molecular $Al_2O_3/CaO+Na_2O+K_2O$) diagram showed that all samples fall within the metaluminous to slightly peraluminous field. The SiO_2-FeO_t /MgO plot diagram showing the granitic rocks fall in the calc-alkaline series. The molecular A/CNK *Vs* A/NK diagram show that the discrimination field for different types of granitic rocks fall in S-type affinity. According to R_1-R_2 binary tectonic discrimination diagram show that they fall in Late Orogenic Zone. The liquidus temperature of granitic rocks are 680^0C to 710^0C, respectively and those crystallized at the depth between 21 km and 25 km. The magma may be emplaced by forceful injection. The depth of the granitoid pluton has mesozonal characters of Buddington's depth zone. According to the trace elements, the granitic rocks have a lot of REEs composition.

Keywords: Calc-alkaline, metaluminous, granitoid, peraluminous, liquidus temperature, S-type

Introduction

The study area is located about 10 miles west of Myeik in the Kyunsu Township, Tanintharyi Region. It is bounded by Latitudes 12°24'00" N to 12°30'00" N and Longitudes 98°19'00" E to 98°27'50" E. It also lies between vertical grids 26-42 and horizontal grids 71-82, and covers part of the one inch topographic map no.95 L/7. The total coverage of approximately 114.8 km^2 shown in figure (1). Physiographically, the western and middle parts of the study area is the higher than the eastern part. The central and northern terrains are more rugged with high relief shown in figure (2). The dominant drainage pattern in the study area can also be observed dendritic type and the sub-dendritic drainage pattern shown in figure (3).

The objectives of the investigation are

1. To prepare the geological map of the study area,
2. To establish the rock sequence,
3. To study the nature, distribution and lithology of the rock units and
4. To describe the geochemical analysis of igneous rocks.

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Materials and Methods

Field Works

Systematic sampling of the representative rock units, measuring geological structures and geological mapping have been carried out by using GPS. The geological data, which are collected from the field, are plotted on the quarter inch topographic map.

Laboratory Works

Total of ten samples from the study area were selected and analysed by XRF. The triangular diagrams were carried out by using GCD kit 3.0 software, SPSS.16 and petrographic software. Modal analyses were made for the samples and the results of the samples plot on IUGS classification diagram (Streckeisen, 1973). Standard C.I.P.W norm and C.I.P.W norm with biotite and hornblende are calculated according to the rules of Hutchison, 1975. The results are shown in Table (3) while Triangular plots were carried out by Tridraw software.

Regional Geologic Setting

Tanintharyi Region is composed of north-south trending, narrow, mountainous and coastal stretch of the mainland part of Myanmar which is referred to either as the Shan-Tanintharyi massif or as the Eastern Highlands Province (Searle and Ba Than Haq, 1964). The granitoids crop out in three north-south trending belts along Thai-Myanmar border on the east, along the central range of hills, and the last isolated islands and high islands on the west (Dr. Win Swe, 2012), shown in figure (4).

Geology of the Study Area

The Shan-Tanintharyi block is mainly constituted of sedimentary and metasedimentary units of Precambrian to Mesozoic Age. The study area is mainly composed of sandstone and shale alternation (Namyau Group), metasedimentary rocks (mudstone intercalated with sandstone and pebbly mudstone, and quartzite in Mergui Group) and igneous rocks (dacite porphyry, porphyritic biotite granite and hornblende biotite granite), shown in figure (5).

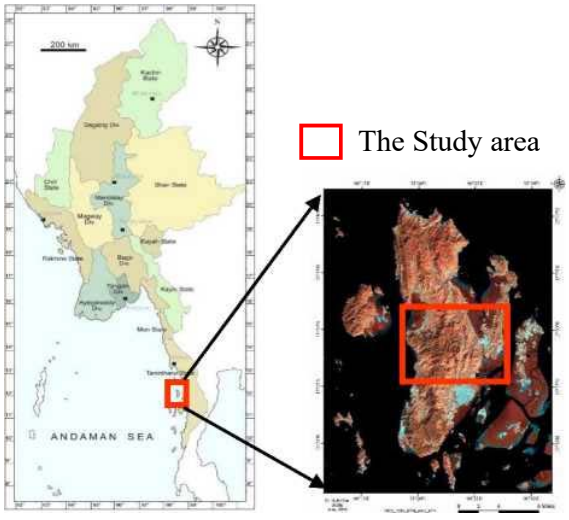

Figure (1). Location map of the study area.

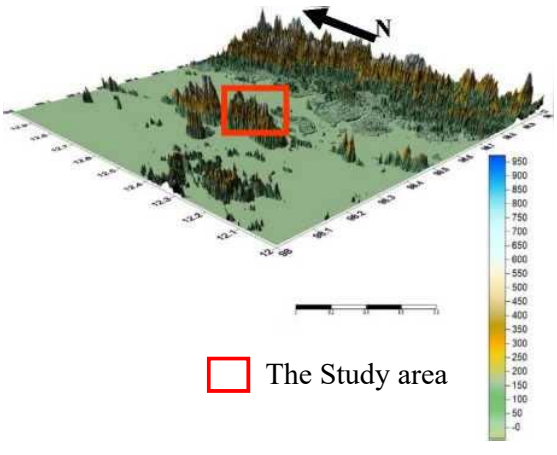

Figure (2). Three dimensional DEM map of the study area.

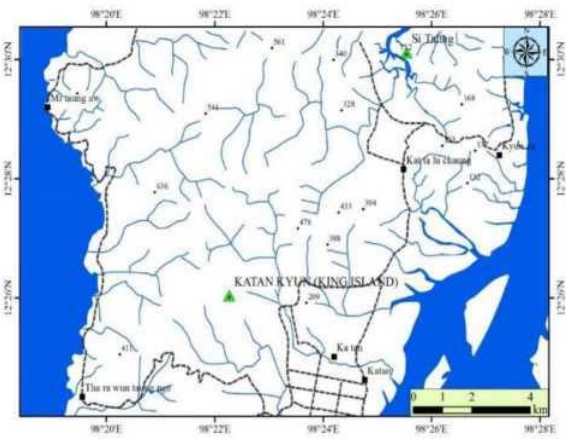

Figure (3). Drainage pattern of the study area

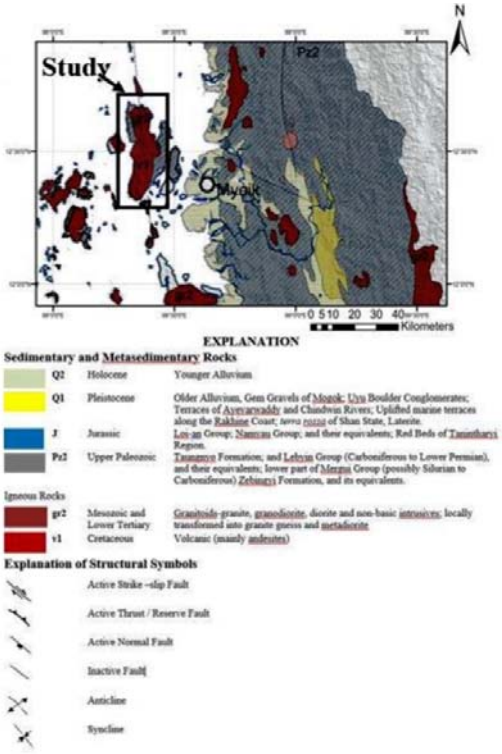

Figure (4). Regional Geologic Setting of the study area and its environs
(After Geosciences Society Geological Map of Myanmar, 2014)

Rock Sequences of the Study Area

- Younger Alluvium	Holocene	Quaternary
- Older Alluvium	Pleistocene	

Igneous Rocks

- Dacite porphyry - Porphyritic biotite granite - Hornblende biotite granite	Paleocene

Sedimentary Rocks (Namyau Group)

- Sandstone & shale alternation	Jurassic

Metasedimentary Rocks (Mergui Group)

-Mudstone intercalated with sandstone and pebbly mudstone - Quartzite	Late Carboniferous to Early Permian

- Age of Mergui Group reference from Dr. Maung Thein, Correlation Table (2014)
- Age of igneous rocks reference from Ph D Thesis of Dr. Su Su Hlaing (2014)

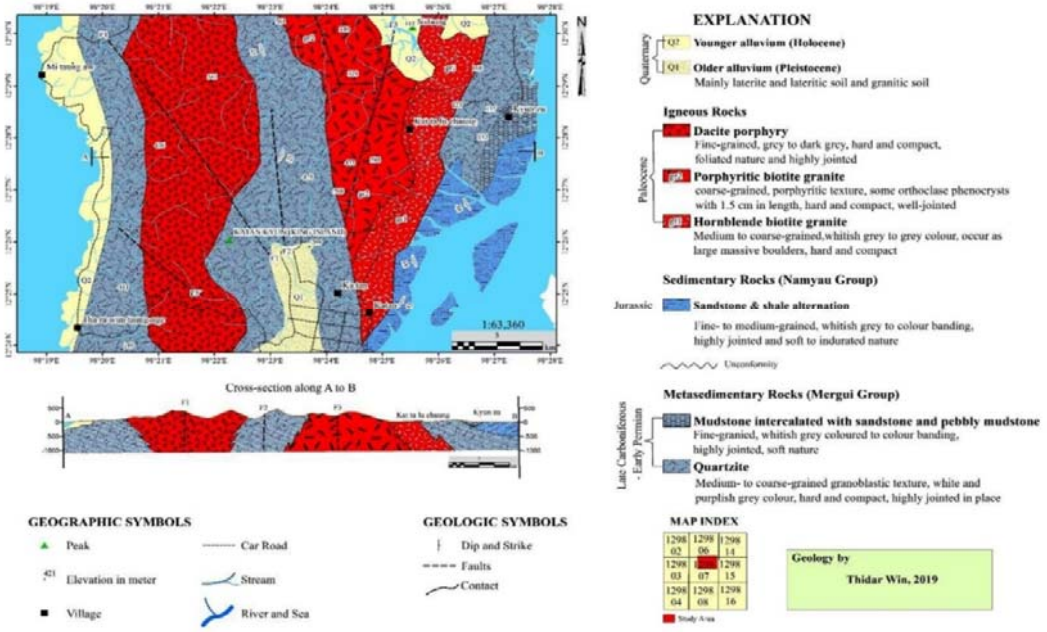

Figure (5). Geological Map of the middle part of Katan Island, Kyunsu Township, Myeik District, Tanintharyi Region

Geochemical Analysis of Igneous Rocks

Analytical Data

The compositions of the representative samples of igneous rocks from the study area are shown in figure (6) and in Table (1). The weight-percent oxide, molar-percent, and normative-percent were calculated and were plotted in variation diagrams, binary diagrams and ternary diagrams which were drawn by using GCDkit 3.0 software and PetroGraph2.0 beta software.

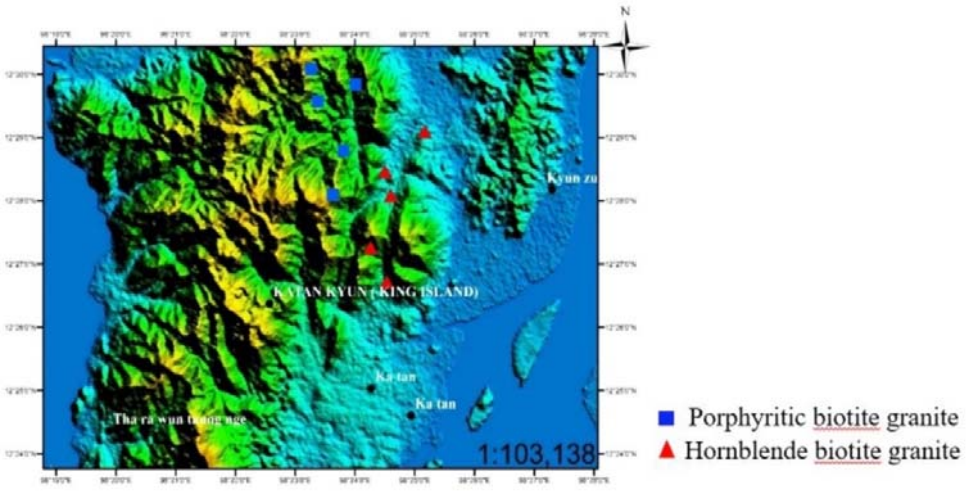

Figure (6). Location map of the analyzed rock samples from the study area

Table (1). Location of the analyzed granitic samples from the study area

Sample No.	Symbol	Lithology	Location
TDW 01	■	Porphyritic biotite granite	N 12°28'05" E 98°23'37"
TDW 02	■	Porphyritic biotite granite	N 12°28'47" E 98°23'48"
TDW 03	■	Porphyritic biotite granite	N 12°29'34" E 98°23'22"
TDW 04	■	Porphyritic biotite granite	N 12°30'05" E 98°23'16"
TDW 05	■	Porphyritic biotite granite	N 12°29'50" E 98°24'00"
TDW 06	▲	Hornblende biotite granite	N 12°27'15" E 98°24'15"
TDW 07	▲	Hornblende biotite granite	N 12°28'05" E 98°24'35"
TDW 08	▲	Hornblende biotite granite	N 12°28'28" E 98°24'30"
TDW 09	▲	Hornblende biotite granite	N 12°29'05" E 98°25'10"
TDW 10	▲	Hornblende biotite granite	N 12°29'35" E 98°24'40"

Chemical characteristics of Igneous Rocks

Table 2 shows the major elements composition of porphyritic biotite granite and hornblende biotite granite. The SiO2 contents ranges between 63.30 and 66.80 Wt.% (Average 65.32 Wt.%) corresponding to an intermediate to acid composition.

According to XRF geochemical analysis data indicates SiO2 (63.30-66.80 Wt.%), TiO2 (0.12- 0.65 Wt.%), M2O3 (16.10- 22.20 Wt.%), Fe2O3 as total iron (0.57-2.35 Wt.%), MnO (0.12-0.65 Wt.%), MgO (0.42-6.275%). CaO (0.446-2.456%), Na2O (0.473-2.364%), K2O (0.02-7.46 Wt.%) and P2O5 (0.01-0.46 Wt.%) .The bulk rock concentration of the granitic rocks is characterized by high SiO2, and MnO and P2O5 concentrations are less than 0.5 Wt.%. In silica variation diagram, major oxides (ALO3, Fe2O3, MgO, CaO and K2O) show negative linear trends with SiO2 but the positive trend of TiO2, MnO, Na2O and P2O5 shown in figures (7) and (8).

The R1-R2 diagram of De La Roche et.al (1980) classification of plutonic rocks based upon their cation proportions, expressed as millications are plotted on an X-Y binary diagram using the plotting parameters, R1=4Si-11(Na+K)-2(Fe+Ti) and R2=6Ca+2Mg+A1. The granitic rocks of the study area confined to the granite and alkali granite field shown in figure (9). With reference to the P-Q diagram of Debon and Le Fort (1983) the rocks of the study area fall in granite field shown in figure (10).

The SiO2-FeOt/MgO plot diagram (After Miyashiro 1974) showing the granitic rocks from the study area fall in the calc-alkaline series shown in figure (11). The SiO2 *Vs* K2O plot after Peccerillo and Taylor (1976) of figure (12) show that the granitic rocks of the study area fall in the high potassium calc-alkaline series and shoshonite series. The plot of AFM diagram from Irvine and Baragar (1971) indicating A= (Na2O+K2O), F= Fe2O3 (as total iron) M= MgO) is shown in figure (13) that subdivides the sub alkaline magma series to tholeiitic and Calc- alkaline series indicated that all samples fall in the calc-alkaline series.

In A/NK (molecular Al2O3 / Na2O+ K2O) *Vs* A/CNK (molecular Al2O3/ CaO+Na2O+ K2O) diagram after Shand (1943) of Fig. 4.9, the majority of all samples fall within the metaluminous to slightly peraluminous field (After Shand, 1943) shown in figure (14).

Table (2). Major oxide (Wt.%) and trace elements (ppm) abundances of the granitic rocks from the study area

Name	**Porphyritic biotite granite**					**Hornblende biotite granite**				
Sample No.	**TDW 01**	**TDW 02**	**TDW 03**	**TDW 04**	**TDW 05**	**TDW 06**	**TDW 07**	**TDW 08**	**TDW 09**	**TDW 10**
SiO_2	66.3	64.4	65.7	66.8	63.7	65.2	63.3	65.8	65.7	66.3
TiO_2	0.13	0.27	0.26	0.65	0.26	0.14	0.18	0.12	0.23	0.13
AI_2O_3	19.90	18.90	16.10	16.80	20.60	18.50	22.20	17.30	19.30	17.90
Fe_2O_3	0.97	0.85	1.69	0.93	2.35	0.85	0.68	0.81	0.89	0.57
MnO	0.32	0.02	0.02	0.03	0.02	0.04	0.03	0.03	0.03	0.03
MgO	0.42	0.62	1.51	0.75	1.71	0.69	0.61	0.63	0.48	0.50
CaO	2.74	2.83	3.09	3.45	2.98	2.83	2.77	3.29	3.46	3.03
N_2O	3.47	3.55	4.03	5.36	3.56	4.58	4.48	5.55	3.83	4.43
K_2O	5.13	5.45	7.46	3.95	3.71	5.56	5.05	6.09	5.65	6.13
P_2O_5	0.11	0.46	0.12	0.43	0.15	0.27	0.26	0.21	0.26	0.21
Total	**99.40**	**97.34**	**99.97**	**99.15**	**99.04**	**98.54**	**99.55**	**99.73**	**99.83**	**99.14**
S	67.00	50.00	368.0	90.00	865.0	130.0	580.0	43.00	620.0	67.00
Cr	77.00	31.00	66.00	99.00	70.00	58.00	51.00	88.00	86.00	77.00
Zn	25.00	20.00	22.00	36.00	225.0	12.00	26.00	18.00	22.00	25.00
As	15.00	30.00	38.00	23.00	23.00	61.00	8.00	8.00	45.00	15.00
Rb	93.00	133.0	72.00	115.0	26.00	135.0	142.0	112.0	148.0	93.00
Sr	57.00	46.00	44.00	73.00	21.00	63.00	52.00	583.0	30.00	57.00
Zr	73.00	634.0	194.0	562.0	19.00	18.00	50.00	67.00	70.00	73.00
Ba	9.00	9.00	9.00	9.00	9.00	9.00	9.00	286.0	98.00	9.00
Y	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The geological values of granitic rocks from the study area fall in the felsic peraluminous and high peraluminous fields of B= Fe+ Mg+ Ti *Vs* A=Al-(K+Na+2Ca) diagram of Debon and Le Fort (1983), shown in figure (15). In the primitive mantle (Sun & McDonough, 1989) normalize trace elements spider diagram shown in figure (16), the granitic rocks are characterized by strong depletion of Y and enrichment of Cr, Rb, Ba, Sr, and Zr. ACF diagram, Figure (17) and A/CNK *Vs* SiO2 diagram Figure (18) suggested that the granitic rocks of the study area fall within the model of S type field. Moreover, mol. A/CNK>1.1, relatively low Na2O content when compared to K2O in weight percent, CaO content is less than 3.7% and trace element Zr is greater than 150 ppm suggest that S-type characteristics.

Condition of the crystallization of the Igneous Rocks

If the igneous rocks have crystallized at minimum pressure of 2kb, their liquids temperature could have been formed as shown in differentiation index and 2kb water pressure diagram. From this diagram, the liquidus temperature for hornblende biotite granite at between 680^{o}C and 700^{o}C and for prophyritic biotite granite at between 690^{o}C and 710^{o}C, shown in figure (19). According to figure (20), depth-temperature relation diagram of Marmo (1969), hornblende biotite granite will probably crystallized at the depth of 21 km to 23 km and porphyritic biotite granite fractionated at between 23 km and 25 km.

Tectonic Discrimination of the Granitic Rocks (Using major elements)

The granitoid rocks classified according to the tectonic environments of Maniar and Piccoli (1989) are as follows:

Orogenic Granitoids	(a) Island Arc Granitoid (IAG)
	(b) Continental Arc Granitoid (CAG)
	(c) Continental Collision Granitoid (CCG)
	(d) Post Orogenic Granitoid (POG)
Anorogenic Granitoids	(e) Rift-Related Granitoid (RRG)
	(f) Continental Epiorogenic Uplift Granitoid (CEUG) and
	(g) Oceanic Plagio-granite (OP)

SiO2 *Vs* K2O variation diagrams are shown to classify the tectonic environment into IAG+CAG+CCG+RRG+CEUG and OP. In SiO2 *Vs* FeOt/(FeOt+MgO) variation diagram shows the granitic rocks of the study area fall within IAG+CAG+CCG and POG field, figure (21).

Tectonic discrimination of Granitic Rocks (Using trace elements)

Pearce (1996) distinguished source of granitic rocks in various tectonic settings on the basis of trace elements data. They are;

(a) Ocean ridge granites (ORG),

(b) Volcanic arc granites (VAG),

(c) Within plate granites (WPG) and

(d) Syn-collision granites, Post-collision granite } COLG

Batchelor and Bowden (1985), used to discriminate the tectonic setting of granite according to R1-R2 binary (in millications) diagram. In this diagram, the porphyritic biotite granite and hornblende biotite granite correspond to Late Orogenic Zone, figure (22).

Summary & Conclusion

The study area lies about 10 miles west of Myeik in the Kyunsu Township, Tanintharyi Region. It is bounded by latitudes 12°24'00" N to12°30'00"N and longitudes 98°19'00" E to 98°27'50"E. Tanintharyi Region is composed of north-south trending, narrow, mountainous and coastal stretch of the mainland part of Myanmar which is referred to either as the Shan- Tanintharyi massif or as the Eastern Highlands Province The Shan-Tanintharyi block is mainly constituted of sedimentary and metasedimentary units of Precambrian to Mesozoic Age. The study area is mainly composed of sandstone and shale alternation (Namyau Group), metasedimentary rocks are mudstone intercalated with sandstone and pebbly mudstone, and quartzite in Mergui Group and igneous rocks are dacite porphyry, porphyritic biotite granite and hornblende biotite granite of the study area.

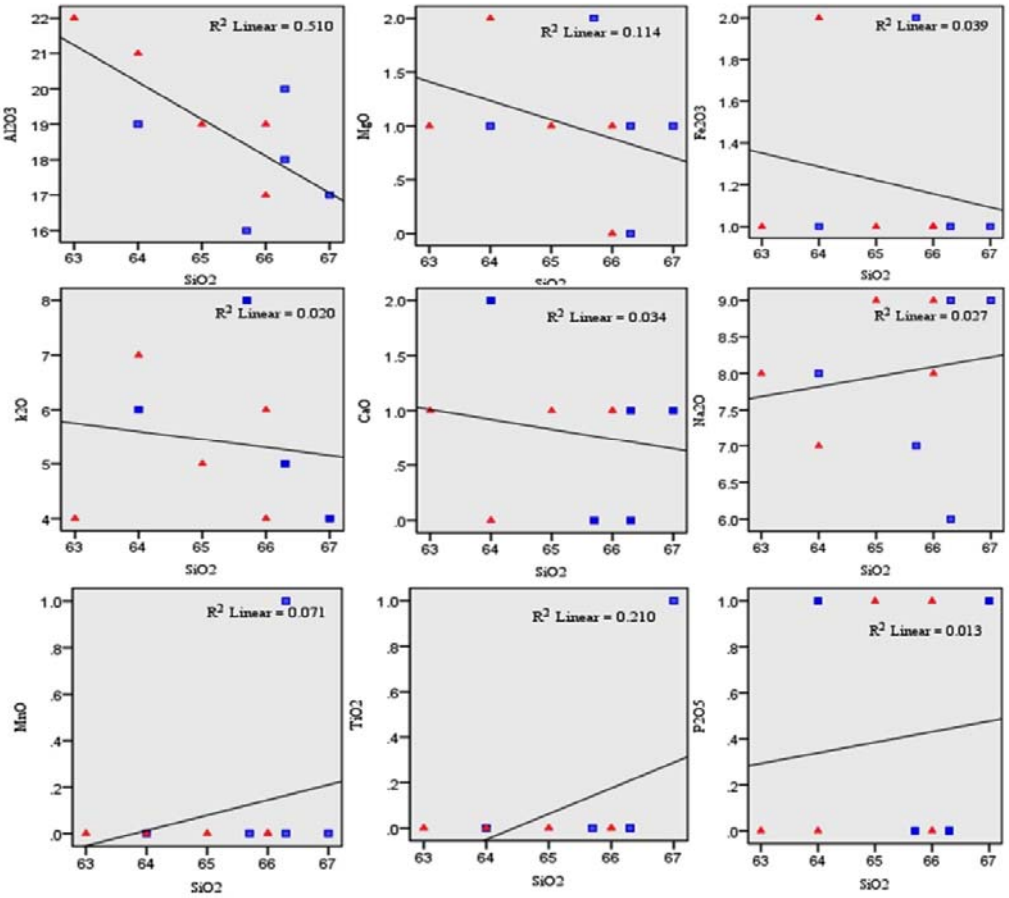

Figure (7). Harker's variation diagrams; silica (SiO2 Wt.%) plotted against a range of major oxides (in Wt.%) for the granitic rocks of the study area. Symbols as in Table (2).

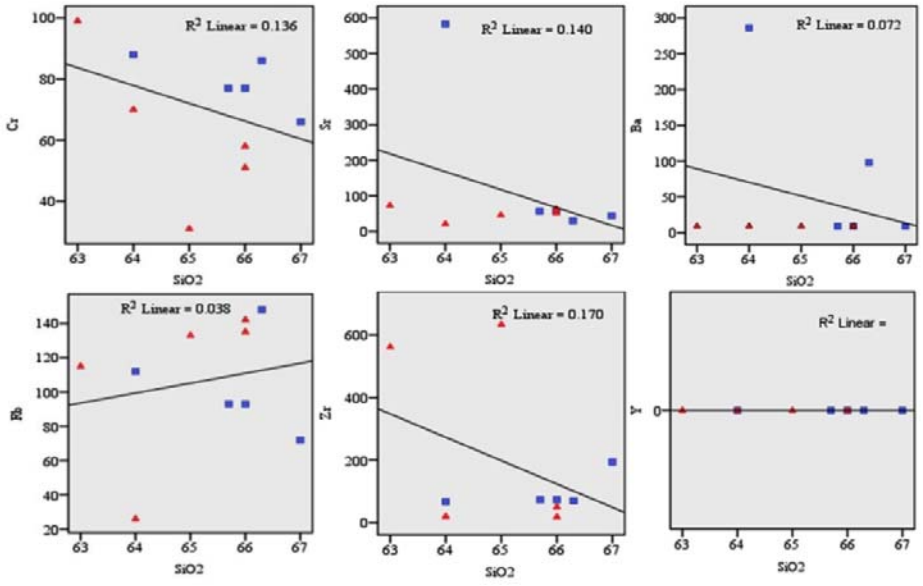

Figure (8). Harker's variation diagrams for trace elements *Vs* SiO2 in the granitic rocks of the study area. Symbols as in Table (2).

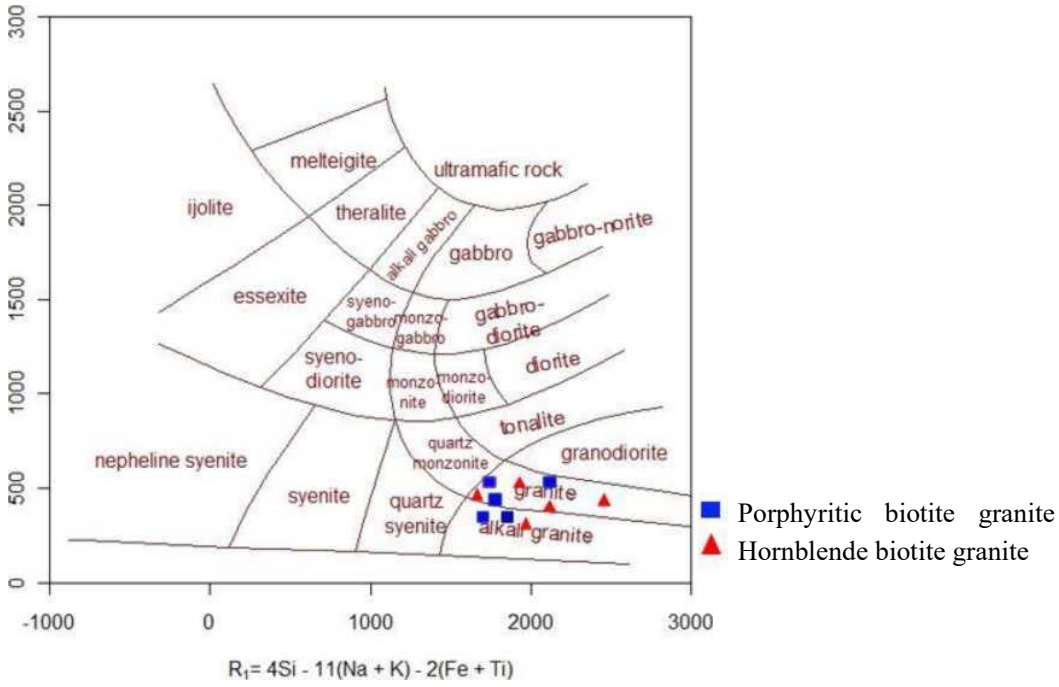

Figure (9). R1-R2 millication classification diagram for the granitic rocks of the study area (Source: De La Roche et.al.1980)

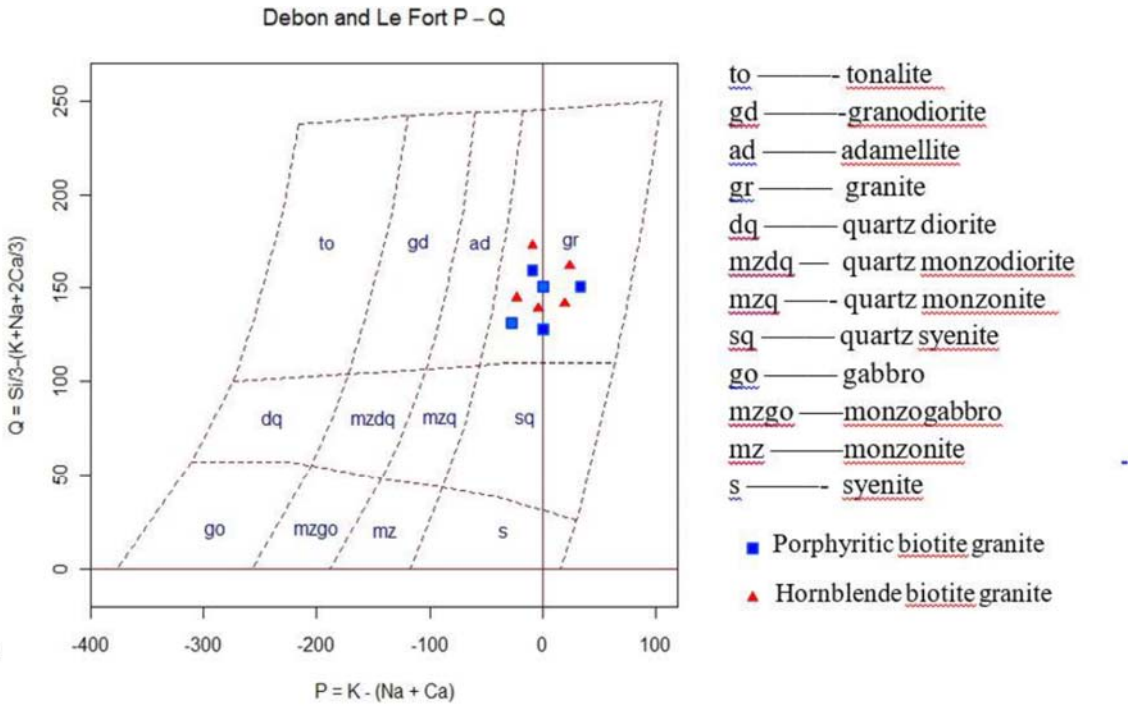

Figure (10). P-Q diagram of Debon and Le Fort (1983) showing the field of igneous rocks of the study area

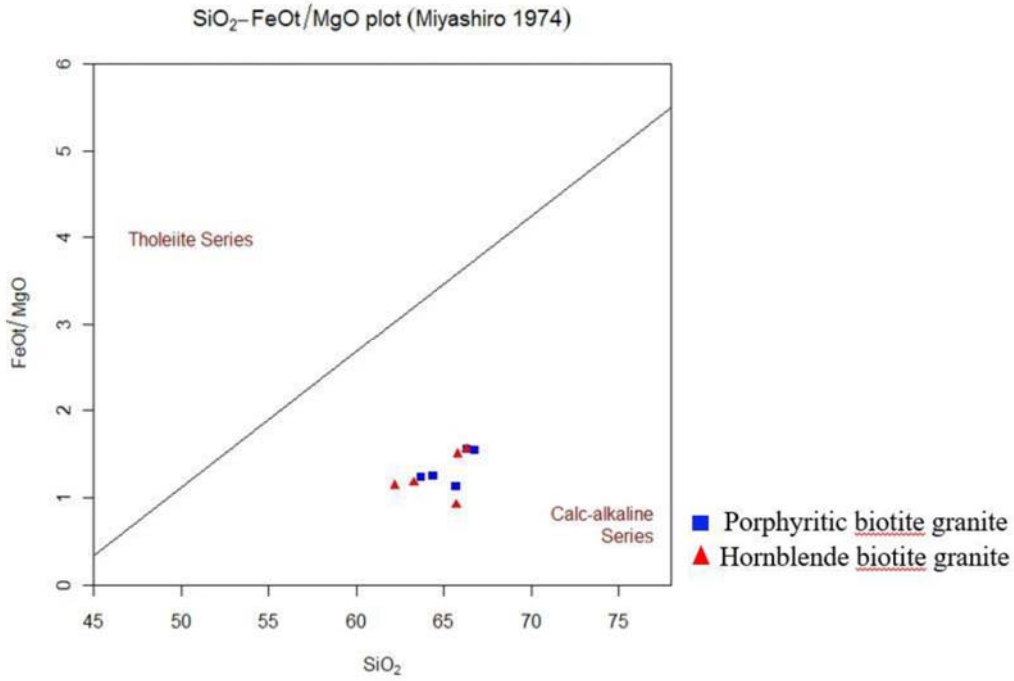

Figure (11). SiO2 -FeOt/MgO plot diagram showing the granitic rocks from the study area fall in the calc-alkaline series (After Miyashiro 1974)

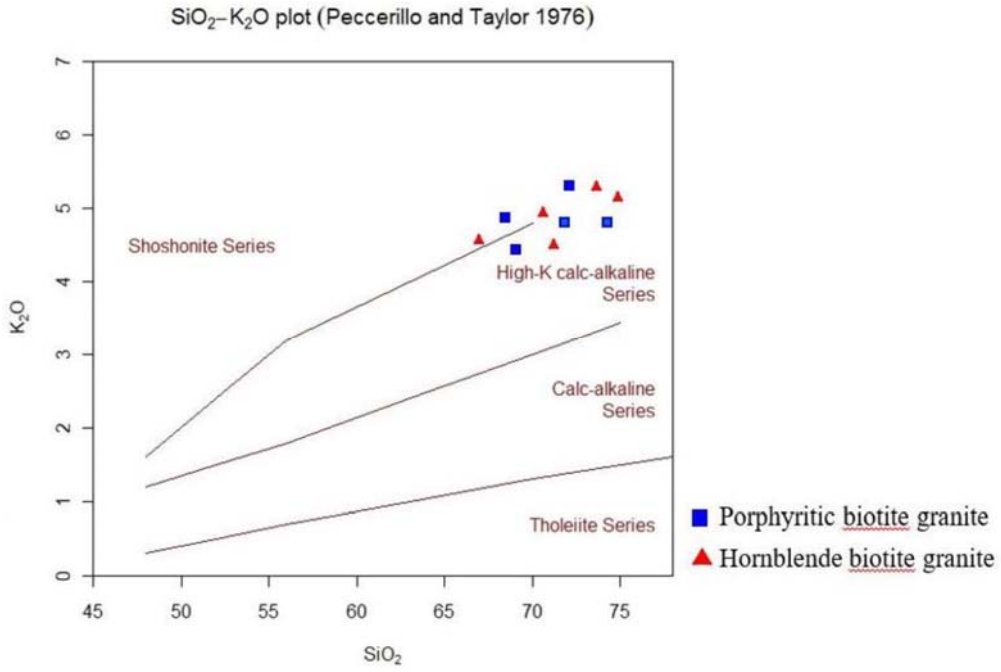

Figure (12). SiO2 +K2 diagram showing the high-K calc-alkaline series to shoshonite Series (According to Peccerillo and Taylor, 1976)

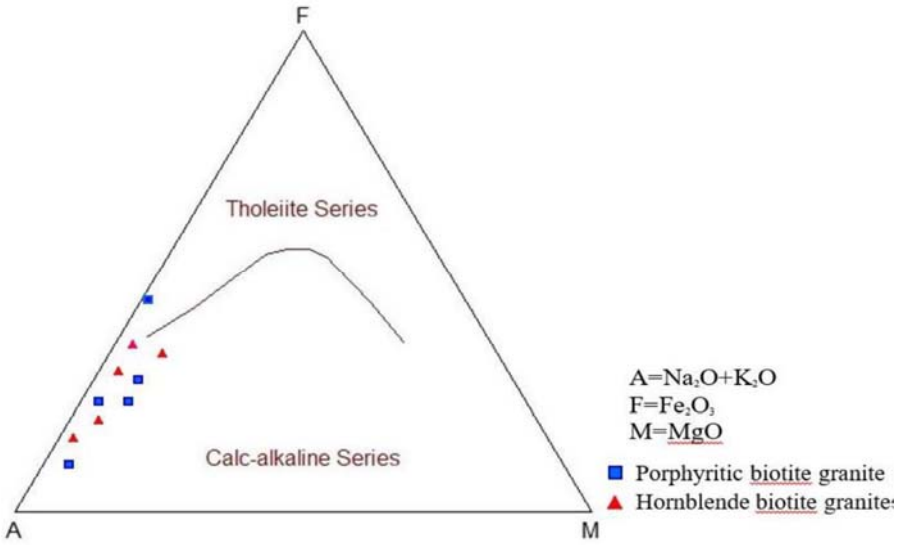

Figure (13). AFM diagram indicates the subdividing of the sub alkaline magma series to tholeiitic and calc-alkaline series (After Ivrine and Baragar, 1971)

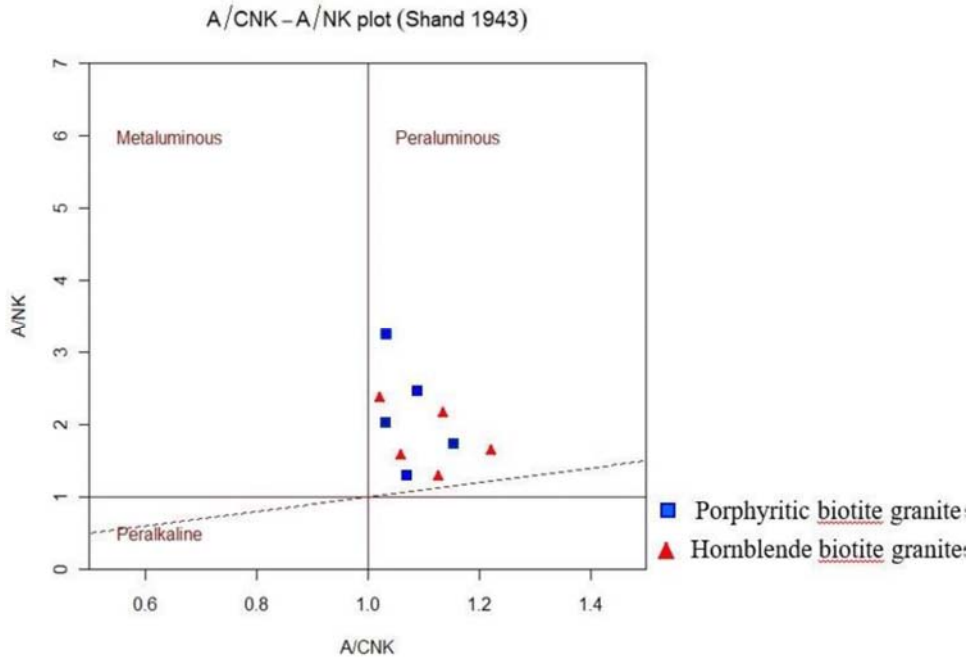

Figure (14).A/NK (molecular Al_2O_3/Na_2O+K_2O) *Vs* A/CNK (molecular $Al_2O_3/CaO+Na_2O+K_2O$) diagram showing the peraluminous and metaluminous (After Shand, 1943)

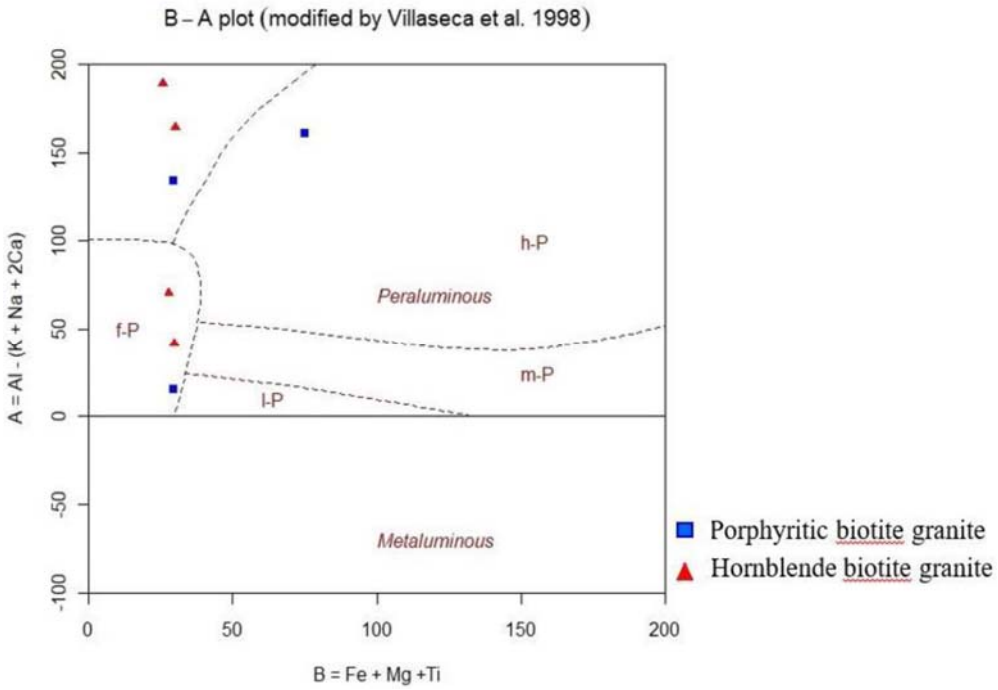

Figure (15). B=Fe+Mg+Ti Vs A=Al-(K+Na+2Ca) diagram of Debon and Le fort (1983), granitic rocks from the study area which fall in low peraluminous and felsic-peraluminous fields

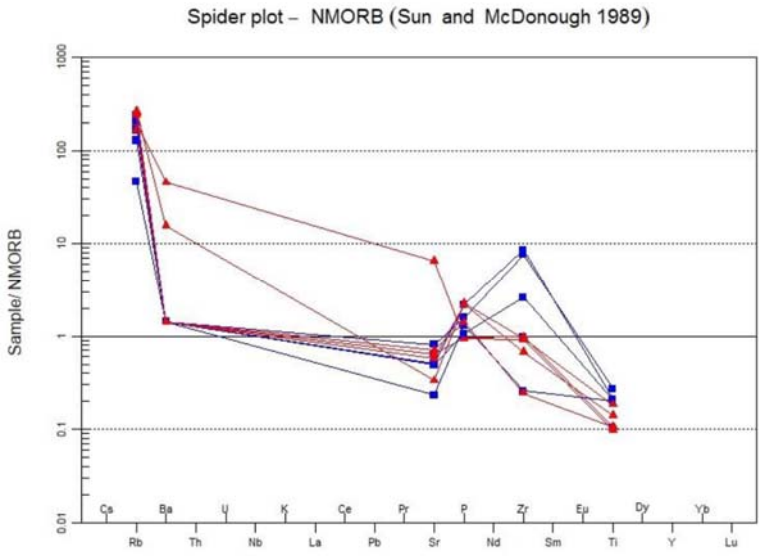

Figure (16). Primitive mantle normalized trace elements multi-element spider diagram for the granitic rocks of the study area. Normalization values are from Sun and McDonough (1989)

A

Figure (17). ACF diagram for the granitoids of the area (After Hyndman, 1985); molar ratio: A=Al_2O3-(Na_2O+K_2O), C=CaO, F=Fe_2O3+MgO

According to Chappell *et al.* (1974);
-Some of the distinctive chemical properties of the granitoids of the study area are;
-relatively low Sodium, Na_2O mostly <3.2%
-mol. Al_2O_3/Na_2O+K_2O+CaO>1%
-mostly >1% C.I.P.W normative corundum
-high SiO_2 type
-associated with cassiterite, scheelite (tin deposit)

According to this diagram and factors, the granitoids of the study area belong to S-type granites.

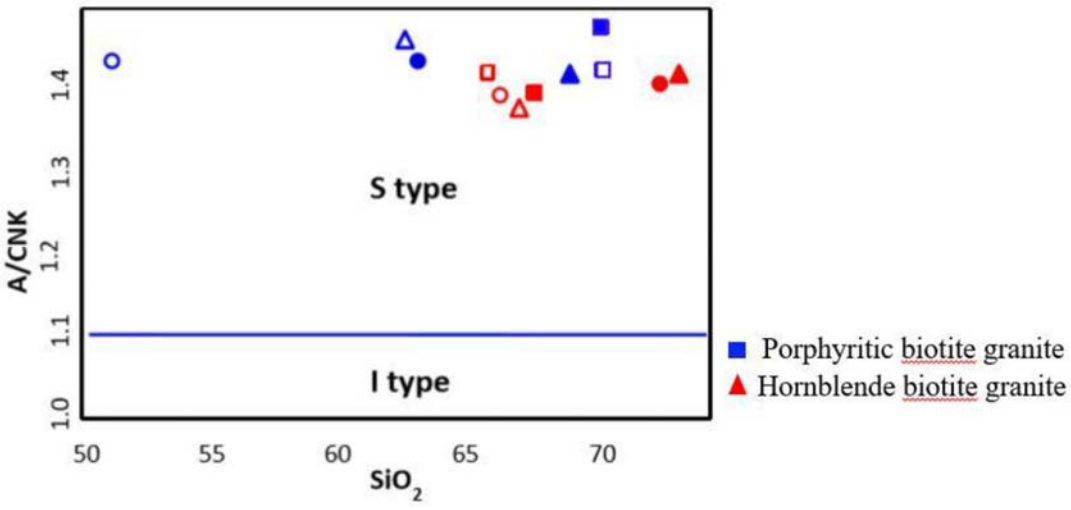

Figure (18). A/CNK Vs SiO2 diagram for classification of I-type and S-type fields (After Hine et al.1978)

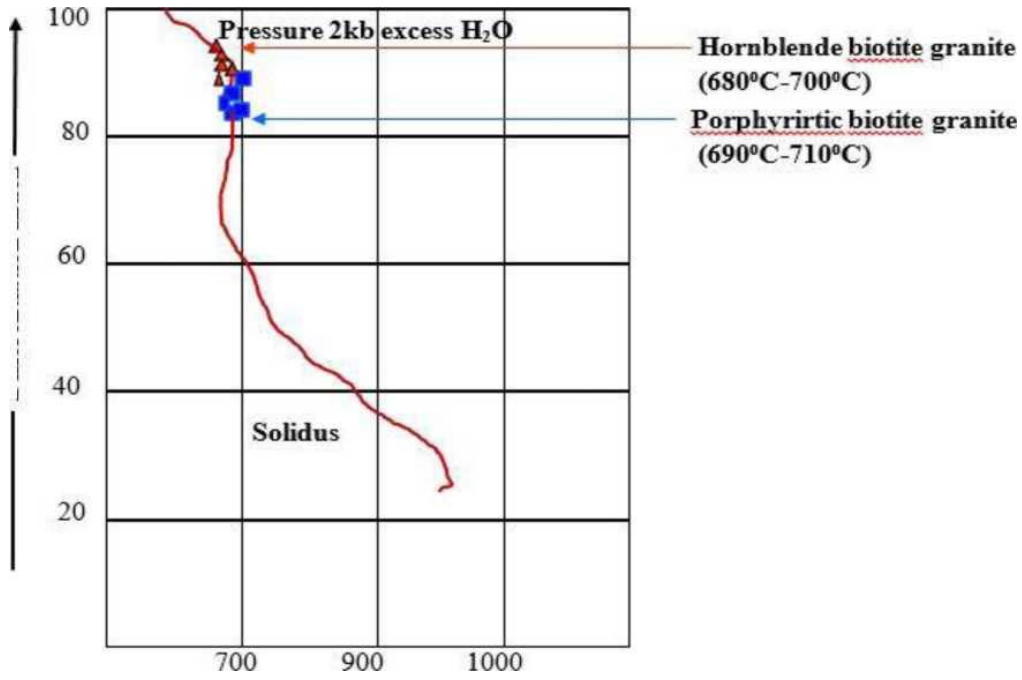

Figure (19). Temperature-differentiation index diagram for the granitic rocks of the study area, at 2 kb water pressure (After Piwinskii and Wyllie, 1970)

Temperature

Figure (20). Schematic depth-temperature relation diagram for the granitic rocks of the study area (After Marmo,1969)

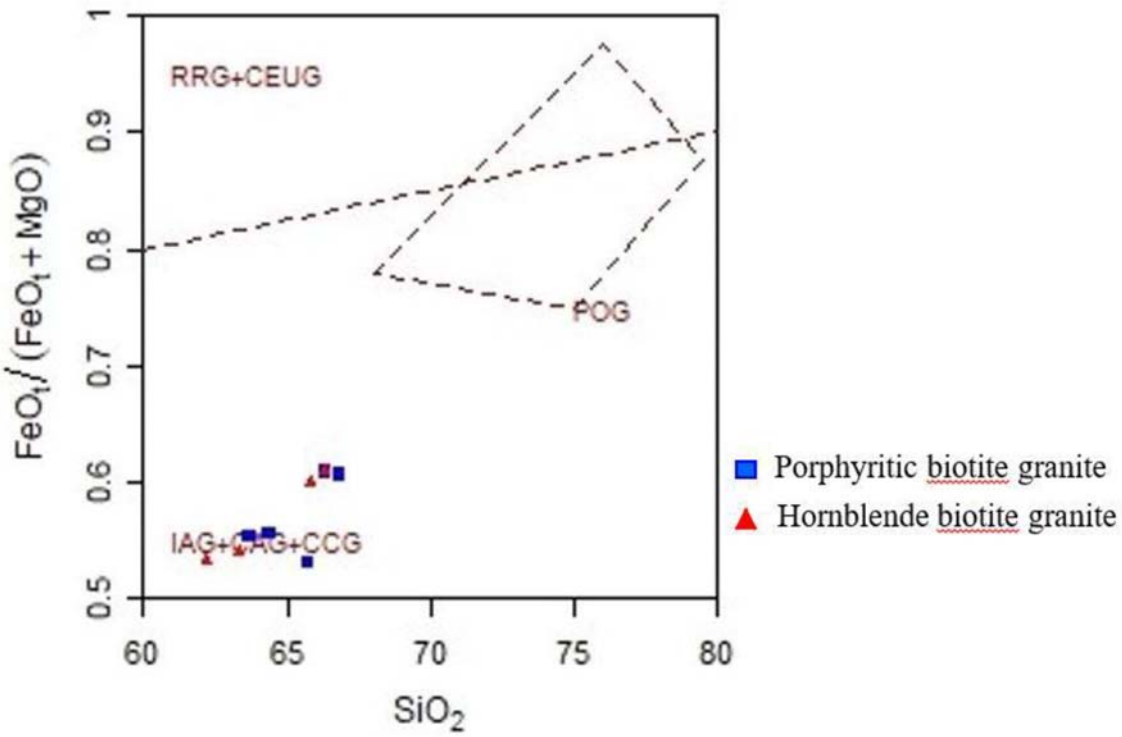

Figure (21). SiO_2 *Vs* FeO_t/FeO_t+MgO diagram showing the tectonic environment of granitic rocks of the study area (After Mariar and Piccoli,1989)

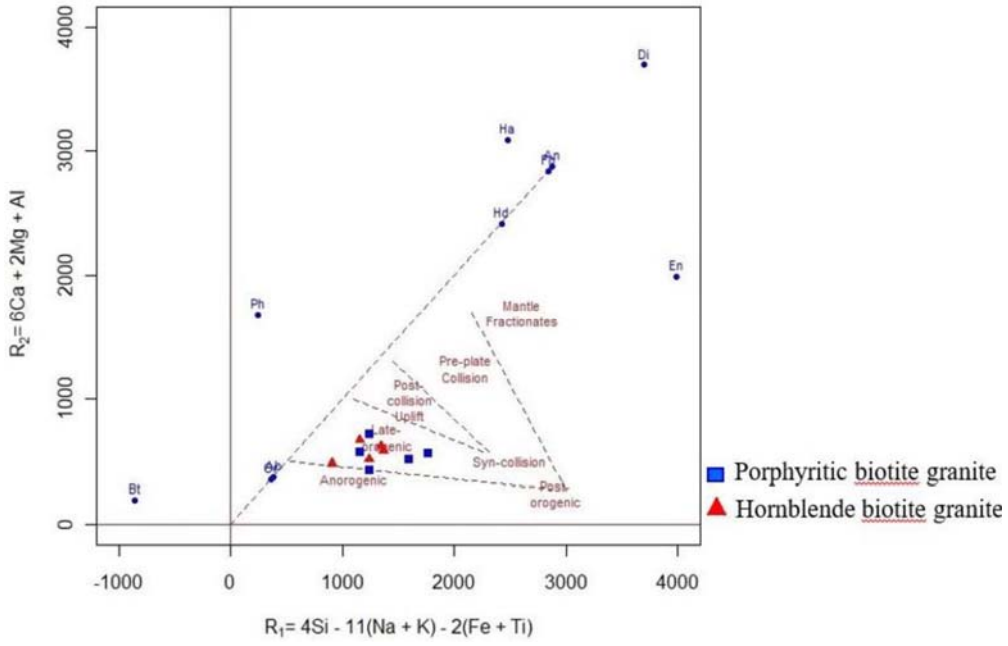

Figure (22). R_1-R_2 binary (in millications) diagram showing the discrimination of the tectonic setting of granite rocks (After Bachelor and Bowden, 1985)

Petrochemically, SiO_2 content in the granitic rocks ranges from 63.30-66.30 Wt.% with Na_2O+K_2O contents 10.96-14.57% with an average of 12.9%. It is characterized by high-K calc-alkaline series and belongs to peraluminous field. Harkar variation diagrams are more irregular hence, these rocks are of doubtlessly S-type granites. They defined A/CNK >1.1 as S-type and the majority of the granitic rocks in the study area fall in S-type affinity. After Maniar and Piccoli, (1989) indicates that all granitoid rocks of the study area are Continental Collision Granite (CCG). According to R_1-R_2 binary tectonic discrimination diagram showed that the porphyritic biotite granite and hornblende biotite granite correspond to Late Orogenic Zone. The liquidus temperatures of granitic rocks are approximately 680ºC to 710ºC and could be suggested that the granitic rocks crystallized at the depth of 21-25km. The magma may be emplaced by forceful injection. The depth of emplacement of the granitoid pluton has mesozonal characters.

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