PETROCHEMICAL CHARACTERS OF THE IGNEOUS ROCKS EXPOSED IN THE MOMEIK-MYITSON AREA, MOMEIK TOWNSHIP, NORTHERN SHAN STATE

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Abstract

The research area is situated within the northern adjacent part of the Momeik Town. It is mainly composed of metamorphic (metapelite, metacarbonate and metaigneous) and associated igneous rocks. The present work deals to describe the characteristics of igneous rocks, to determine the rock types and to investigate the tectonic setting of the emplacement of granitic rocks for the study area. Based on geochemical data, the granitic rocks of the study area can be considered as being derived from partial melting of already peraluminous sedimentary source rocks. The depth of igneous emplacement could be considered either in the upper level of mesozone or lower level of epizone. The tectonic environment of the granitic rocks from the study area is interpreted by making use of major and trace elements. Although all of the granitic rocks fall within the CCG field based on major element discrimination of Shand's index diagram, the content of the trace element composition and ORG normalized spider diagram suggest that the granitic rocks of the study area belong to the syn-collision granite (syn-COLG), S-type granitioid and upper crust contaminant in relation to the subduction of oceanic plate beneath the continent.

Keywords: *geochemical data, emplacement, tectonic environment*

INTRODUCTION

The study area, the northern continuation of Mogok Metamorphic Belt, is situated within the northern adjacent part of the Momeik Town. The area is bounded by latitude 23°9' N to 23°19'N and longitude 96°32' to 96°43'E in one inch to one mile scale topographic maps of 93-A/11 and 93-A/12. It covers approximately about 285 square kilometer with 18 km in length and 16 kilometer in width of rugged and mountainous terrains (Fig.1-A).

The Mogok Metamorphic Belt containing the study area is mainly composed of metamorphic (metapelite, metacarbonate and metaigneous) and associated igneous rocks. The main objective of this work is to describe the characteristics of igneous rocks, to determine the rock types and to investigate the tectonic setting of the emplacement of granitic rocks for the present study. To analyze the petrochemical characters of igneous rocks, ten representative fresh rock samples which lack alteration and veining as much as possible were carefully selected. The results of geochemical analysis are presented in Tables 1, 2 and 3.

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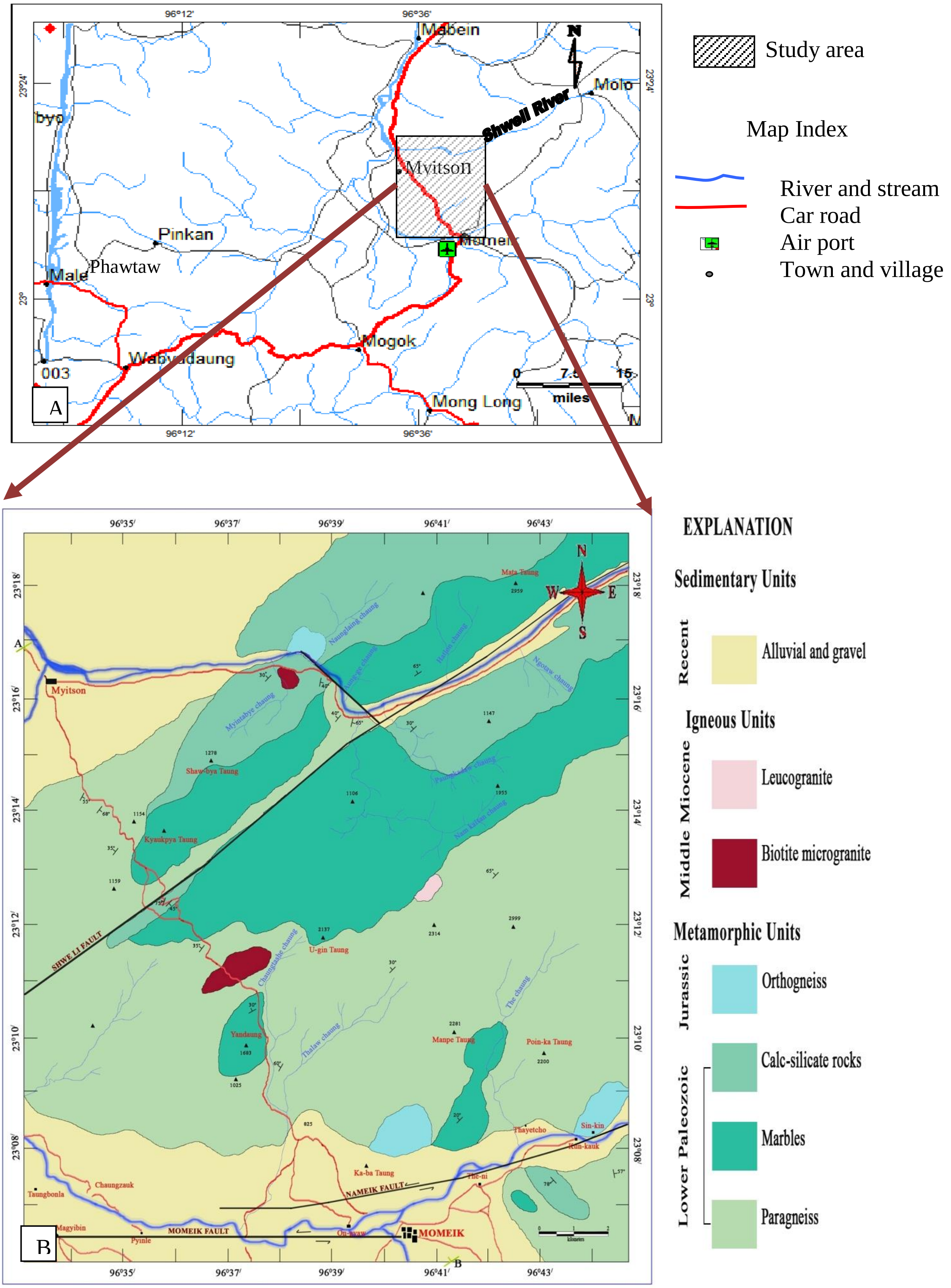

Figure (1-A&B) Location and geological maps of the Momeik-Myitson area

DISTRIBUTION OF THE PETROGRAPHIC UNITS

The most abundant metamorphic rocks occupied in this area is metapelites (garnet-biotite gneiss, biotite gneiss, silliminite schist and biotite schist) which are well exposed at the southern and western parts of the study area. Metacarbonate units (forsterite-graphite marble, phlogopite marble, diopside marble, white marble and diopside calc-silicate rock) are found in the central and northeastern part of the study area. Metaigneous rocks (Orthogneiss) are commonly observed along the Momeik fault zone in the southern part of the area. The igneous units are found at central and northern parts of the area. The geological map of the study area is as shown in figure (1-B).

PETROCHEMICAL CHARACTERS OF GRANITIC ROCKS

The chemical compositions of the ten representative samples are evaluated and plotted in the binary diagrams so that they can be used for classification of igneous rocks.

When chemical data are plotted on the total alkalis versus silica (TAS) diagram (Fig.2-A, Cox et al, 1979) to give a preliminary classification of plutonic igneous rocks which is one of the most useful classification schemes, the bulk composition of igneous rocks fall in the granite field. In the normative An-Ab-Or diagram, most of the igneous rocks fall in the granite field (Fig.2-B).

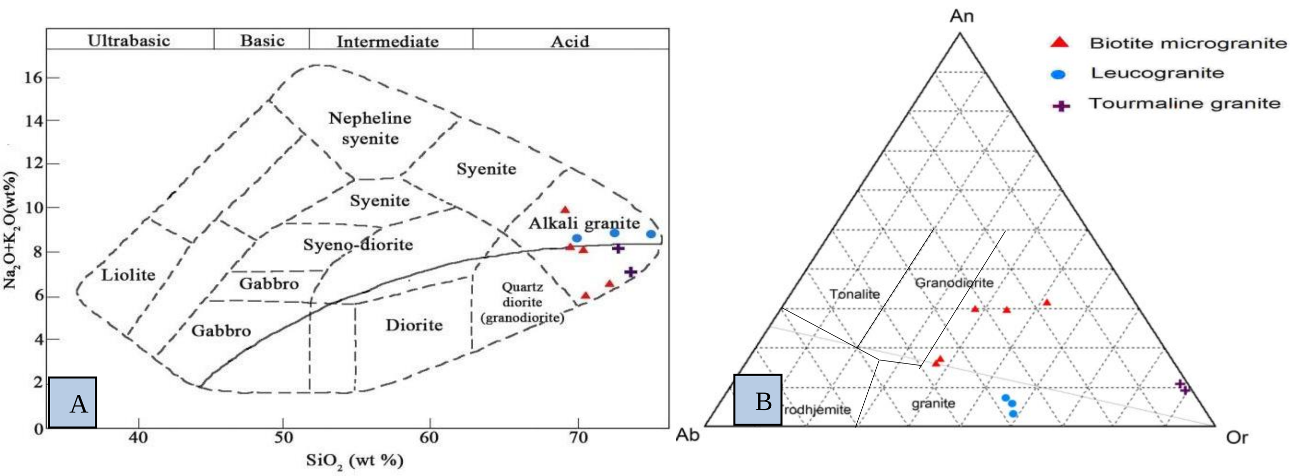

Fig. (2-A)Totat alkali versus silica (TAS) diagram (after Cox et al., 1979) showing the field of the granitic rocks of the study area.

Fig. (2-B)Normative An-Ab-Or diagram for the granitic rocks of the study area.

Rock Type	biotite microgranites								
Sample	NI-1	NI-2	NI-3	NI-4	NI-5	NI-6	NI-7	NI-8	NI-9
SiO_2	71.82	72.6	70.66	71.23	71.11	74.24	71.73	70.87	70.98
TiO_2	0.5	0.44	0.45	0.47	0.14	0.06	0.43	0.12	0.21
Al_2O_3	15.51	15.19	15.27	16.04	16.23	16.15	15.54	16.56	15.22
FeO	1.62	1.24	0.23	0.22	1.26	0.44	1.67	1.25	3.15
MnO	0.08	0.06	0.05	0.07	0.08	0.01	0.04	0.01	0.07
MgO	0.23	0.08	0.21	0.42	0.26	0.08	0.41	0.18	0.25
CaO	3.05	2.84	1.78	3	2.07	0.74	2.21	0.92	1.57
Na_2O	0.45	1.21	2.74	3.75	3.97	2.63	3.47	3.46	2.54
K_2O	4.96	5.29	7.8	4.57	4.21	5.54	3.57	6.3	4.7
P_2O_5	0.19	0.21	0.13	0.22	0.1	0.01	0.08	0.07	0.12
Sum	98.41	99.16	99.32	99.99	99.43	99.9	99.15	99.74	98.81

CIPW Norm or Wt % Norm

Quartz	31.62	40.16	21.61	25.5	27.52	36.1	33.04	24.85	36.45
Orthoclase	29.21	31.49	46.4	27	25.01	32.77	21.27	37.32	27.57
Albite	19.9	10.41	23.34	31.72	33.78	22.27	29.61	29.35	21.34
Anorthite	13.84	12.93	6.37	13.43	9.67	3.61	10.53	4.11	6.95
Corundum	1.16	2.86	0	0	1.62	4.51	2.15	2.55	3.36
Diopside	0	0	0	0	0	0	0	0	0
Hypersthene	2.86	0.58	0.1	1.04	0.65	0.19	1.03	0.44	0.61
Ilmenite	0.94	0.62	0.59	0.61	0.17	0	0.08	0.02	0.14
Hematite	0	0	0	0	1.26	0.44	1.68	1.25	3.12
Apatite	0.44	0.5	0.31	0.52	0.23	0.02	0.19	0.16	0.28
Titanite	0	0	0	0	0	0	0	0	0
Rutile	0	0.11	0	0.14	0.05	0.06	0.38	0.01	0.13
Sum	99.97	99.66	98.72	99.96	99.96	99.97	99.96	100.06	99.95
DI	81.63	84.72	91.36	84.23	91.50	92.12	87.66	90.12	89.94

Table-1. Major- and minor-element analyses and norms of the biotite micrograntie of the study area.

Rock Type	Leucogranites			toumaline granites	
Sample	NI-10	NI-11	NI-12	NI-13	NI-14
SiO_2	76.27	73.27	74.15	74.46	73.36
TiO_2	0.12	0.07	0.1	0.12	0.11
Al_2O_3	14.05	14.21	13.39	15.85	14.98
FeO	1.67	0.71	1.39	2.14	1.93
MnO	0.04	0.02	0.04	0.1	0.07
MgO	0.12	0.02	0.03	0.24	0.25
CaO	0.98	1.07	1.06	0.95	0.79
Na_2O	2.58	2.67	2.83	0.04	3.01
K_2O	6.29	6.34	6.26	6.02	5.4
P_2O_5	0.22	0.15	0.19	0.03	0.02
Sum	102.34	98.53	99.44	99.95	99.92

CIPW Norm or Wt % Norm

Quartz	30.56	32.04	32.13	48.9	53.67
Orthoclase	38.62	38.02	37.19	35.59	31.93
Albite	22.68	22.92	24.07	0.33	0.08
Anorthite	3.55	4.39	4.03	4.51	3.79
Corundum	1.81	1.3	0.48	7.61	7.73
Diopside	0	0	0	0	0
Hypersthene	0.31	0.05	0.07	0.59	0.62
Ilmenite	0.08	0.04	0.08	0.21	0.15
Hematite	1.73	0.72	1.39	2.14	1.93
Apatite	0.54	0.36	0.45	0.07	0.04
Titanite	0	0	0	0	0
Rutile	0.07	0.04	0.05	0	0.03
Sum	99.95	99.88	99.94	99.95	99.97
DI	93.68	94.38	93.89	92.45	93.42

Table-2. Major- and minor-element analyses and norms of the leucogranite and tourmaline granite of the study area.

Rock Type	Biotite microgranites				Leucogranites			Tourmaline granites	
Sample No.	NI-1	NI-2	NI-3	NI-4	NI-10	NI-11	NI-12	NI-13	NI-14
Locality	N 23°11' E 96°37'	N 23°11' E 96°38'	N 23°11' E 96°36'	N 23°16' E 96°38'	N 23°12' E 96°41'	N 23°12' E 96°40'	N 23°11' E 96°40'	N 23°09' E 96°43'	N 23°09' E 96°42'
Rb	9.07	92.30	164.39	95.21	118.69	115.34	140.66	323.92	288.21
Cs	1.80	27.10	5.86	6.43	22.58	5.57	5.54	5.73	19.61
Ba	153.64	1226.44	1060.89	1532.51	464.63	244.10	465.95	73.44	75.91
Sr	68.06	587.80	193.68	663.60	73.66	50.12	99.32	36.51	33.85
Ga	2.54	21.60	26.85	26.88	20.26	24.68	20.80	29.69	30.09
Tl	0.27	2.60	3.08	2.73	2.45	2.23	2.63	3.44	2.82
Ta	0.40	5.21	3.78	3.55	2.63	2.16	3.57	5.10	2.63
Nb	0.42	2.37	12.18	4.04	5.81	2.09	4.93	6.10	7.03
Hf	1.57	13.19	18.78	17.38	10.58	11.43	9.70	7.45	1.20
Zr	13.01	114.15	212.14	139.27	39.21	54.31	18.80	52.95	70.90
Y	1.86	10.43	25.97	15.13	8.51	11.01	8.87	60.96	66.50
Th	1.32	8.40	32.13	10.30	5.93	5.30	1.66	37.58	37.08
U	0.30	0.72	0.58	0.64	1.41	2.92	1.66	5.88	8.59
La	5.40	2.89	38.44	30.10	2.58	2.78	2.77	2.86	2.68
Ce	9.63	2.89	120.32	3.21	2.58	41.00	2.77	2.86	2.68
Yb	-	-	-	-	-	-	-	2.86	2.68
V	0.07	11.24	0.73	0.81	29.81	25.11	15.60	32.13	24.45
Cu	0.83	6.48	7.73	9.51	11.34	9.13	9.85	8.93	11.26
Pb	5.19	5.07	65.38	52.90	52.83	58.01	52.00	66.44	59.99
Zn	6.41	56.72	370.75	76.95	12.33	10.19	14.59	43.21	40.58
Bi	0.35	2.60	2.20	2.89	2.71	24.82	3.46	3.15	3.09
Cd	0.29	2.89	2.93	3.21	2.58	2.78	2.77	2.86	2.68
Sn	0.46	1.86	4.12	5.04	0.20	7.62	3.00	9.91	16.29
W	0.15	1.49	1.51	1.65	1.33	1.43	1.42	1.47	1.38
Mo	0.04	1.44	1.46	1.60	1.03	0.55	0.13	1.14	0.53
Ag	0.29	2.89	2.93	3.21	2.58	2.78	2.77	2.86	2.68
Ge	0.07	0.72	0.73	0.80	1.41	1.39	1.66	1.00	0.67
As	0.09	1.20	0.83	0.73	1.17	0.79	1.05	1.24	1.06
Se	0.14	1.30	1.61	1.44	1.41	1.67	1.38	1.86	1.34
Sb	0.34	5.67	4.52	3.75	1.94	4.93	2.08	1.51	1.82

Table-3. Trace element analyses (in ppm) of the plutonic rocks of the study area

Based on the silica and alkali content, igneous rocks have been classified into two major series: alkaline and subalkaline. In SiO_2 vs (Na_2O+K_2O) diagram, all granitic rocks fall in the field of subalkaline (Fig.3-A) according to Irvine and Baragar (1971) classification scheme (in Philpott, 1990). The sub-alkaline series was further subdivided into tholeiitic and calc-alkaline series. Data plotted on the AFM diagram (Fig.3-B) clearly indicate that almost all of the igneous rocks fall in the field of calc-alkaline. So, it can be interpreted that calc-alkaline nature of granitic rocks from the study area is genetically related to the subduction related plate tectonic process.

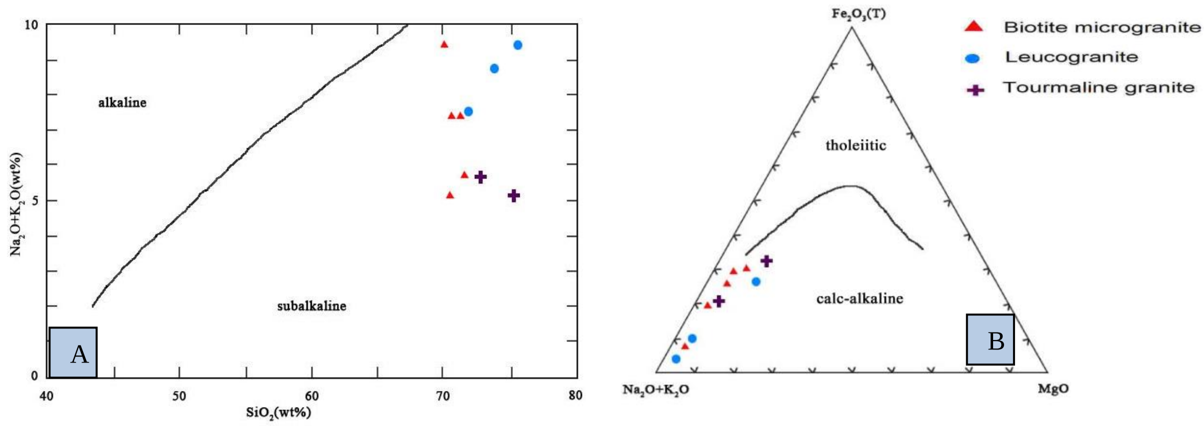

Fig. (3-A&B)Diagrams showing the classification of (A) subalkaline and (B) calc-alkaline rocks for the granitic rocks of the study area. (Irvine and Baragar, 1971 in Philpott, 1990). (after Tuttle and Bowen, 1958)

According to the analysis of K_2O vs. SiO_2 (Le Maitre et al., 1989), the granitic rocks of the study area fall within the High-K Calc-Alkaline series and Shoshonitic series (Fig.4-A). The Al_2O_3-CaO-(Na_2O+K_2O) diagram (Fig.4-B) reveals the peraluminous nature of the granitic rocks in the study area. The above mentioned facts point out that the granitic rocks of the study area have the charatcteristics of acid clan, peraluminous nature and calc-alkaline series.

To classify the I-type and S-type granitoids, when plotted on the ACF (Al_2O_3+ Na_2O+K_2O , CaO and FeO+MgO) diagram on the basis of major oxides, it is found that almost all of the granitic rocks of the study area fall within the S-type field (Fig.5). In addition, some distinct chemical properties such as being more felsic type (typically SiO_2 > 71 wt%), having higher Al_2O_3[molar ratio Al_2O_3/ ($CaO+Na_2O+K_2O$) > 1%] and having CIPW corundum content > 1% in the granitic rocks of the study area point out S-type nature. On the basis of the above data, the granitic rocks of the study area can be considered as being derived from partial melting of already peraluminous sedimentary rocks.

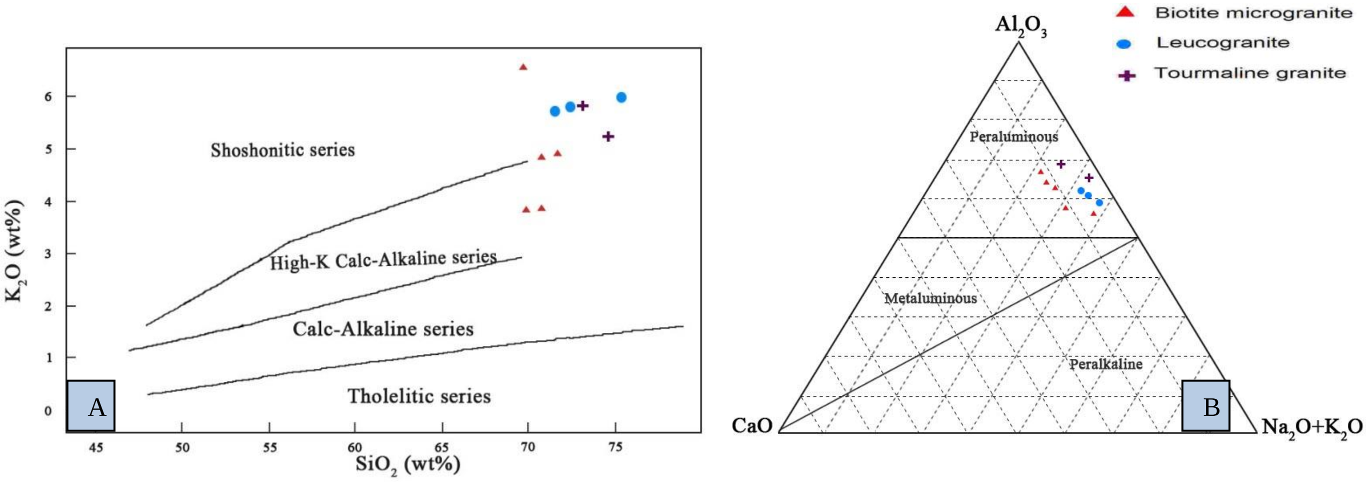

Fig. (4-A) SiO_2 versus K_2O diagram showing the high-K Calc-alkaline and Shoshonitic nature of the granitic rocks of the study area. (After Le Maitre et al., 1989 in Rollinson,1995)

Fig. (4-B) Al_2O_3-CaO-(Na_2O+K_2O) diagram showing peraluminous nature of the granitic rocks of the study area.

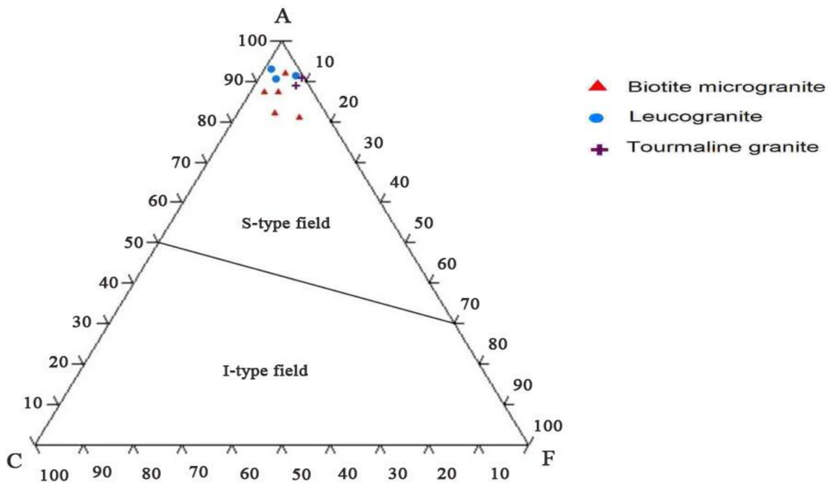

Fig. (5) ACF diagram showing S-type characters of the granitic rocks of the study area. Molar ratios: A-Al_2O_3+Na_2O+K_2O, C-CaO, F-Fe_2O_3+MgO (after Hyndman, 1985).

Emplacement and Depth of intrusions

The field evidence and petrochemical data suggest that leucogranite and tourmaline granite intruded forcefully into the highly deformed metamorphic rocks of the study area. In middle Miocene, the S-type biotite microgranite intruded into the metamorphic rocks by forceful intrusion.

Depending on the classification by Hyndaman (1978) and Winter (2001), the depth of emplacement of igneous rocks in the study area has been determined.

The characteristics of the epizonal emplacement of granitic rocks are suggested as follows:

(1) Presence of grossularite-bearing skarn zones.
(2) The blocky nature of the biotite microgranite and the invaded rocks.
(3) The widespread medium-grained texture of the biotite microgranite.
(4) The rarity of microcline in granitic rocks.

The above mentioned features seem to agree with those of epizonal emplacement. On the other hand, mesozonal characters are seen as follows:

(1) Miarolitic cavities are absent in all granitic rocks.
(2) No graditional contact between country rocks and intrusions.
(3) Mostly discordant structural relations to the country rocks.
(4) The country rocks are observed that intrusive temperature was greater than 450 ^{o}C and belong to amphibolites facies.
(5) Absence of chilled border zone.

The granitic bodies of the study area show partly epizonal characters and partly mesozonal characters. So, it might be concluded that they might have emplaced either in the upper level of mesozone or lower level of epizone.

Tectonic Discrimination of Granitic Rocks

The tectonic environment for the emplacement of granitic rocks from the study area is firstly discriminated by using major elements according to Manior and Piccoli (1989). They classified the granitic rocks on the basis of tectonic setting 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 epirogenic granitoid (CEUG)
	(g) Oceanic plagiogranites (OP)

K_2O versus SiO_2 diagram discriminates the distinction between OP and IAG + CAG + CCG + RRG + CEUG, (Fig.6). In this diagram, all of the granitic rocks fall within the field of IAG + CAG + CCG + RRG + CEUG.

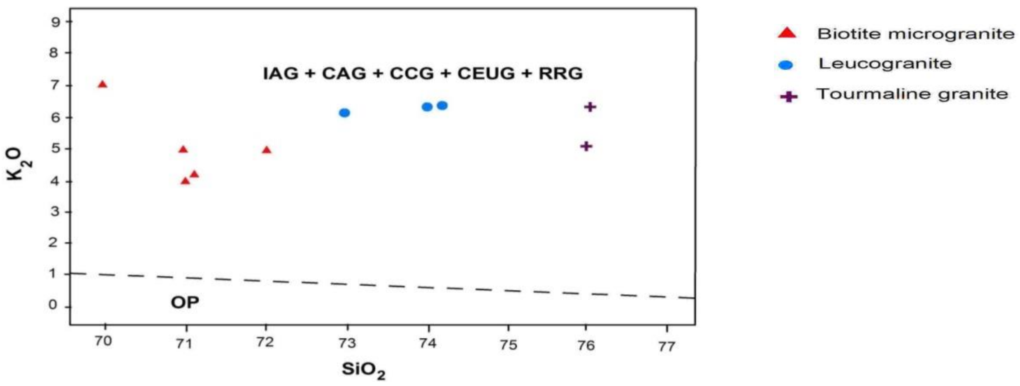

Fig. (6) K_2O versus SiO_2 diagram showing the tectonic environment of the granitic rocks of the study area.

Variation diagrams of Al_2O_3 versus SiO_2 and MgO versus SiO_2 subdivide the granitic rocks into three groups (IAG + CAG + CCG , POG and RRG + CEUG), (Fig.7- A&B). When data are plotted on these diagrams, all of the granitic rocks fall within the field of IAG + CAG + CCG except for only two samples which fall in POG field in Al_2O_3 versus SiO_2 diagram.

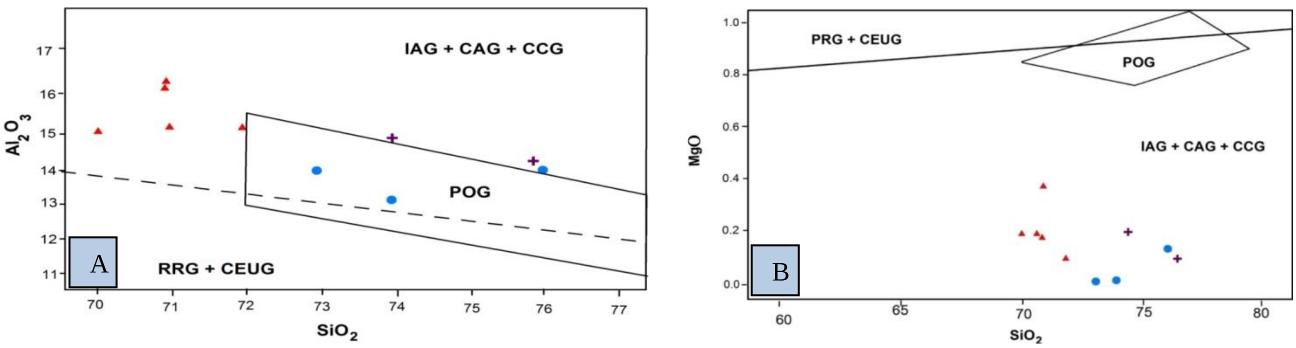

Fig. (7-A) Al_2O_3 versus SiO_2 diagram showing the tectonic environment of the granitic rocks of the study area.
Fig. (7-B) MgO versus SiO_2 diagram showing the tectonic environment of the granitic rocks of the study area.

Shand's index diagram clearly points out the distribution within the IAG , CAG and CCG groups. All of the granitic rocks of the study area belong to only the CCG field (Fig.8) when plotted on this diagram.

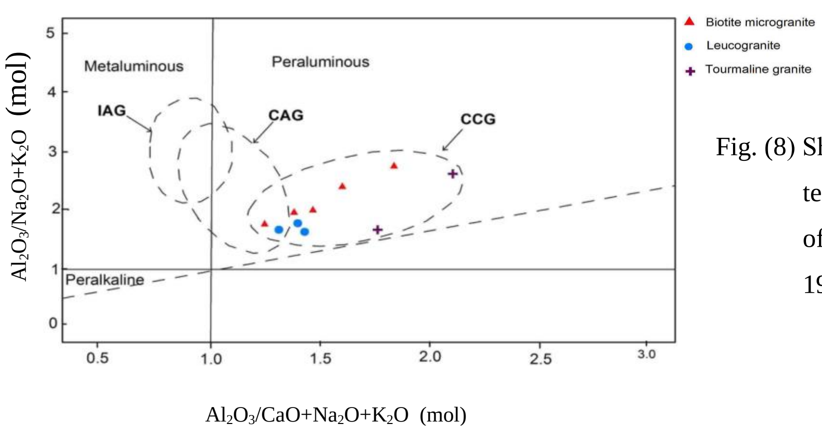

Fig. (8) Shand's index diagram showing the tectonic environment of the granitic rocks of the study area. (after Maniar and Piccoli, 1989)

According to the above criteria, it can be concluded that the igneous rocks of the study area fall only within the CCG field based on the Shand’s index diagram. So, the granitic rocks of the study area might be designated as the orogenic granitods which was formed in the continent in relation to the subduction of an ocenic plate beneath the continent.

The trace element data are used in the discrimination of tectonic provinces associated with particular magma types. On the basis of trace elements, Pearce et al. (1984) classified the granite types into four main groups : ocean ridge (ORG), volcanic arc (VAG), within plate (WPG), and syncollision (syn-COLG) granitic rocks in terms of tectonic setting. In the Y versus Nb diagram, many of the granitic rocks fall within the VAG + syn-COLG field, (Fig-9-A). Pearce also describes the Rb versus (Y + Nb) binary diagram to distinguish between volcanic arc granite (VAG) and syn-collisional granite (syn-COLG) (Fig.9-B). In this diagram, almost all of the granitic rocks of the present area fall in the volcanic arc granite (VAG) field, but two samples of tourmaline granites fall in the syn-collisional granite (syn-COLG) field.

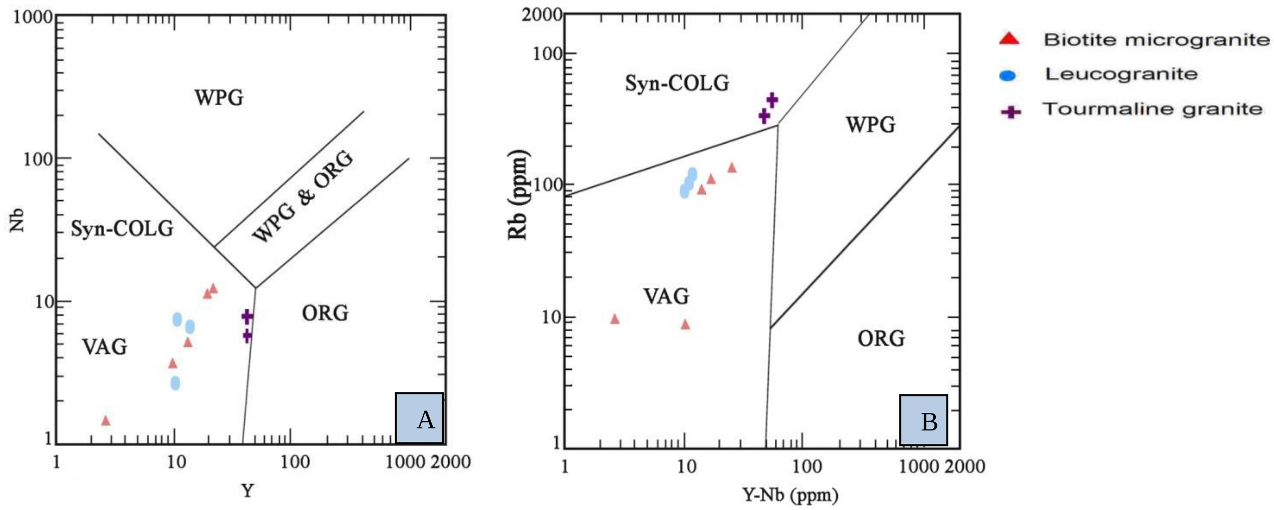

Fig. (9-A) Nb-Y diagram showing the tectonic environment of the granitic rocks of the study area.(after Pearce et al., 1984)

Fig. (9-B) Rb-(Y+Nb) discrimination diagram showing the tectonic environment of the granitic rocks of the study area. (after Pearce et al., 1984).

Spider diagrams normalized to ocean ridge granite of Pearce et al (1984) for the biotite microgranite show particularly obvious peaks at Rb, Th and Ce with pronounced trough at Nb content (Fig.10). The Nb trough character appears to be a distinctive feature of contaminated magma (Winter, 2010). The normalized diagram for the studied granitic rocks is characterized by Rb, Ba enrichment, but depleted in Zr and Y indicating the crustal interaction. The comparison of the ORG normalized pattern of the granitic rocks with the trace element contents of MORB, upper crust and lower crust shows that the geochemical signatures of the granitic rocks of the study area are closely similar to that of the upper crust.

Therefore, the content of the trace element composition and ORG normalized spider diagram suggest that the granitic rocks of the study area belong to the syn-collision granite (Syn-COLG), supracrustral S-type granites in relation to the subduction of oceanic plate beneath the continent.

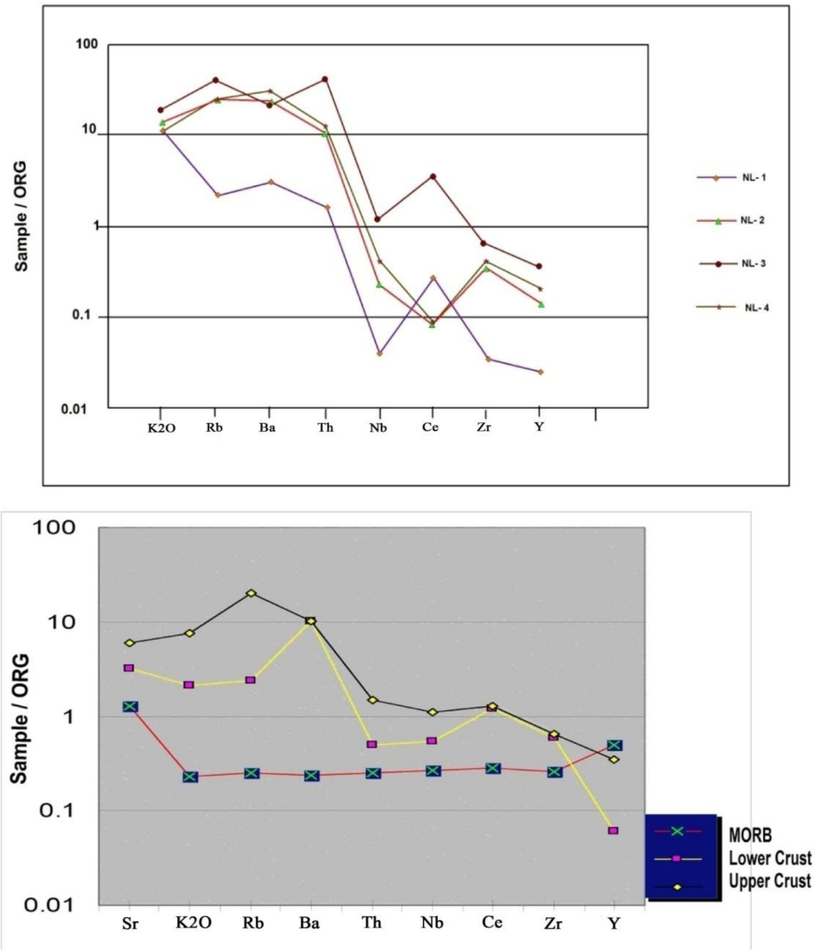

Fig. (10) Oceanic ridge granite (ORG) normalized spider diagram of the granitic rocks of the study area compared with normalized diagram of MORB, upper crust and lower crust. Normalized value from Pearce et al., 1984.

CONCLUSION

The research area was dominated by metamorphic (metapelite, metacarbonate and metaigneous) and associated igneous rocks. The tectonic environment of the granitic rocks from the study area is interpreted by making use of major and trace elements. Although all of the granitic rocks fall within the CCG field based on major element discrimination of Shand's index diagram, the content of the trace element composition and ORG normalized spider diagram suggest that the granitic rocks of the study area belong to the syn-collision granite (syn-COLG), S-type granitioid and upper crust contaminant in relation to the subduction of oceanic plate beneath the continent.

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