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A STUDY ON PETROCHEMICAL ANALYSIS OF GRANITIC INTRUSION AT ME'NETAUNG AREA, HOPONG TOWNSHIP, SOUTHERN SHAN STATE

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Abstract

The research area lies between latitude 20˚ 34′ 00″ to 20˚ 45′ 00″ north and longitude 97˚ 15′ 00″ to 97˚ 22′ 30″ east, which is situated about 21 km, southeast of Hopong township, Southern Shan State. The intrusive igneous rocks are granites and muscovite-biotite granites. The granitic rocks show chemical composition (weight percent) of SiO_2 (70.35-74.20), Al_2O_3 (13.69-16.59), TiO_2 (0.21-0.39), Na_2O+K_2O (7.85-9.31), Fe_2O_3+MgO (1.72-3.74), MnO (0.03-0.05), CaO (0.56-0.80) and P_2O_5 (0.20-0.30). Petrochemically, P (K-(Na+Ca)) - Q (Si/3-(K+Na+2Ca/3)), R_1-R_2, normative (Ab - Or - An) and TAS diagrams indicate that the granitic rocks from the research area belong to the granite field. In the molar Na_2O-Al_2O_3-K_2O and B-A plot diagrams show that granites and muscovite-biotite granites are predominantly peraluminous. AFM diagram indicates that the granitic rocks belong to the calc alkaline series. From the result of K_2O Vs Na_2O diagram, granites and muscovite-biotite granites of the research area involve S-type. Normative data plot of Quartz-Albite-Orthoclase diagram shows that the granitic rocks lie within 2kb and 10 kb during crystallization. According to ternary plot of Quartz-Anorthite-Orthoclase diagram exhibits that the majority of all granitic rock samples were formed between 0.5kb and 5kb. It can be interpreted that the granitic rocks were consolidated under the low pressure condition. Due to the relationship between differentiation index and temperature, the liquidus temperatures are 720˚C for granites and muscovite-biotite granites. From the schematic depth-temperature diagram, it is indicated that the granitic rocks from the research area crystallized at the depth of 26 km. The granitoid rocks of the research area are Orogenic granitoids. Therefore, the granitic rocks were formed on the continent relation to the subduction of an oceanic plate beneath the continent. R_1-R_2 binary (millication) diagram indicates the granitic rocks of the research area correspond to syn-collision zone.

Keywords: granites, muscovite-biotite granites, S-type, liquidus temperatures, depth of crystallization

Introduction

Location, size and accessibility

The research area lies between latitude 20˚ 34′ 00″ to 20˚ 45′ 00″ north and longitude 97˚ 15′00″ to 97˚ 22′ 30″ east, which is situated about 21 km, southeast of Hopong town. It is bounded by grids no 87 to 02 and 92 to 23 in one-inch topographic map No. 93 H/6 and H/5 and it covers 414 square km. The Taunggyi-Mong Pong car road passes through the northern part of the research area. It can be accessed by car and motorcycle from Hopong throughout the year. The location map of the research area is shown in Figure. 1(A).

Drainage system

In the research area, the common drainage systems vary from trellis to dendritic patterns. The distinct stream of the research area is Samphu, which generally flow from south to north,

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which are parallel to general strike of the rock units. The drainage map of the research area is shown in Figure. 1(B)

(A) (B)

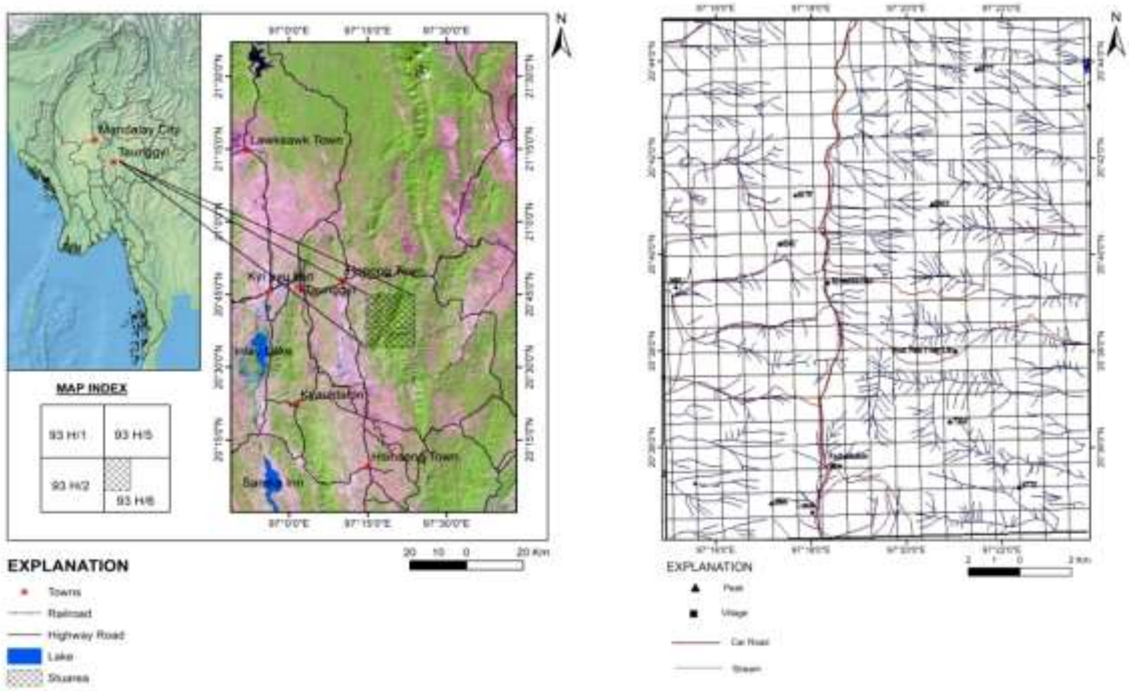


Figure 1. (A) Location map of the research area and its environs

(B) Drainage map of Me'netaung area, Hopong Township (Source: one-inch map)

Regional Geologic Setting

The research area is located in Eastern highland that elevated more than 914 m above sea level. Regional geological map of the research area is shown in Figure 2. Ordovician rocks (Lokepyin Formation, Wunbye Formation, Nan on Formation, Tanshauk Member), Silurian rocks (Linwe Formation, Wabya Formation), Plateau Limestone Group (Nwabangyi Dolomite Formation, Thitsipin Limestone Formation) and Molohein Group are cropped out at the southern part of Loi Samphu ranges. There is a large anticline plunging to the south. Metamorphic rocks and intrusive igneous rocks are exposed in the northern part, especially at the peak of Loi Samphu.

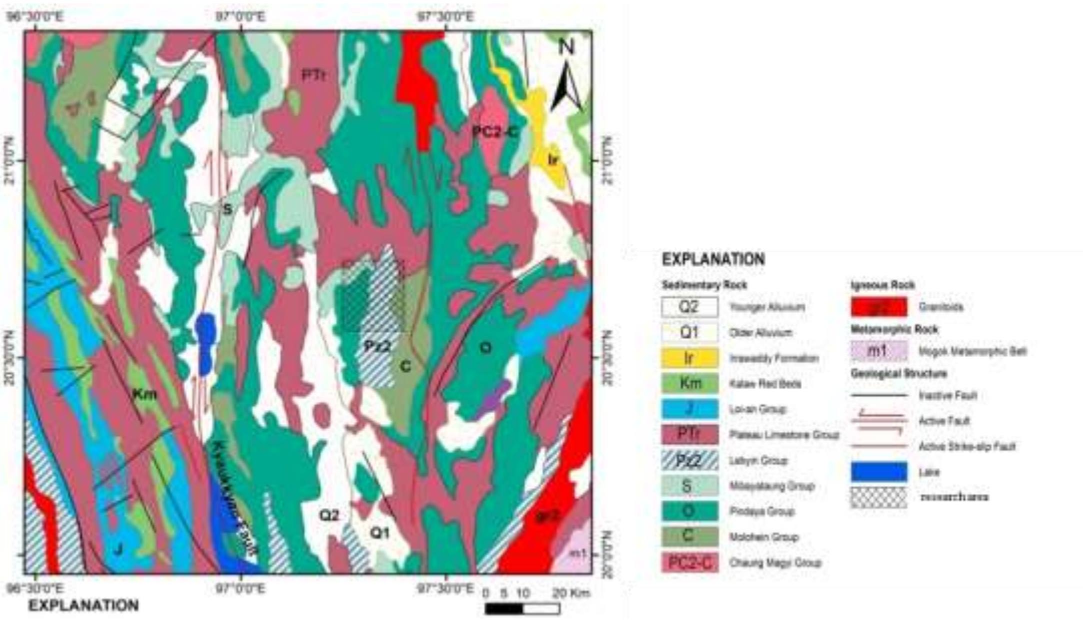


Figure 2. Regional geological map of the research area (Source: Myanmar Geosciences Society, 2014)

Purpose of Investigation

- To determine petrochemical characteristics of granitic rocks
- To interpret the genetic types of granitic rocks
- To describe condition during crystallization of the granitic rocks

Materials and Methods

The major oxide and trace elements abundance were determined by X-ray fluorescence spectrometry. The representative granitic rock samples including 3 granites and 4 muscovite-biotite granites from the research area were selected for analysis and were sent to DSSTRC (Defense Service Science and Technology Research Centre) in Pyin-Oo-Lwin Township, in Table. 1&2. The analyzed data are shown in Table. 2. Standard C.I.P.W norms and C.I.P.W norms with biotite and hornblende were calculated according to the rules of Hutchison (1975) is displayed in Table. 3. Thornton and Tuttle Differentiation Index (TTDI or DI, Differentiation Index) can be used as an indicator of bulk composition which was calculated from the standard C.I.P.W norms. These results are exhibited in Table.3. Triangular plots of some analyses results were carried out by Tridraw 2.6 software. For Differentiation Index diagram, Major oxides and Trace elements variation diagrams, Ternary diagrams, Binary diagrams and Triangular plots diagrams were drawn by using SPSS-17.0 software, GCD kit 3.0, Tridraw software and Microsoft excel.

Results and Findings

Geology of the Me' netaung Area

The stratigraphic succession of the research area, in ascending order is Chaung Magyi Group (Pre-Cambrian), Molohein Group (Late Cambrian), Lokepyin Formation, Wunbye Formation, and Nan-on Formation of Pindaya Group (Early to Middle Ordovician), Linwe Formation and Taungmingyi Orthoquartzite Member of Mibayataung Group (Silurian), Devonian Unit (Early Devonian) , Carboniferous Unit (Carboniferous), Plateau Limestone Group (Early Permian to Middle Triassic), Loi-an Group (Jurassic) and Alluvium (Holocene). The intrusive igneous rock is porphyritic biotite granite (Late Triassic to Early Jurassic). The geological map of the research area is shown in Figure 3.

Petrochemical Analysis of Granitic Rocks

The granitic rocks of the research area are granites and muscovite-biotite granites. The granites, muscovite-biotite granites show chemical composition (weight percent) of SiO_2 (70.35-74.20), Al_2O_3 (13.69-16.59), TiO_2 (0.21-0.39), Na_2O+K_2O (7.85-9.31), Fe_2O_3+MgO (1.725-3.74), MnO (0.03-0.05), CaO (0.56-0.804) and P_2O_5 (0.20-0.30).

In Harker's variation diagram, CaO, Na_2O, K_2O, TiO_2, Al_2O_3, MgO and P_2O_5 are negatively correlated with SiO_2. FeO_t are positively correlated with SiO_2. Plots of selected trace elements of Cr and Zr are positively correlated with SiO_2, Figure. 4. Plots of trace elements Mg, Rb versus SiO_2 show decreasing of those elements with increasing of SiO_2 contents. Differentiation Index (DI) of the igneous rocks in the area varies from 93.141 to 95.381. Standard CIPW normative corundum ranges from 2.693 to 4.267. Total alkali content (Na_2O+K_2O) ranges from 7.85 to 9.31. TAS diagram after Cox et. al. (1979), Figure.5 (A) indicates four groups of igneous rocks and the dividing line between alkaline and subalkaline magma series. The granitic rocks from the research area belong to the subalkaline affinity. TAS diagram of Middlemost (1994), Figure.5 (B) exhibits granites and muscovite-biotite granites fall in the granite field.

According to the P (K-(Na+Ca)) – Q (Si/3-(K+Na+2Ca/3)) diagram of Debon and Le Fort, (1983), Figure.6 (A), the granitic rocks in the research area fall in the granite field. R_1= 4Si-11(Na+K) – 2(Fe+Ti) and R_2= 6 Ca+ 2Mg+ Al, (R_1-R_2) diagram of De La Roche et. al (1980) classification diagram indicated that the granites and muscovite-biotite granites confined to the granite field, in Figure.6 (B). B-A plot diagram from (after Villaseca et al, 1998) show granites and muscovite-biotite granites are predominantly peraluminous, Figure. 7.

In the AFM diagram, FeO_t - (Na_2O+K_2O) - MgO shows that the decrease of MgO with a rise of FeO_t during the initial stage of differentiation. In the later stage of differentiation, there is an increase of alkali (Na_2O+K_2O) with a depletion of FeO_t is shown in Figure. 8. SiO_2-Na_2O+K_2O - FeO_t+MgO diagram, Figure. 9 show the rise of SiO_2 and depletion of FeO_t+MgO during the entire process of magmatic differentiation. K_2O - Na_2O - CaO ternary diagram, Figure. 10 exhibits that the enrichment of CaO during the initial stage of differentiation with addition of Na_2O. There is an increase of K_2O which is subsequently replaced by Na_2O in the late stage of magmatic evolution.

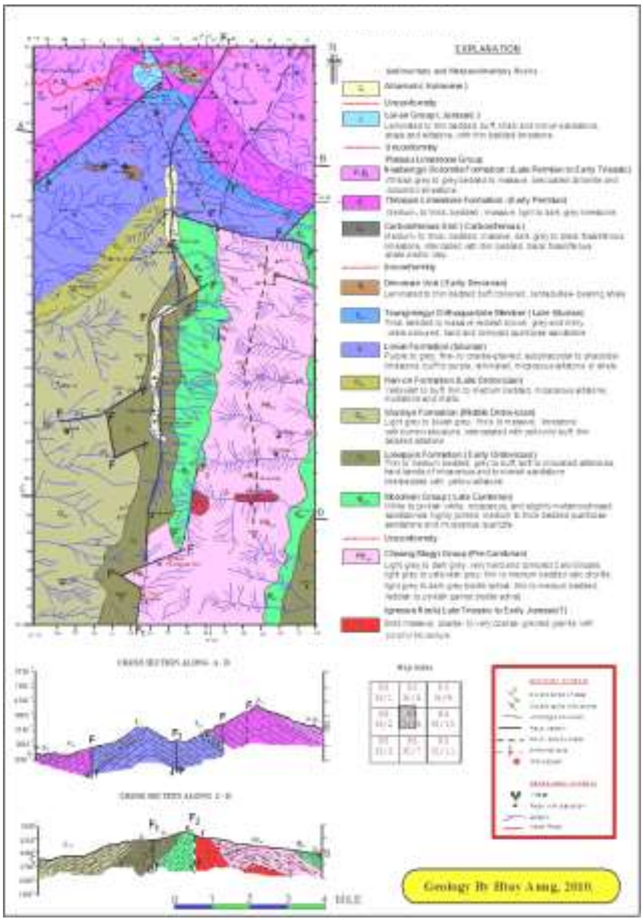


Figure. 3 Geological Map of the Me'netaung area (Source: Htay Aung, 2010)

Table. 1 Analyzed samples and locations of the granitic rocks of the research area

Samples	Rock Types	Locality
■ mmk-1	Granite	N 20˚37′32″E 97˚20′42″
■ mmk-2	Granite	N 20˚37′32″E 97˚20′43″
■ mmk-3	Granite	N 20˚37′35″E 97˚20′41″
▲ mmk-4	Muscovite-biotite granite	N 20˚37′32″E 97˚20′42″
▲ mmk-5	Muscovite-biotite granite	N 20˚37′34″E 97˚20′44″
▲ mmk-6	Muscovite-biotite granite	N 20˚37′32″E 97˚20′47″
▲ mmk-7	Muscovite-biotite granite	N 20˚37′33″E 97˚20′46″

Table.2 Major oxides (wt. %) and trace elements (ppm) abundances of the granitic rocks from the research area

Sample No	**mmk-1**	**mmk-2**	**mmk-3**	**mmk-4**	**mmk-5**	**mmk-6**	**mmk-7**
Types	**granite**	**granite**	**granite**	**muscovite-biotite granite**	**muscovite-biotite granite**	**muscovite-biotite granite**	**muscovite-biotite granite**
SiO_2	74.2	73.25	73.56	71.38	71.64	70.35	70.83
TiO_2	0.23	0.247	0.21	0.39	0.35	0.247	0.22
Al_2O_3	13.69	13.9	14.56	15.00	14.93	16.59	16.18
Fe_2O_3	1.865	2.00	1.679	3.18	2.88	1.99	1.722
MnO	0.03	0.028	0.03	0.05	0.05	0.032	0.03
MgO	0.34	0.402	0.29	0.56	0.48	0.387	0.33
CaO	0.79	0.804	0.62	0.62	0.56	0.645	0.59
Na_2O	2.61	2.76	2.74	2.71	2.91	3.278	3.18
K_2O	5.24	5.29	5.89	5.54	5.82	5.93	6.13
P_2O_5	0.22	0.205	0.24	0.30	0.28	0.271	0.27
Total	99.23	98.93	99.83	99.73	99.89	99.72	99.482
A/CNK	1.588	1.569	1.574	1.691	1.607	1.683	1.629
A/NK	1.743	1.726	1.687	1.818	1.710	1.821	1.732
Ba	0.06	1.67	0.06	-	-	-	-
Cu	-	0.011	-	-	-	-	-
Zn	0.0067	0.0077	0.0061	0.0119	0.0099	0.0069	0.0065
Mg	0.21	0.24	0.18	0.34	0.29	0.23	0.20
Fe	1.31	1.40	1.18	2.22	2.01	1.39	1.20
Sr	0.004	0.038	0.004	-	-	0.003	0.003
Sb	0.036	-	0.049	-	-	-	-
Ca	0.57	0.58	0.44	0.44	0.40	0.46	0.46
P	0.097	0.089	0.107	0.129	0.123	0.118	0.188
Mg	0.21	0.24	0.18	0.34	0.29	0.23	0.20
Ti	0.136	0.105	0.128	0.232	0.208	0.148	0.134
Al	7.248	7.36	7.71	7.93	7.90	8.78	8.56
Na	1.94	2.05	2.04	2.01	2.16	2.43	2.37
K	4.35	4.39	4.892	4.60	4.83	4.93	5.09
Zr	0.0129	0.0117	0.0114	0.0182	0.0177	0.0142	0.0118
S	0.03	0.49	0.07	0.08	0.06	0.01	0.02
Rb	0.0517	0.0447	0.0481	0.0577	0.0561	0.0485	0.0494
Tl	0.136	0.148	0.128	0.232	0.208	0.148	0.134

Table. 3 Standard CIPW norm and standard CIPW norm with biotite and hornblende of the granitic rocks in the research area

Standard CIPW norm

Sample no.	mmk-1	mmk-2	mmk-3	mmk-4	mmk-5	mmk-6	mmk-7
Quartz	37.681	35.603	34.058	33.186	31.345	27.471	27.84
Corundum	2.837	2.693	3.13	4.147	3.499	4.267	3.857
Orthoclase	31.205	31.608	34.863	32.82	34.42	35.134	36.395
Albite	22.256	23.613	23.223	22.988	24.643	27.809	27.289
Anorthite	2.501	2.679	1.51	1.119	0.95	1.433	1.168
Hypersthene	0.853	1.012	0.723	1.398	1.196	0.966	0.826
Ilmenite	0.065	0.061	0.064	0.107	0.107	0.069	0.064
Hematite	1.88	2.022	1.682	3.188	2.882	1.995	1.73
Rutile	0.198	0.218	0.177	0.335	0.294	0.212	0.187
Apatite	0.525	0.491	0.569	0.712	0.664	0.644	0.643
Sum	100	100	100	100	100	100	100
D.I	93.979	93.517	95.274	93.141	93.907	94.682	95.381
C.I	3.099	3.388	2.017	2.098	1.788	2.11	1.747

D.I - Differentiation Index of Thornton and Tuttle (1960)

C.I - Crystallization Index of Poldervaart and Parker (1965)

Standard CIPW norm with biotite and hornblende

Sample no.	mmk-1	mmk-2	mmk-3	mmk-4	mmk-5	mmk-6	mmk-7
Quartz	38.46	36.505	34.741	34.427	32.412	28.359	28.61
Corundum	3.126	3.005	3.392	4.547	3.84	4.572	4.13
Orthoclase	30.353	30.605	34.129	31.456	33.254	34.165	35.561
Albite	22.209	23.561	23.178	22.936	24.598	27.748	27.235
Anorthite	1.69	1.805	0.776	-	-	0.569	0.398
Ilmenite	0.065	0.06	0.064	0.107	0.107	0.068	0.064
Hematite	1.876	2.018	1.679	3.181	2.877	1.991	1.727
Apatite	0.524	0.49	0.568	0.711	0.663	0.642	0.641
Sphene	0.568	0.612	0.515	0.786	0.668	0.606	0.541
Sum	100	100	100	100	100	100	100

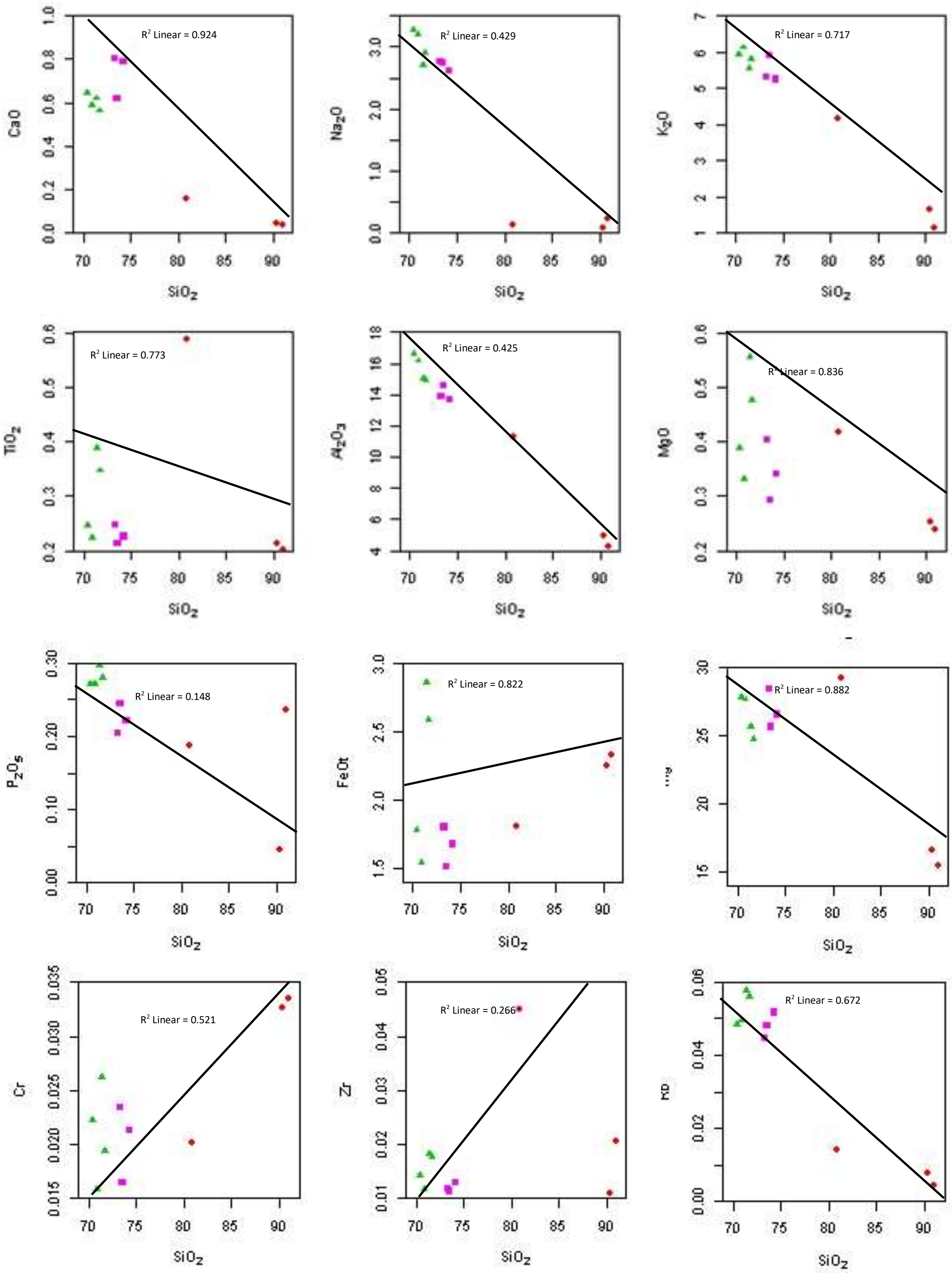


Figure 4. Harker's variation diagrams illustrating major oxide Vs SiO_2 of the granitic rocks from the research area. Symbols as in Table (2)

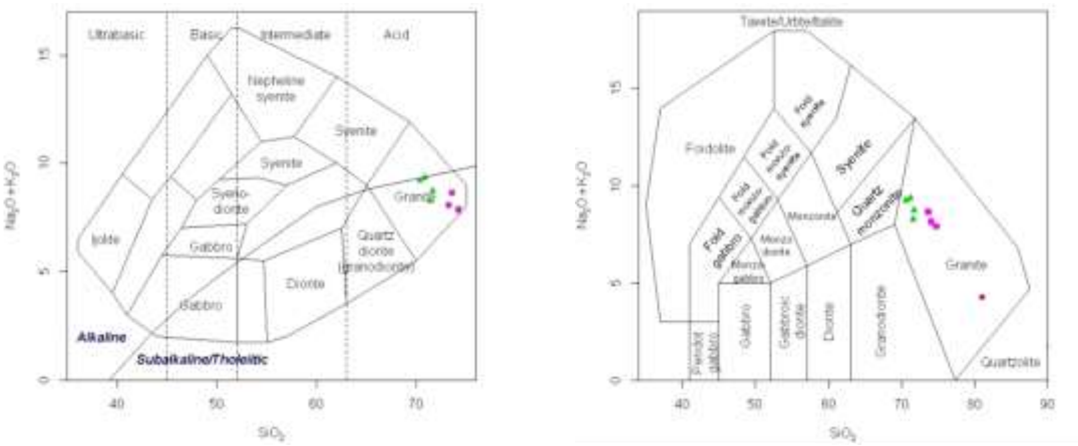


Figure 5. (A) TAS diagram of Cox et. al. (1979) showing subalkaline series of the research area, Symbols as in Table (2)
(B) TAS diagram of Middlemost (1994), granitic rocks fall in the granite field

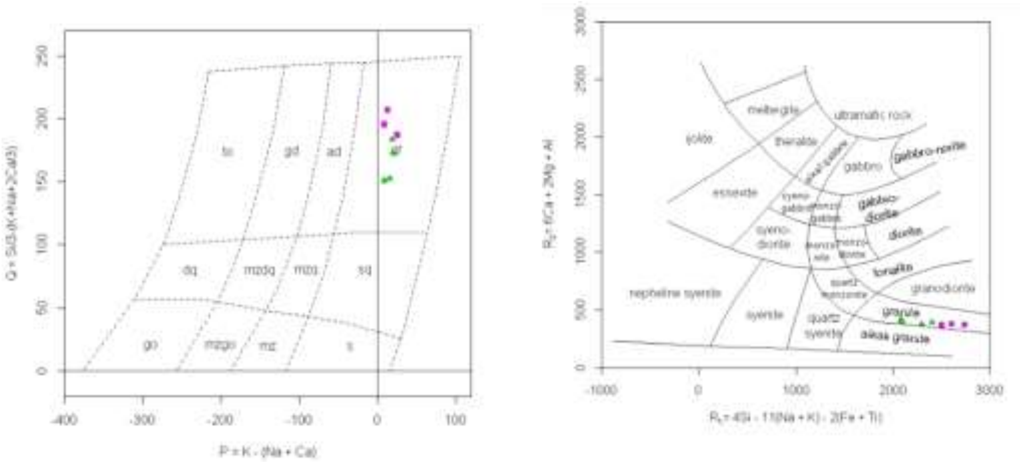


Figure 6. (A) P-Q (Debon and Le Fort, 1983) diagram showing the igneous rocks of the research area. Symbols as in Table (2)
(B) R_1-R_2 multication classification diagram for the igneous rocks of the research area (after De la Roche et. al. 1980), Symbols as in Table (2)

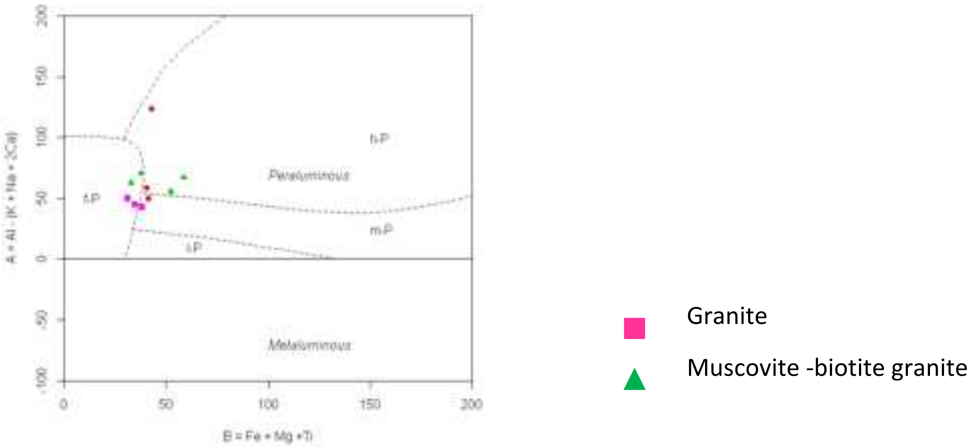


Figure 7. A = Al - (K + Na + 2Ca) Vs B (Fe + Mg + Ti) diagram showing the peraluminous and metaluminous characters of granitic rocks of the research area (B-A plot modified by Villaseca et al, 1998), Symbols as in Table (2).

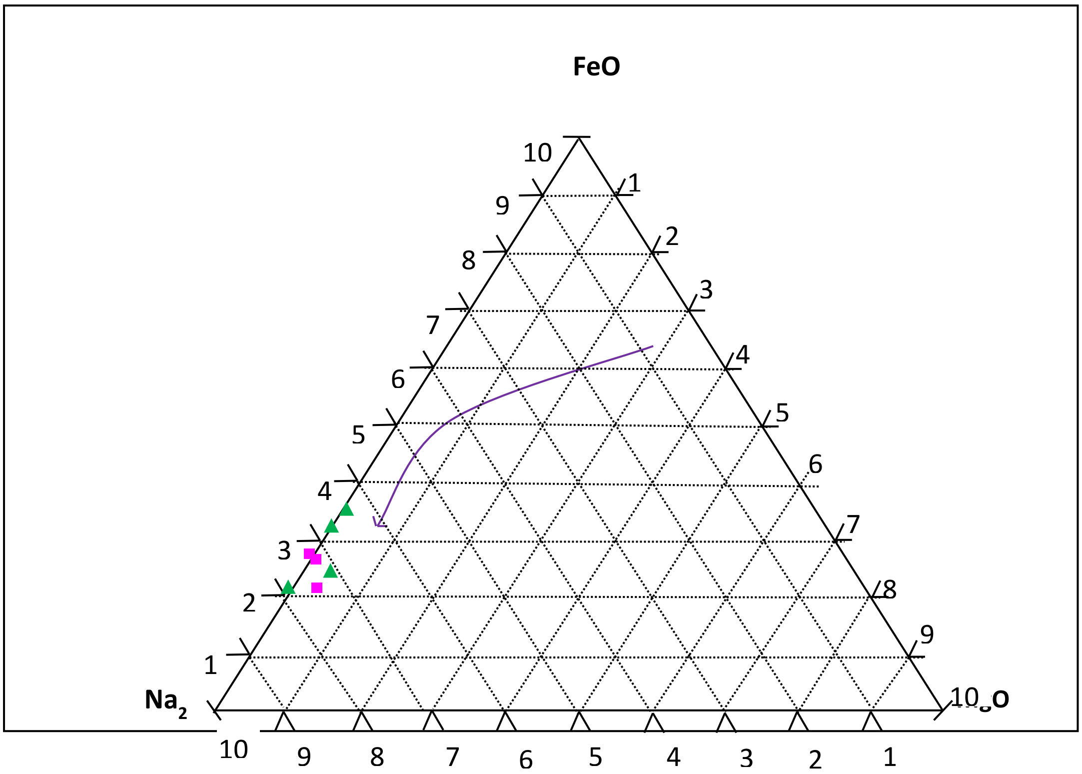


Figure 8. FeO_t - Na_2O+K_2O - MgO (AFM) diagram explains magmatic differentiation within the series (after Hine et. al, 1978). Evolutionary trend is indicated by the arrow. Symbols as in Table (2)

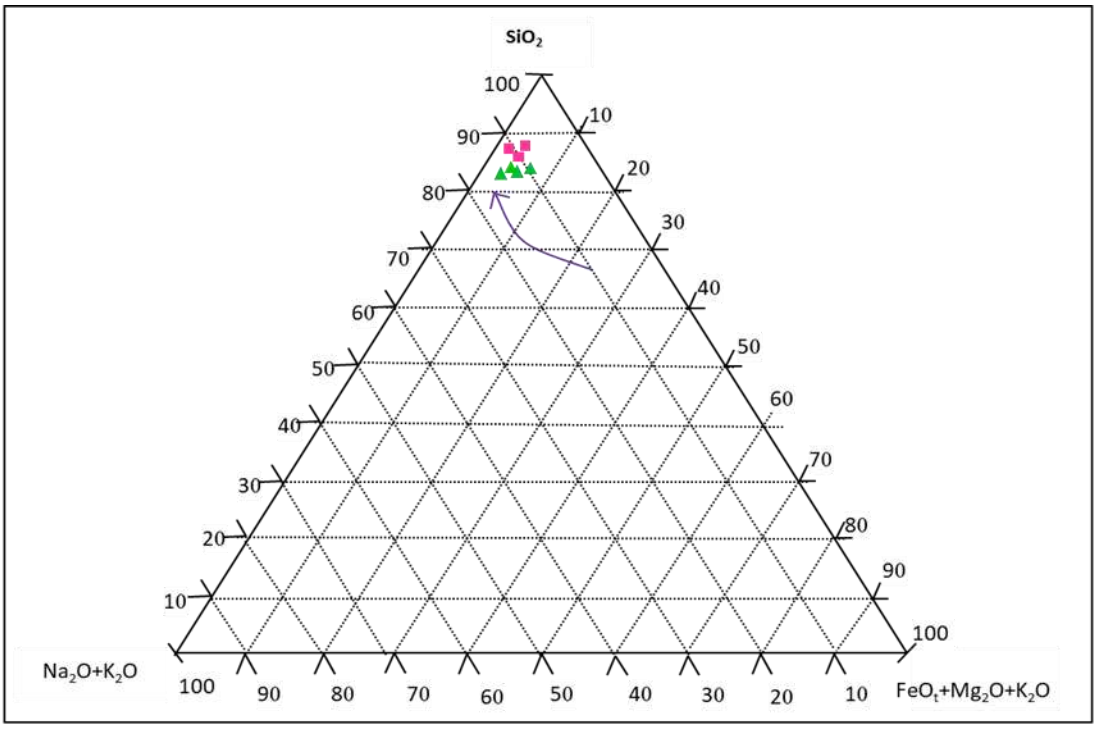


Figure 9. SiO_2 - Na_2O+K_2O - FeO_t+MgO diagram shows the evolutionary trend of the igneous rocks differentiation (after Le Maitre, 1989). Differentiation within the series is indicated by the arrow. Symbols as in Table (2)

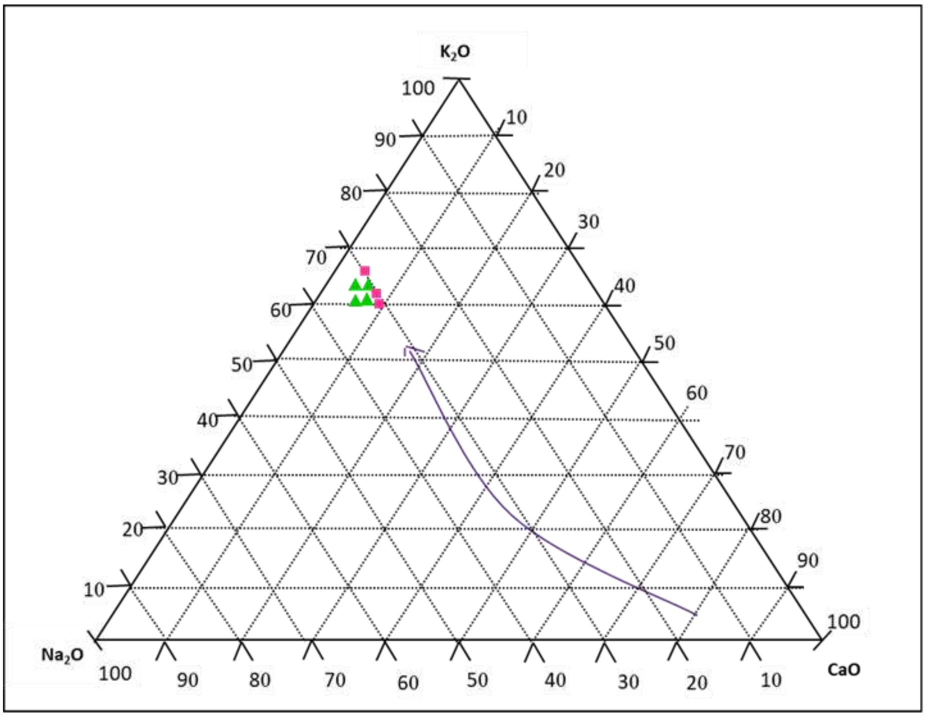


Figure 10. K_2O-Na_2O-CaO ternary diagram exhibits magmatic differentiation of the granitic rocks in the research area, (after Chappell and White, 1974). Evolutionary curve is indicated by the arrow. Symbols as in Table (2)

Genetic type of granitic rocks

Major elements characteristics of the granitic rocks have been used as a key for the interpretation of the origin of granite. The granitic rocks from the research area are predominantly peraluminous. Molecular Al_2O_3/Na_2O+K_2O, A/NK>1.1, A/NK value is 1.687 - 1.821 and Molecular Al_2O_3/ $CaO + Na_2O + K_2O$, A/CNK> 1.1, A/CNK value is 1.569 - 1.691. Some muscovite-biotite granites are relatively high in sodium, Na_2O normally $> 3.2\%$ with approximately 5% K_2O and three granites and two muscovite-biotite granites are low in sodium, Na_2O normally$< 3.2\%$. The normative corundum ranges from 2.693 - 4.267. Lack of normative magnetite is characteristic of S-type. From the result of K_2O Vs Na_2O diagram, the granitic rocks of the research area involve S-type is exhibited in Figure.10. Two mica granites are considered as sedimentary protolith of S-type. Above these facts, the granitic rocks in the research area are S-types granite according to Chappell and White (1974). The relatively high quartz content, in the range of (27.471-37.681wt %) of this S type granite can be considered that this granite was derived from the quartz rich sedimentary rocks. It may be formed from the supracrustal origin (Chappell and White, 2001). Rb-Ba-Sr diagram, Figure.11 shows that two granites and four muscovite-biotite granites are fitted in strongly differentiated granite and only granite from the research area is fitted as low Ca granite (El Bouseily and El Sokkary, 1975).

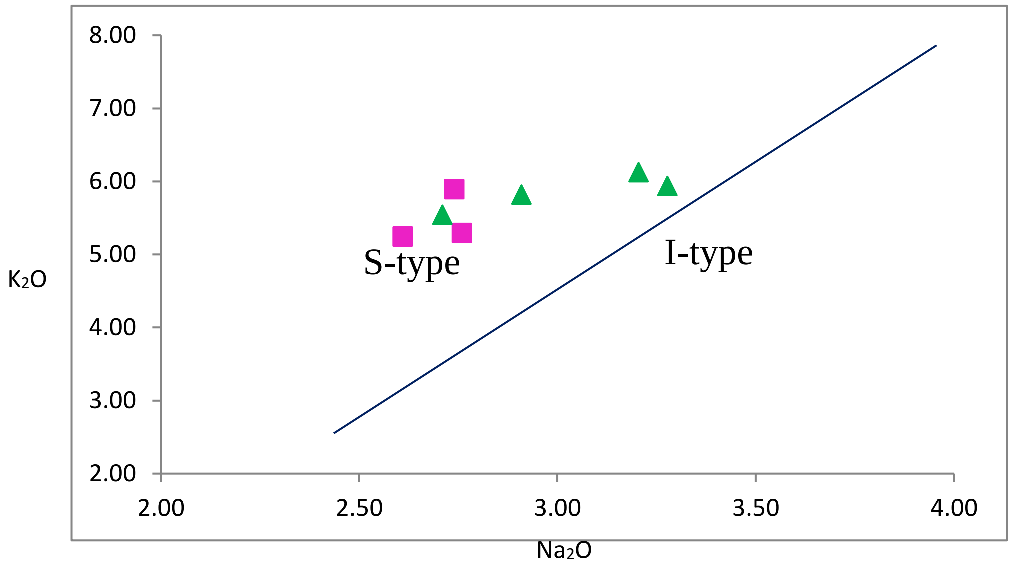


Figure 11. K_2O Vs Na_2O diagram for the granitic rocks of the research area, (after Chappell and White, 1983)

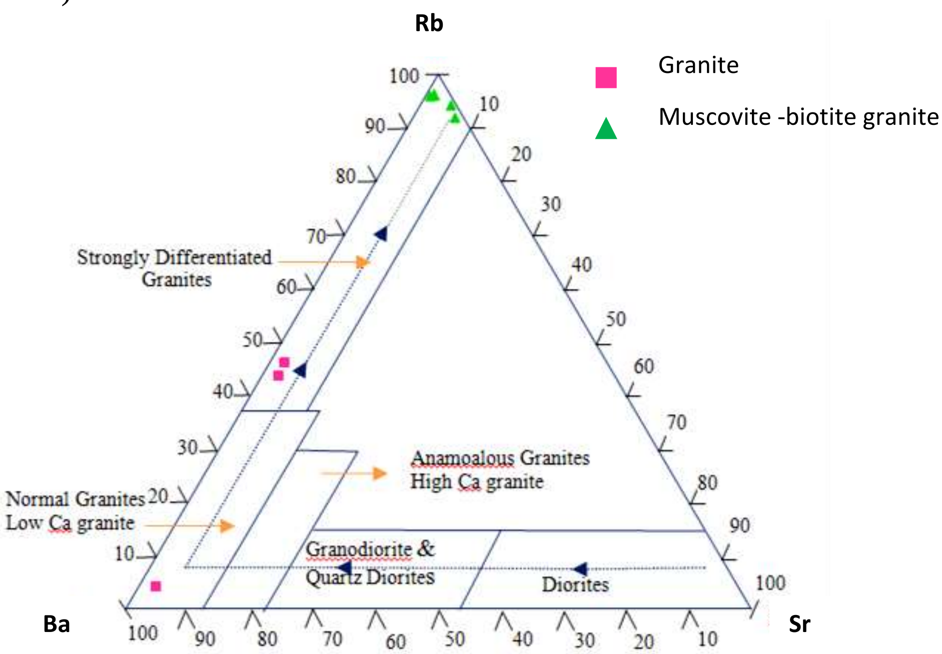


Figure 12. The different fields of the ternary relation Rb-Ba-Sr on some investigated igneous rocks. Arrow indicates differentiation trend. (after EL Bouseily and EL Sokkary, 1975)

Condition during Crystallization of the Granitic Rocks

Normative data plot of Quartz - Albite - Orthoclase diagram after Tuttle and Bowen (1985), H_2O saturated liquidus field boundaries in the system for various water pressures. This diagram, Figure.12 (A) indicates that the granitic rocks in the research area lie within 2kb and 10 kb during crystallization. Ternary plot of the normative weight percent composition of Quartz-Anorthite-Orthoclase (after Tuttle and Bowen, 1958), Figure.12 (B) exhibits that the majority of all granitic rock samples were formed between 0.5kb and 5kb. It can be suggested that the granitic rocks from the research area were consolidated under the low pressure condition. If the igneous rocks were assumed as crystallization at minimum pressure of 2kb, their liquid temperature can be estimated from the diagram showing the relationship between differentiation index and temperature at 2 kb water pressure. From this diagram, the liquidus temperatures are 720˚C for granites and muscovite-biotite granites, Figure.13. Depth of the crystallization of the granitic rocks can be expressed from the schematic depth-temperature diagram (after Marmo, 1956) in Figure.14. Generally, it may be suggested that granites and muscovite-biotite granites crystallized at the depth of 26km.

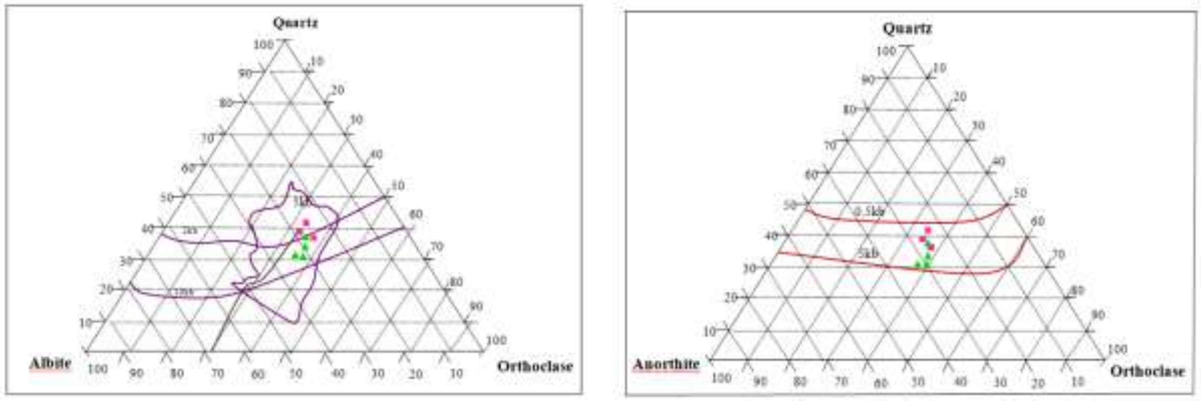


Figure 13. (A) Normative data plot of Quartz-Albite-Orthoclase ratio exhibits the granitic rocks in the research area have water pressure within 2kb and 10kb (after Tuttle and Bowen, 1985). Symbols as in Table (2)

(B) Ternary plot of the normative Quartz-Anorthite-Orthoclase shows the granitic rocks were formed between 0.5kb and 5kb water pressure (after Tuttle and Bowen, 1985). Symbols as in Table (2)

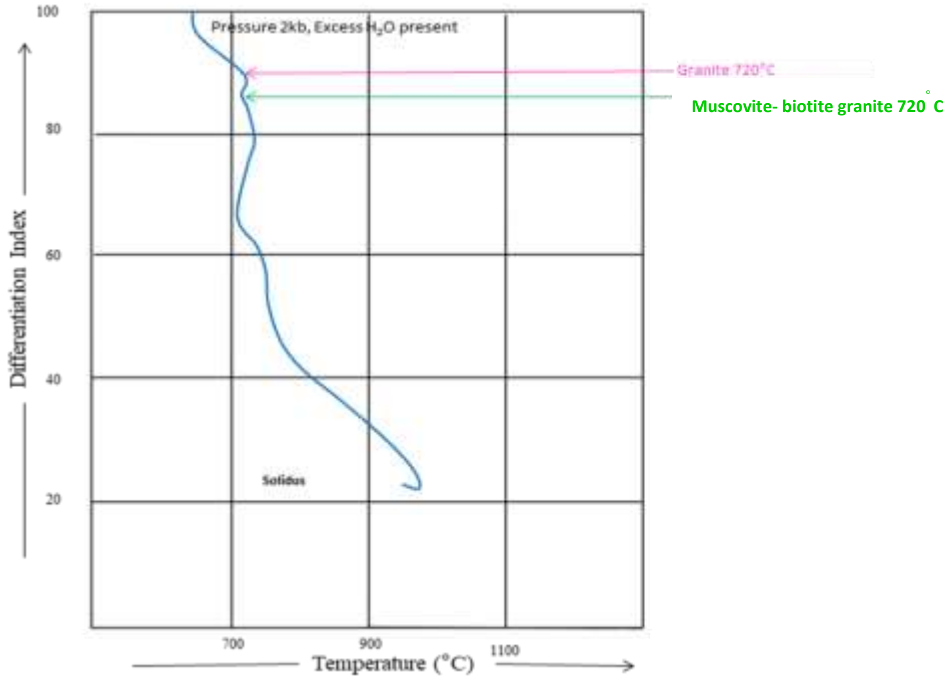


Figure 14. Temperature-differentiation index diagram for the igneous rocks of the research area, at 2 kb water pressure (after Piwinskii and Wyllie, 1970)

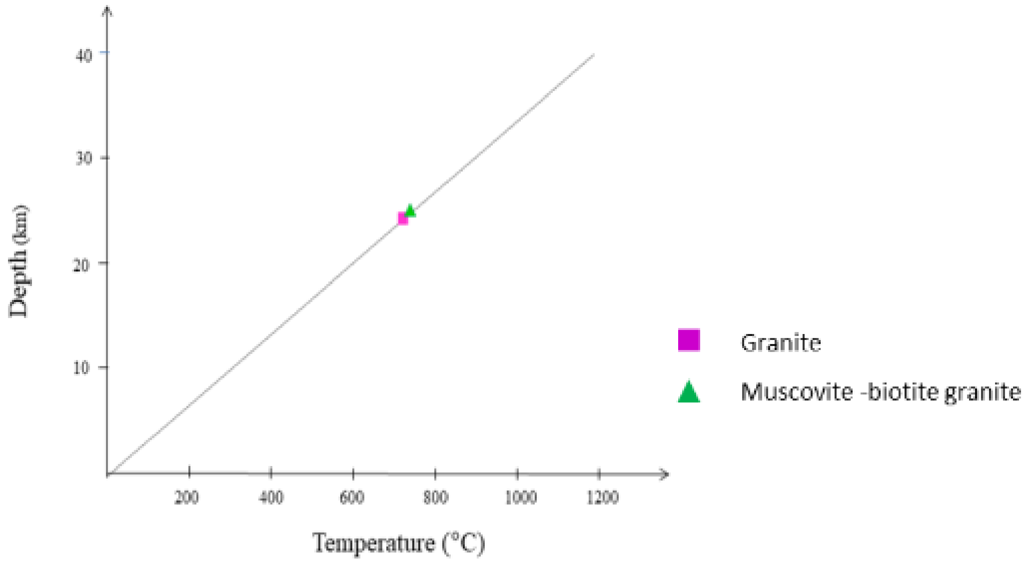


Figure 15. Schematic depth-temperature relation diagram for the igneous rocks of the research area, (after Marmo, 1969)

Tectonic Discrimination of the Granitic Rocks

The configurations of tectonic environments for the granitic rocks of the research area were made by using Maniar and Piccoli (1989) classification schemes. They classified the granitoid rocks by 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 epeirogenic uplift Granitoid (CEUG)

(g)Oceanic Plagiogranite (OP)

In plots of M/AFM (MgO/Al_2O_3+FeO+MgO) versus F/AFM (FeO /$Al2O_3$ +FeO +MgO) and C/ACF (CaO /Al_2O_3 +CaO + FeO) versus F/ACF (FeO/Al_2O_3+CaO+FeO) variation diagrams show the granitic rocks of the research area fall within the IAG+CAG+CCG field. is exhibited in Figure.16 (A&B). According to SiO_2 Vs Al_2O_3 diagram (after Maniar and Piccoli, 1989), Figure.17(A) showing the environment of the granitic rocks from the research area fall within the IAG+CAG+CCG field. Again in the Shand's Index diagram, Figure.17(B) exhibited that plots of the granitic rocks fall in the CAG and CCG field. According the above mentioned data, it can be safely considered that the granitoid rocks of the research area are Orogenic granitoids. Therefore, the granitic rocks were formed on the continent relation to the subduction of an oceanic plate beneath the continent. Batchelor and Bowden (1985) used to discriminate the tectonic setting of granite, according to R_1-R_2 binary (millication) diagram, Figure.18 indicates the granitoid rocks of the research area correspond to syn-collision zone.

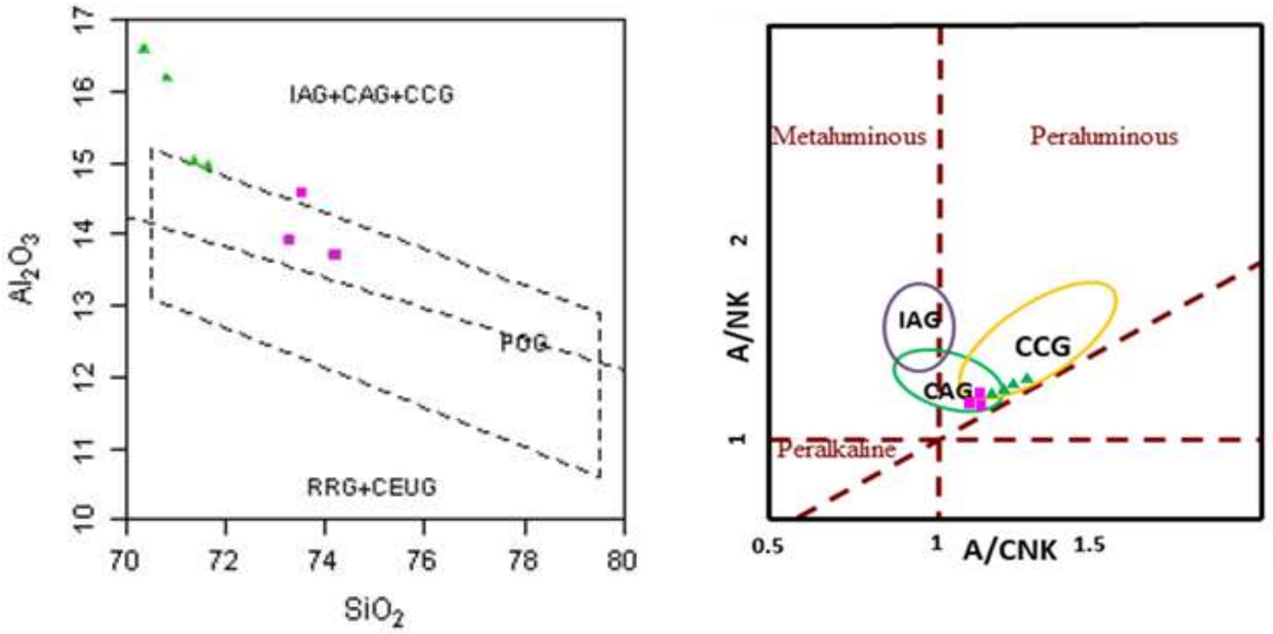
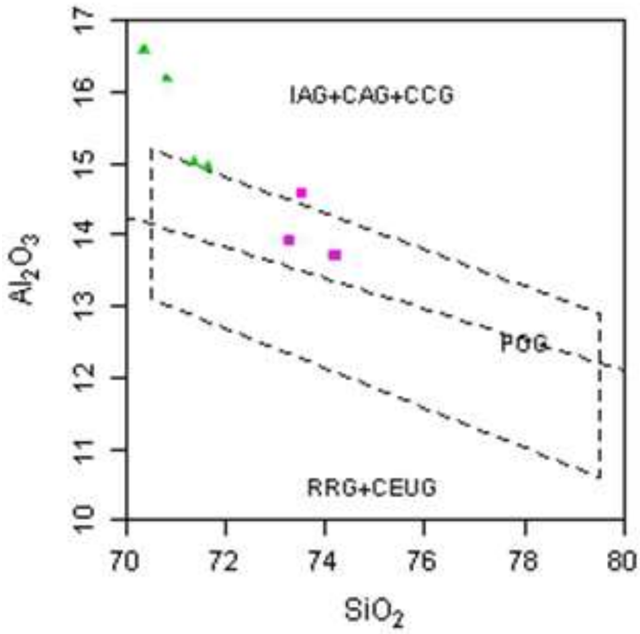
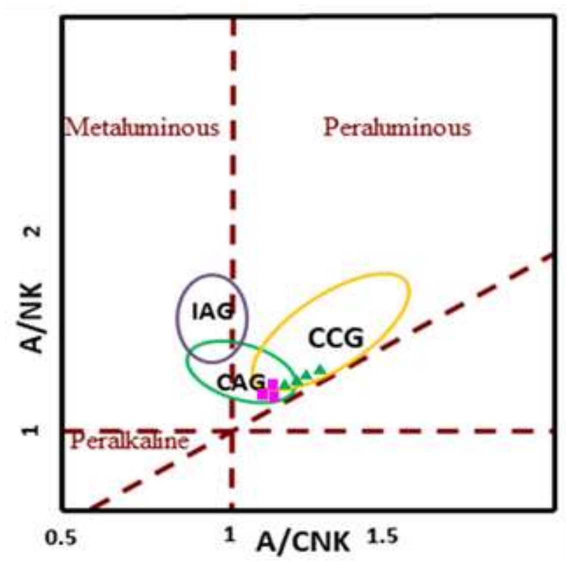


Figure 16. (A)AFM diagram showing the environment of the granitic rocks from the research area fall within the IAG+CAG+CCG field (after Maniar and Piccoli, 1989)

(B) ACF diagram showing the granitic rocks of the research area fall within the





IAG+CAG+ CCG field (after Maniar and Piccoli, 1989)

Figure 17. (A)SiO_2 Vs Al_2O_3 diagram showing the environment of the granitic rocks from the research area fall within the IAG+CAG+CCG field (after Maniar and Piccoli, 1989)

(B) Shand's Index diagram for granitic rocks of research area, which fall within the CAG and CCG field

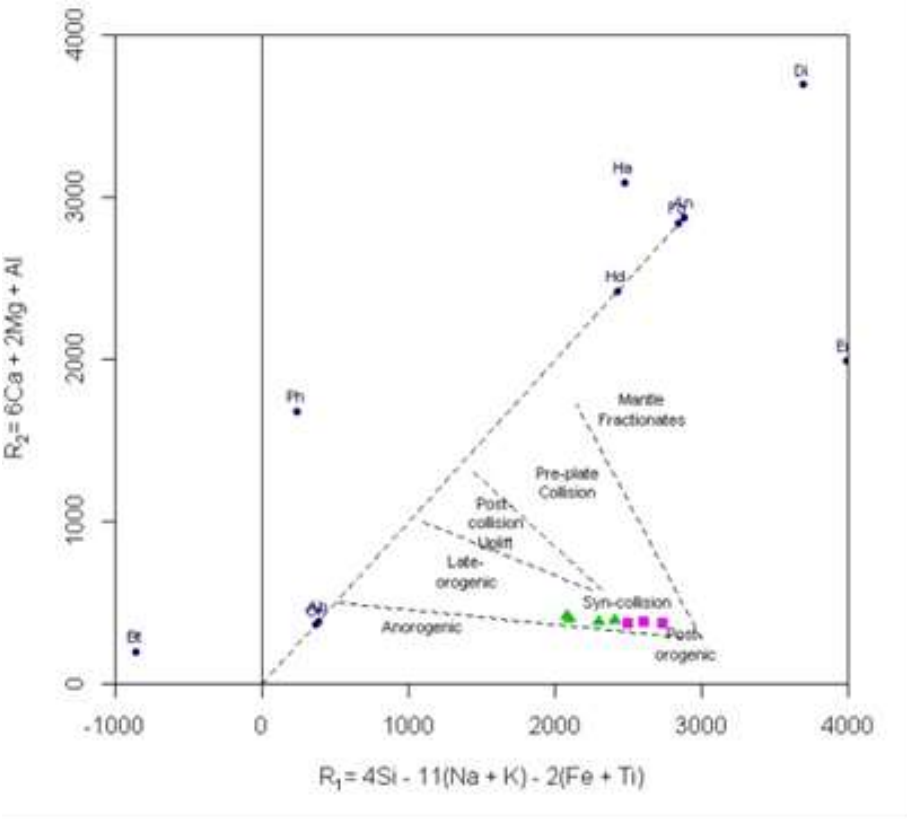


Figure 18 R_1-R_2 binary (millication) diagram showing the discrimination of the tectonic setting of granitic rocks (after Batchelor and Bowden, 1985)

Conclusion and Discussion

The research area is situated about 21km, southeast of Hopong township, Southern Shan State. The intrusive igneous rocks are granites and muscovite-biotite granites. Petrochemically, P - Q, R_1-R_2, normative (Ab - Or - An) and TAS diagrams indicate that the granitic rocks belong to the granite field. Na_2O-Al_2O_3-K_2O and B-A plot diagrams show that granites and muscovite-biotite granites are predominantly peraluminous. Two mica granites are considered as sedimentary protolith of S-type. K_2O Vs Na_2O diagram indicates that granites and muscovite-biotite granites involve S-type, it formed from the supracrustal origin. Quartz - Albite - Orthoclase diagram indicates that it lies within 2kb and 10 kb. According to ternary plot of Quartz-Anorthite-Orthoclase diagram exhibits that the majority of all granitic rock samples were formed between 0.5kb and 5kb. It can be suggested that the granitic rocks from the research area were consolidated under the low pressure condition. From differentiation index and temperature diagram, the liquidus temperatures are 720˚C for granites and muscovite-biotite granites. Depth of the crystallization of the granitic rocks can be expressed from the schematic depth-temperature diagram, it may be interpreted that granites and muscovite-biotite granites crystallized at the depth of 26km. In plots of M/AFM Vs F/AFM, C/ACF Vs F/ACF and SiO_2 Vs Al_2O_3 diagrams show the granitic rocks of the research area fall within the IAG+CAG+CCG field. Again, in the Shand's Index diagram, the granitic rocks fall in the CAG and CCG field. According the above mentioned data, it can be safely considered that the granitoid rocks of the research area are Orogenic granitoids. Therefore, the granitic rocks were formed on the continent relation to the subduction of an oceanic plate beneath the continent. R_1-R_2 binary (millication) diagram indicates the granitic rocks of the research area correspond to syn-collision zone.

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