A Study on the Genetic Types of Granitoids from Kyaing Tong Batholith, Eastern Shan State, Myanmar

Khine Zar Wai[1], Day Wa Aung[2], Min Aung[3], Zin Maung Maung Thein[4]

Abstract

The study area is situated about 8 km north of Kyaing Tong. It is bounded by North Latitudes 21º 23´ 47″ to 21°28´15″ and East Longitudes 99°34´45″ and 99°42´35″. Seven representative samples were choice to analyze the geochemical data of granitoid rocks from Kyaing Tong batholith. It is mainly composed of leucogranite, biotite granite and granodiorite. SiO_2 contents are range from 73.23 to 74.73 wt (%) in leucogranite, (65.83%-68.77%) in biotite granite and (65.73 - 66.49%) in granodiorite. Na_2O contents are (1.4 to 3.65 %), (1.77-1.81%) and (1.3 to 1.61%) in leucogranite, biotite granite and granodiorite respectively. K_2O contents are (4.01 to 6.31%), (3.64-3.95%) and (3.24 to 5.52%) in leucogranite, biotite granite and granodiorite respectively. CaO contents in leucogranite range from 0.31 to 0.52%, (1.92-3.06%) in biotite granite and (3.4 t- 3.76%) in granodiorite. Although total contents of (Na_2O+K_2O) % in leucogranite is more constituent than in granodiorite, total (CaO+ Na_2O+K_2O) % in leucogranite is lesser constituent than in granodiorite. Molecular values of A/CNK ratio is less than 1.1 limited values in granodiorite while greater than 1.1 limited values in both leucogranite and biotite granite. On the other hand, the composition of quartz and feldspar proportions is very important to identify the nomenclature and igneous classification of granitoid rocks. Geochemical data proved to be useful in distinguishing parental magma, genetic types from I-type or S-type and granitoid rock classifications.

Keywords: geochemical data, granitoid rocks, Kyaing Tong batholith

Introduction

The Kyaing Tong batholith is mainly composed of granitoid rocks. It is located in N 21˚ 22´ – N 21˚ 29´ & E 99˚ 35´ - E 99˚ 44´. It is also situated in northeastern part of eastern granitoid belt of Myanmar (Khin Zaw, 1990) (Figure 1). Geotectonically, it is directly related to the collision of Shan-Thai (Sibumasu Block) and Indochina block. Kyaing Tong batholith is mainly composed of various granitoid rocks such as leucograntie, biotite granite, hornblende granite, foliated granite, porphyritic biotite granite and granodiorite.

This paper is emphasized on the significant role of SiO_2, Al_2O_3, Na_2O, K_2O and CaO proportions in IUGS classification and genetic types of granitoid rocks of Kyaing Tong batholith as an approach to two leucogranite samples, two biotite granite and three granodiorite samples. Leucogranite is marked by highly weathered and kaolinization features on most outcrop (Figure 2 a). Biotite granite is widely distributed in main batholiths (Figure 2b). Granodiorite outcrops are recognized by very compact (Figure 2c). Age dating of Kyaing Tong granite is recognized by late Triassic (219.3 ±1.3 & 220.1± 1.1) (Gardiner et al.2015).

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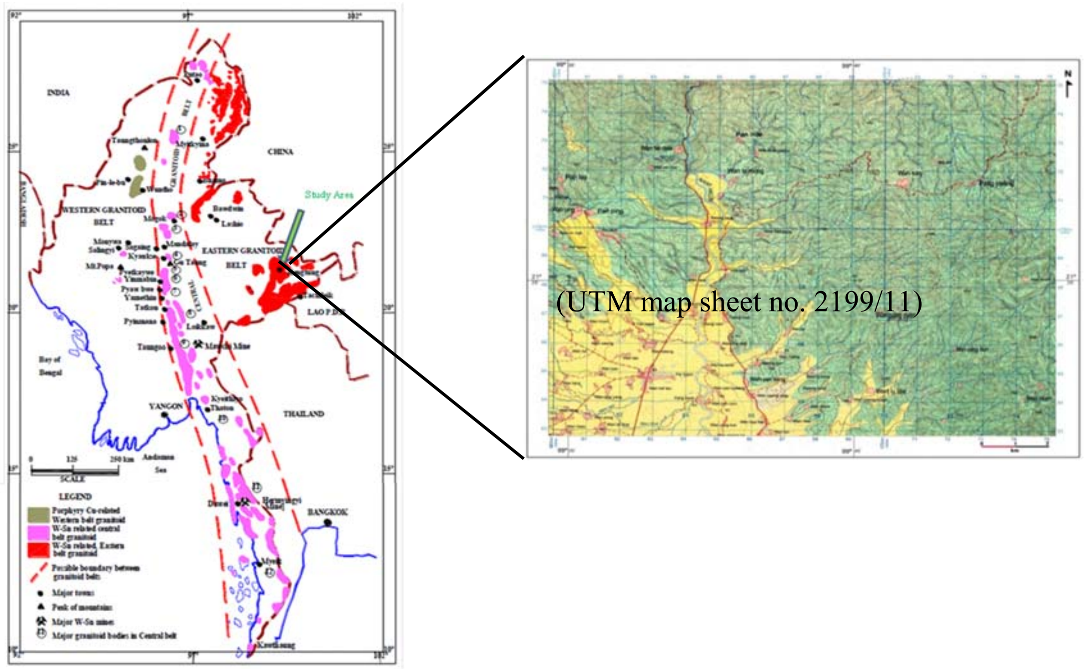


Figure (1). Map showing three granitoid belts of Burma viz. western, central and eastern granitoid belts.(after Khin Zaw,1990)

Regional Geologic Setting

The study area in the easternmost province of Myanmar, comprising high lands and plateaus, east of the Sagaing fault, referred to as the Eastern High Lands Province (EHP) covers the entire eastern half of the country, known as the Shan-Thai Block (STB) which is part of the Sibumasu Block (SB). The Sibumasu block was also sutured with the Indochina Block to the east, forming a more extensive landmass called Sundaland which covers much of the mainland of Southeast Asia and is often addressed as Sunda Plate or Southeast Asian plate (Win Swe, 2012). Regional geological map around the study area is shown in (Figure 3). This region is geotectonically situated in the eastern part of Shan- Tenasserim Block. Western boundary of this section of continental crust is marked by the N-S striking Shan Boundary Fault, which accompanies the Shan Escarpment in the west and is presumed to continue to the south in the Gulf of Martaban. Also it forms part of the land mass of the Indo-Chinese Peninsula (Yunnan, Thailand and Malaysia), which extends to the south in Sundaland (Hutchison, 1973). The easternmost part of the study area is approximately bordered by the Mekong River. The middle course of the river is largely controlled by the regional position of granitic intrusions and metamorphic rocks mostly situated on the right bank of the river regionally trending NE to NS striking bands. They are regionally presumably interrupted by intercalations of marine rocks which are probably due to the episodic inundations (Wolfrat, 1984).

The eastern belt granitoids of Myanmar is characterized by medium to coarse porphyritic textures and country rocks of regionally metamorphosed, turbiditic sediments of Chaung Magyi Group (Upper Precambrian). Geological map of the study area is shown in (Figure 4). This eastern granitoid belt lies immediately to the north of mostly Triassic granitoids in northern Thailand, and the Sn-W bearing, mesozonal, Permo-Triassic, Main Range granitoids in the western part of the Malay Peninsula.

Figure (2). (a) Highly weathered and Kaolinization feature on massive leucogranite outcrop. (b) Highly jointed feature of bluish grey colored biotite granite outcrop. (c) Polished surface feature of very compact light grey colored granodiorite outcrop.

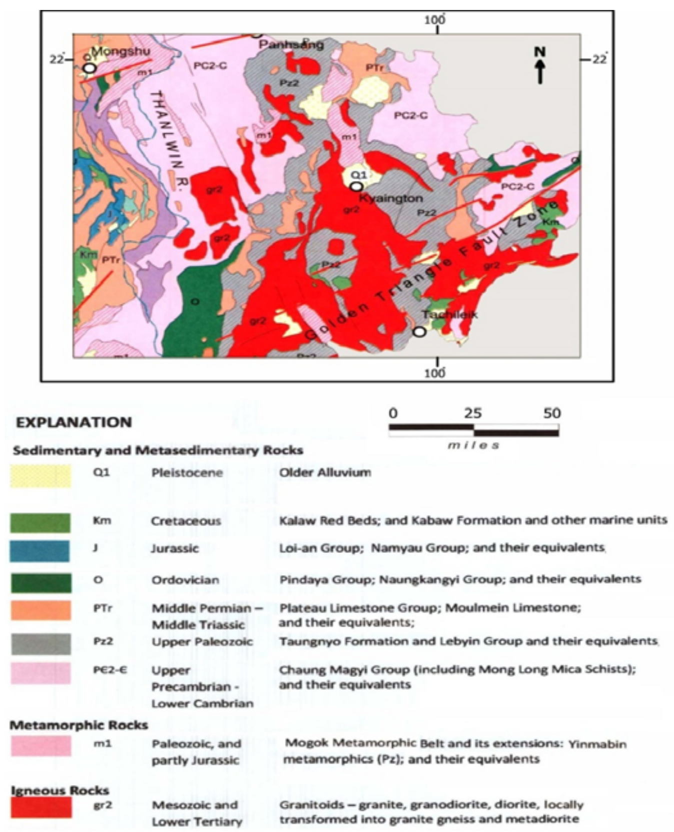


Figure (3). Regional geological map of around the study area.(Source:Myanmar Geosciences, 2014).

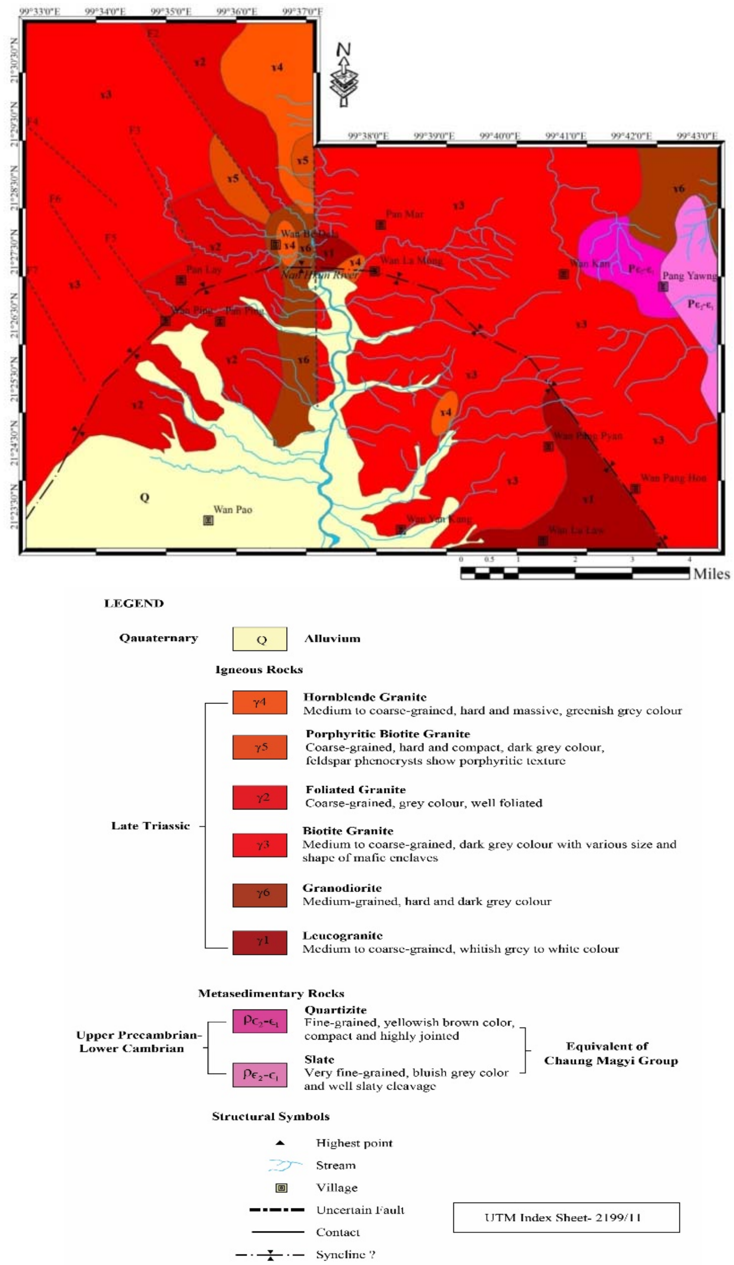


Figure (4). Geological map of the study area.(Khine Zar Wai, 2018)

Analytical Methods

A total of seven representative samples have been selected and analysed to major oxide wt (%) and trace element (ppm) composition by XRF (X-ray fluorescence) spectrometer using standard calibration method at Petrology Lab., Geology Department, Kyushu University.

Data Presentation

The major oxide and trace element compositions of the representative granitic rocks from the study area are shown in (Table 1 & 2). Standard CIPW norms with biotite and hornblende are calculated according to the rules of Hutchison (1975) by using the aid of computer (Table 3). The major and trace elements data were illustrated in variation diagrams, ternary diagrams, binary diagrams and triangular plots by using GCD kits 3.0 software. Thornton and Tuttle Index (TTID or D.I, Differentiation Index), orthoclase (Or), albite(Ab), anorthite (An) and corundum wt (%) were calculated from the data of standard CIPW norms which can be used as an indicator of bulk composition.

Table (1). Major oxide wt (%) composition of the Kyaing Tong granitoid rocks.

Sample NO.	KZW-7	KZW-10	KZW-54	KZW-3	KZW-12	KZW-18	S-1
SiO_2	66.49	65.73	65.98	74.73	73.23	65.83	68.77
TiO_2	0.90	0.85	0.71	0.02	0.23	0.89	0.83
Al_2O_3	13.7	13.83	14.2	14.06	13.8	13.96	13.6
Fe_2O_3	5.98	5.98	5.24	1.19	2.01	5.54	4.87
MnO	0.11	0.1	0.09	0.31	0.02	0.09	0.07
MgO	3.88	3.96	3.32	0.36	0.76	3.51	2.47
CaO	3.76	3.61	3.40	0.52	0.31	3.06	1.92
Na_2O	1.61	1.3	1.3	3.65	1.4	1.81	1.77
K_2O	3.24	4.21	5.52	4.01	6.31	3.64	3.95
P_2O_5	0.32	0.29	0.23	0.06	0.2	0.31	0.19
Total	99.99	99.99	99.99	98.91	98.27	98.64	98.44

Table (2). An emphasized data based on major oxide wt (%) composition of the Kyaing Tong granitoid rocks.

Sample no.	KZW-7	KZW-10	KZW-54	KZW-3	KZW-12	KZW-18	S-1
SiO_2	66.49	65.73	65.98	74.73	73.23	65.83	68.77
Al_2O_3	13.7	13.98	14.2	14.06	13.8	13.96	13.6
CaO	3.76	3.61	3.4	0.52	0.31	3.06	1.92
Na_2O	1.61	1.3	1.3	3.65	1.4	1.81	1.77
K_2O	3.24	4.21	5.52	4.01	6.31	3.64	3.95
Na_2O+K_2O(%)	4.85	5.51	6.82	7.66	7.71	5.45	5.72
Na_2O+K_2O+CaO	8.61	9.12	10.22	8.18	8.02	8.51	7.64
A/CNK	1.05	1.05	0.99	1.24	1.42	1.84	1.27
K_2O/Na_2O	2.01	3.24	4.25	1.1	4.51	2.01	2.23

SiO_2, Al_2O_3, CaO, Na_2O and K_2O contents are very significant in identification the classification and origin of granitoid rocks. Norm values of quartz (according to geochemical data) in leucogranite range from 35.92% to 38.83%, in biotite granite range from 28.28% to 34.32 and in granodiorite range from 22.85 to 28.75%. Orthoclase contents in leucogranite is range from 23.70% to 37.65%, in biotite granite range from 15.32% to 24.07% and in granodiorite (20.74 – 34.22%), plagioclase contents in leucogranite is range from 12.08% to 33.08%, in biotite granite range from 23.32% to 35.45% and in granodiorite (26.55 - 30.37%).SiO_2 contents are (73.23 - 74.73%), (65.83 - 68.77%) and (65.73-66.49%) in leucogranite, biotite granite and granodiorite respectively.

Al_2O_3 contents are (13.8%-14.06%), (13.6%-13.96%) and (13.7%-14.2%), CaO contents are (0.31%-0.52%), (1.92%- 3.06%) and (3.4%-3.76%), Na_2O contents are (1.4%-3.65%), (1.77%-1.81%) and (1.3% -1.61%), (Na_2O+K_2O) contents are (7.76%-7.71%), (5.45%05.72%) and (4.85%-6.82%), (Na_2O+K_2O+CaO) contents are (8.02%-8.18%), (7.64%-8.51%) and (8.61%-10.22%) in leucogranite, biotite granite and granodiorite respectively. According to Chappell and White (2001), molecular weight percent of A/CNK values are (1.24-1.42), (1.27-1.84) and (0.99-1.05), normative corundum values are (2.91-4.52), (2.07-3.22) and (0.09-1.11) in leucogranite, biotite granite and granodiorite respectively.

Table (3). Standard CIPW norm and standard CIPW norm with biotite and hornblende of the granitoid rocks of Kyaing Tong area.

Sample No.	KZW-7	KZW-10	KZW-54	KZW-3	KZW-12	KZW-18	S-1
Quartz	28.75	26.18	22.85	35.92	38.83	28.28	34.32
Orthoclase	20.74	26.48	34.22	23.70	37.65	15.32	24.07
Albite	13.62	11.00	11.00	30.89	11.85	13.21	14.98
Anorthite	16.75	16.20	15.55	2.19	0.23	22.24	8.34
Corundum	1.11	1.05	0.09	2.91	4.52	2.07	3.22
Hypersthene	13.83	14.05	12.03	2.50	3.26	12.36	8.88
Magnetite	2.60	2.60	2.28	0.52	0.87	2.41	2.07
Ilmenite	1.71	1.61	1.35	0.04	0.44	1.69	1.58
Apatite	0.74	0.67	0.53	0.14	-	0.72	0.44
Zircon	0.04	0.04	0.04	-	0.03	0.06	0.06
Pyrite	-	-	-	0.02	0.13	0.11	0.38
D.I	79.9	79.9	83.6	92.7	88.6	79.0	81.7
Total	99.89	99.88	99.94	98.84	98.27	98.49	98.34

In this paper, two main modal are used for genetic types of granitoid rocks whether tholeiite series or calc-alkaline magma series based on SiO_2 versus FeOt/MgO (after Myiashiro, 1974) and based on AFM plot (after Ivrine & Baragar, 1971). In addition to SiO_2–K_2O plot (after Peccerillo & Taylor, 1976) is used to get more definitely possible genetic source whether shoshonite series or high K-calc-alkaline series or calc-alkaline series or tholeiite series. Moreover, the origin of granitic rocks are whether peralkaline magma series or metaluminous/peraluminous magma series to analyze corresponding clan by using the modal of (A/CNK- A/NK) plot (after Shand, 1943) and molar Al_2O_3 - Na_2O - K_2O plot. According to Villaseca et al. 1998, show more detail source of metaluminous or low - peraluminous (l-p) or moderately - peraluminous (m-p) or high - peraluminous or highly felsic peraluminous granitoids (f-P) by using the B-A plot based on the composition and proportions of Al, K, Na, Ca, Fe, Mg and Ti. Genetic type classification of granitoid rock is very important for plutonic igneous rocks whether I-type or S-type genesis. According to (Chappell & White, 2001), genetic classification is very useful which are based on the proportions of SiO_2 versus molecular (A/CNK) ratio.

In this paper, six main classification modal are used for classification of granitoid rocks. TAS diagram (after Cox et al.1979) is based on the proportions of SiO_2 (wt %) and (Na_2O+K_2O) (wt %). It is generally subdivided into four types of acid, intermediate, basic and ultrabasic clans of intrusive igneous rocks. Moreover, it is useful in nomenclature and definite rock name classification of plutonic igneous rocks in which depends on this variable proportions especially for acid to basic compositions. On the other hand, Middlemost (1985) also described the new designate classification modal of plutonic rocks by using the proportions of SiO_2 (wt %) and (Na_2O+K_2O) (wt %). This classification is described by more advanced plutonic rock types especially depends on variable proportions of (Na_2O+K_2O) (wt %). Moreover, he also updated this classification for more advanced granitoid rock types especially depends on (Na_2O+K_2O) (wt %) in 1994. (R_1-R_2) plot diagram (after De La Roche et al.1980) is also the classification modal based on the proportions of R_1 = (Si, Na, K, Fe and Ti) (wt %) and R_2 = (Ca, Mg and Al) (wt %) for plutonic rocks. P-Q plot diagram (after Debon & Le Fort, 1983) is also the classification modal especially for more advanced granitoid rocks based on the proportions of P = (Na, K & Ca) (wt %) and Q = (Si, Na, K & Ca) (wt %).

Result Discussion

According to Harker variation diagrams of SiO_2 versus major oxide compositions, TiO_2, MgO, CaO, P_2O_5 and FeOt diagrams show negative correlation trends. Na_2O diagram shows positive correlation trend while Al_2O_3 and K_2O diagrams do not show strongly exhibit trend (Figure 5).

According to (Myiashiro, 1974) and (Ivrine & Baragar, 1971), Kyaing Tong granitoids is calc-alkaline magma series based on the compositions of SiO_2, FeOt/MgO and AFM plot (Figure 6 &7). According to (Peccerillo & Taylor, 1976), most selected samples are high-K-calc-alkaline magma series and two samples show shoshonite series (Figure 8). According to (Shand, 1943), (A/CNK- A/NK) plot (Figure 9) and molar Al_2O_3 - Na_2O - K_2O plot (Figure 10), Kyaing Tong granitoids is proved by peraluminous origin of most selected samples and one granodiorite sample shown in metaluminous origin. According to Villaseca et al. 1998, Kyaing Tong granitoids is proved by more detail source of one granodiorite sample in metaluminous, two granodiorite samples and one biotite granite sample in moderately - peraluminous (m-p), one biotite granite sample and one leucogranite sample in high - peraluminous and one leucogranite sample in highly felsic peraluminous (f-P) based on the B-A plot (Figure 11). According to (Chappell & White, 2001), Kyaing Tong granitoids is proved by both I & S-types origin based on SiO_2 versus the molecular weight percent proportions of A/CNK (Figure 12). A comparative study of the significant chemical character such as SiO_2 (%), K_2O/Na_2O (%), FeOt/MgO (%), Sr (ppm), Rb/Sr (ppm), Ni (ppm), Co (ppm), Cr (ppm) ratios and normative corundum values in I-type and S-type granitoid rocks of Kyaing Tong area is shown in (Table 4).

According to TAS diagram (after Cox et al.1979) which is more depend on SiO_2 percentage (Figure 13), (De la Roche, 1980) (Figure 14) and Middlemost (1985) (Figure 15) which are more depend on total feldspar proportions, most selected samples fall in quartz diorite (granodiorite) field and two leucogranite samples fall in granite field. On the other hand, according to Middlemost (1994), one granodiorite sample fall in tonalite field, two leucogranite samples fall in granite field and the rest are granodiorite field (Figure 16). According to (Debon & Le Fort, 1983) which is more depend on total feldspar proportions; three of selected samples (one leucogranite, one granodiorite and one biotite granite) fall in adamellite field and the others are granite field (Figure 17). According to the feldspar triangle (O'Connor ,1965), Kyaing Tong granitoids is proved by most selected samples in quartz monzonite field and the two leucogranite samples in granite field which are especially depend on only feldspar proportions (Figure 18). The significant role of SiO_2 is also recognized by the relative variation diagrams of trace elements (ppm) versus SiO_2 (%) composition (Figure19). The corresponding relative trace elements variations proved to be assigned the possible granitoids sources.

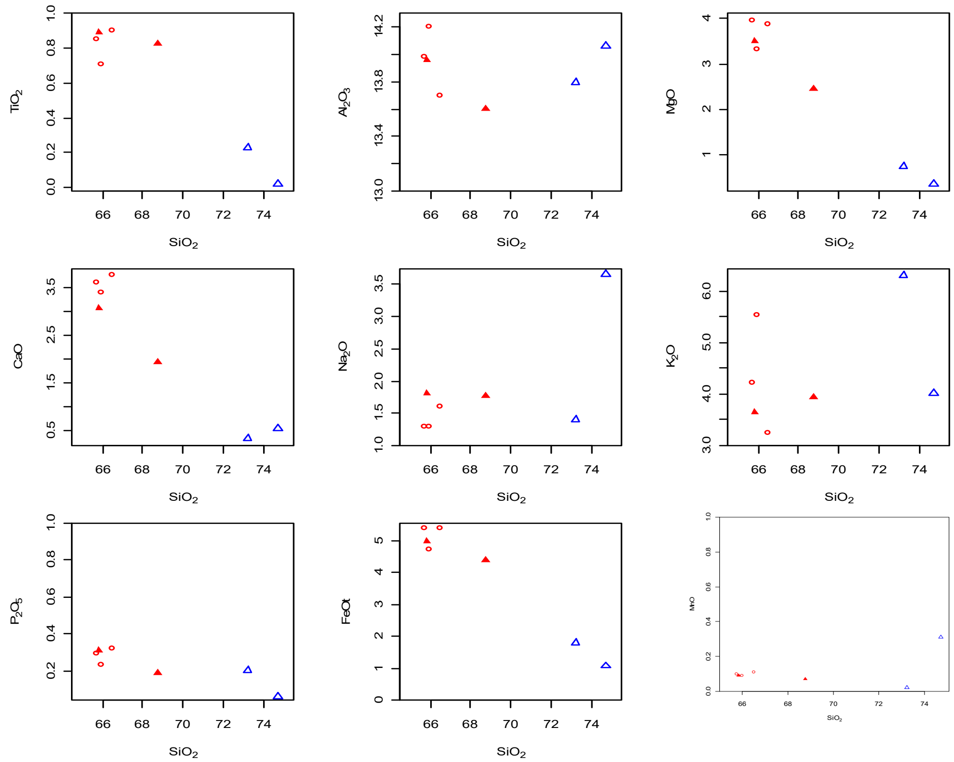
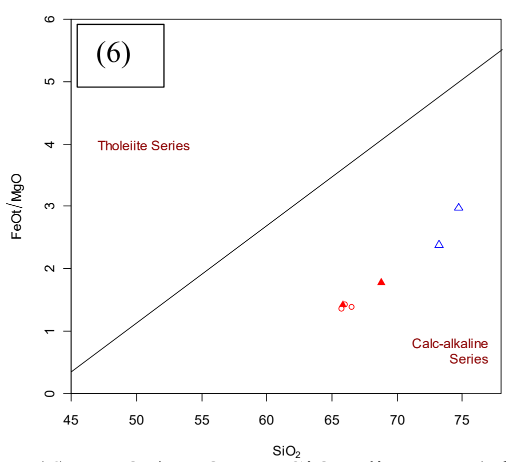


Figure (5). Major oxide Vs SiO_2 Harker variation diagrams of the granitoid rocks of the study area.



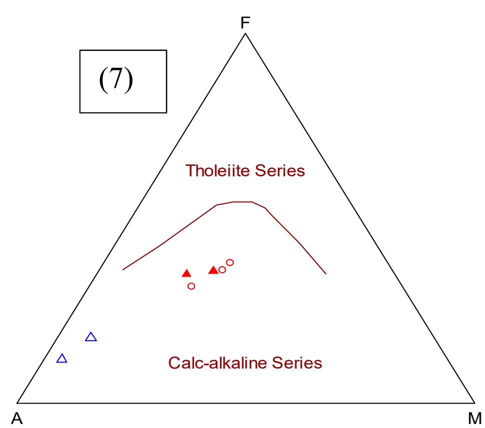


Figure (6). FeOt/MgO Vs SiO_2 diagram (after Miyashiro, 1974) showing the source of granitoid rocks (Tholeiitie series and calc-alkaline series) of the study area.

Figure (7). AFM diagram (Irvine and Barragar ,1971) showing the source of granitoid rocks (Tholeiitie series and calc-alkaline series) of the study area.

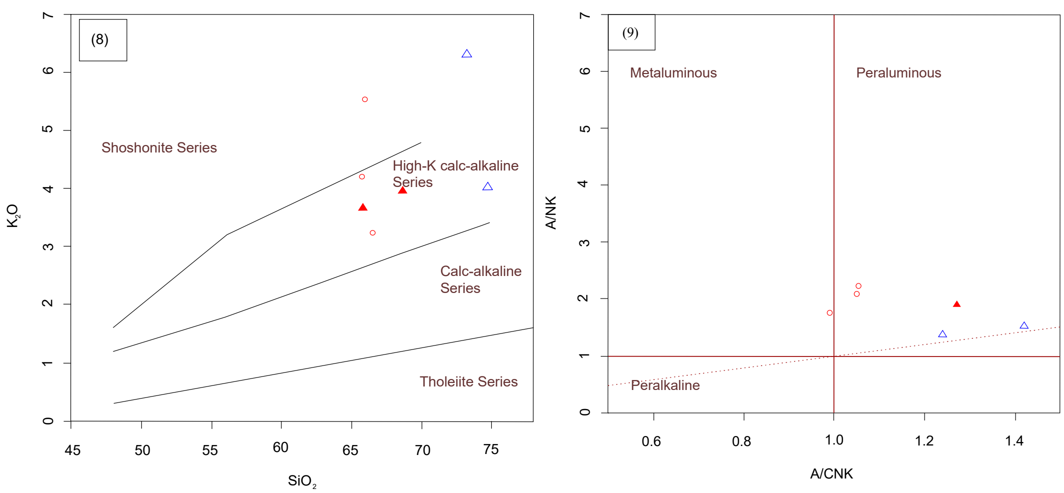


Figure (8). K_2O Vs SiO_2 diagram (after Peccerillo & Taylor, 1976) showing the source of granitoid rocks of the study area.

Figure (9). A/NK (molecular $Al_2O_3/(Na_2O+K_2O)$) versus A/CNK (molecular $Al_2O_3/(CaO+Na_2O+K_2O)$) diagram (after Shand,1943) showing the source of granitoid rocks of the study area both in metaluminous and peraluminous fields.

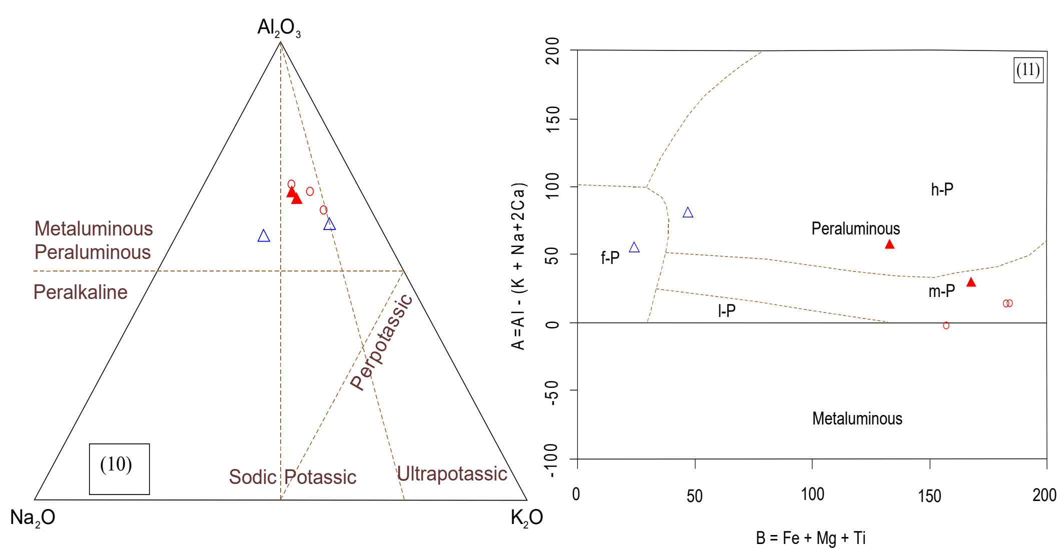


Figure (10). Molar Na_2O-Al_2O_3-K_2O diagram showing the source of granitoid rocks of the study area.

Figure (11). A=(Al-(K+Na+2Ca)) versus B=(Fe+Mg+Ti) diagram (after Villaseca et al., 1998) showing the definite source of granitoid rocks of the study area.

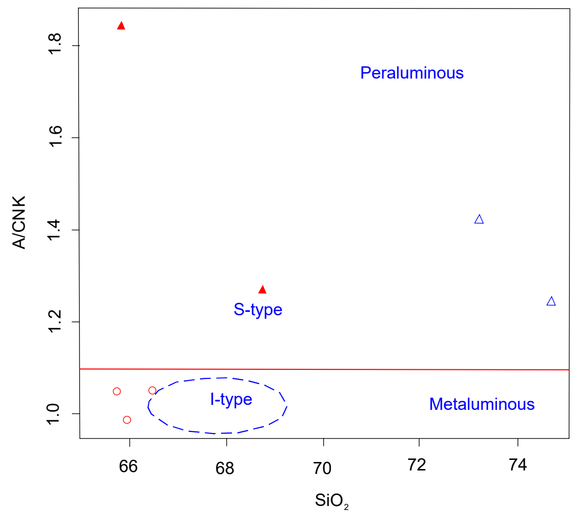
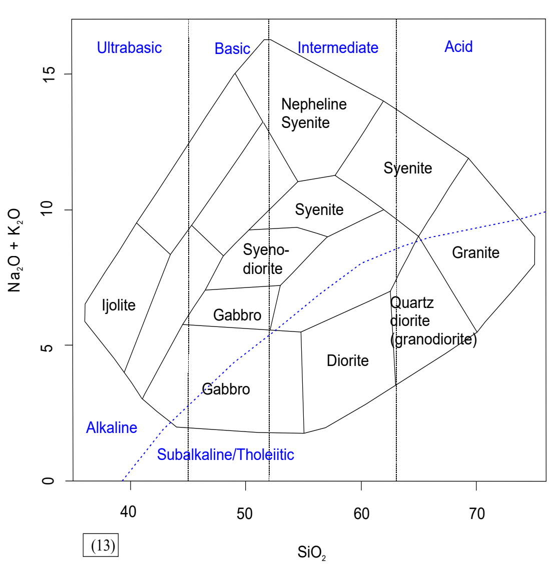


Figure (12). A/CNK vs SiO_2 diagram showing the classification of I-type (or) S-type granitoid rocks of the study area (after Chappell & White, 2001).



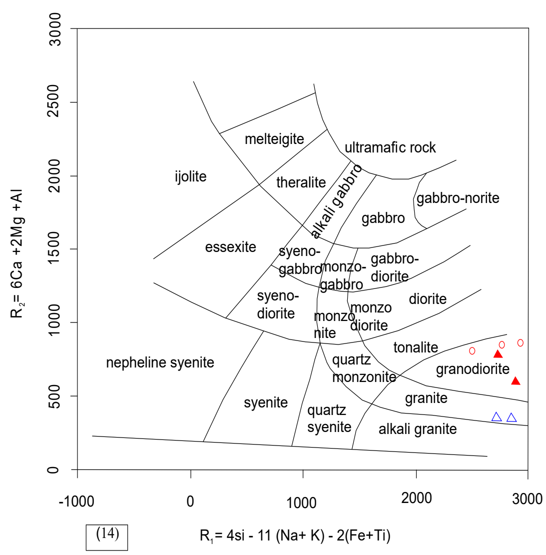
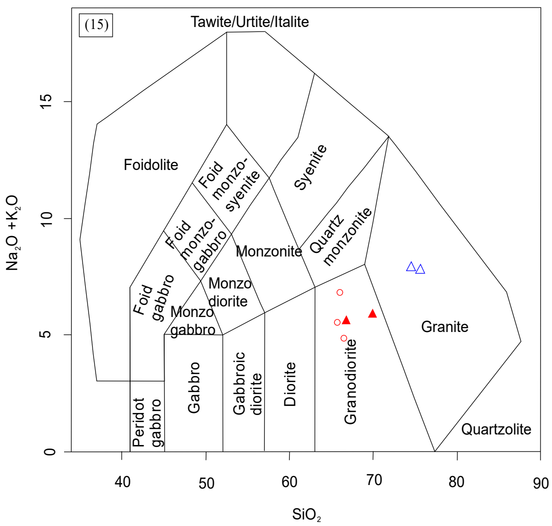


Figure (13). TAS classification diagram showing the different named by relative proportions of SiO_2 and (Na_2O+K_2O) in plutonic of the study area (after Cox et al., 1979).

Figure (14). R_1-R_2 chemical variation diagram (after De La Roche et al., 1980) showing the classification of plutonic igneous rocks of the study area.



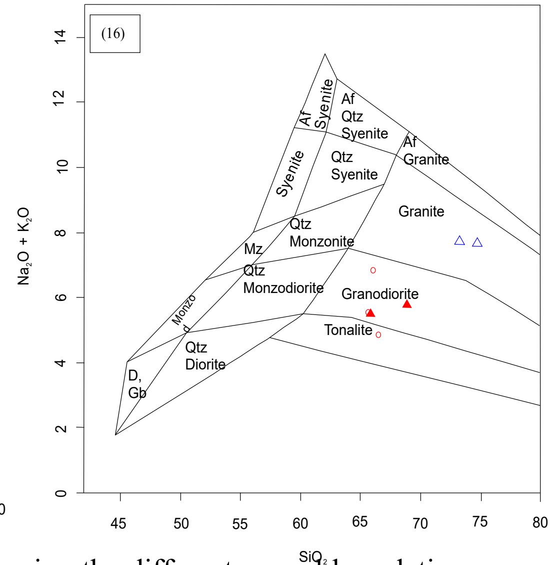


Figure (15).TAS classification diagram showing the different named by relative proportions of SiO_2 and (Na_2O+K_2O) in plutonic of the study area (after Middlemost, 1985).

Figure (16). TAS classification diagram showing the different named by relative proportions of SiO_2 and (Na_2O+K_2O) in plutonic of the study area (modified after Middlemost, 1994).

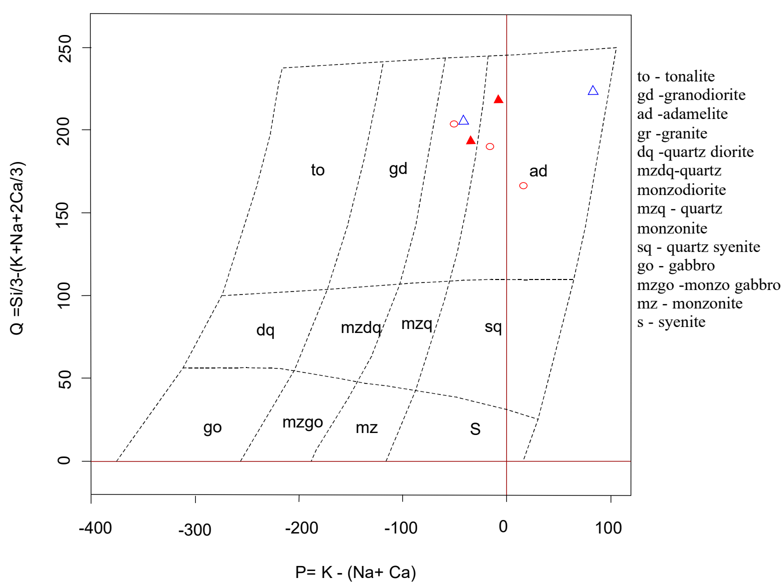


Figure (17). P- Q diagram (after Debon and Le Fort, 1998) is showing the nomenclature and classification of plutonic igneous rocks of the study area.

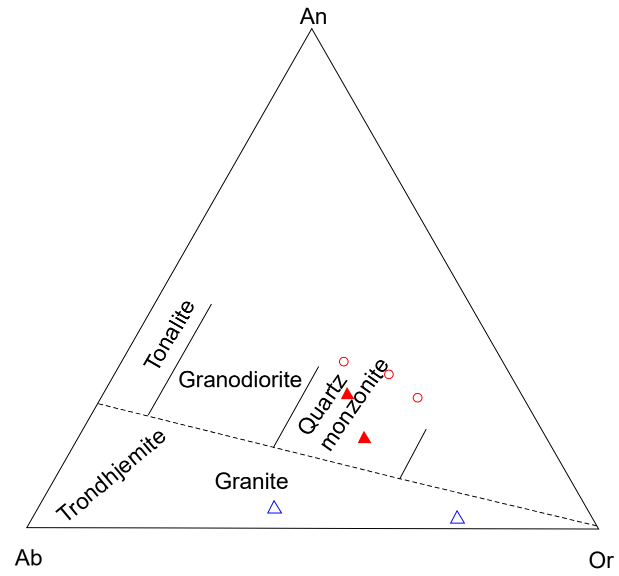


Figure (18). Normative An-Ab-Or diagram showing the classification of plutonic igneous rocks of the study area, with dividing lines according to O'Connor, 1965.

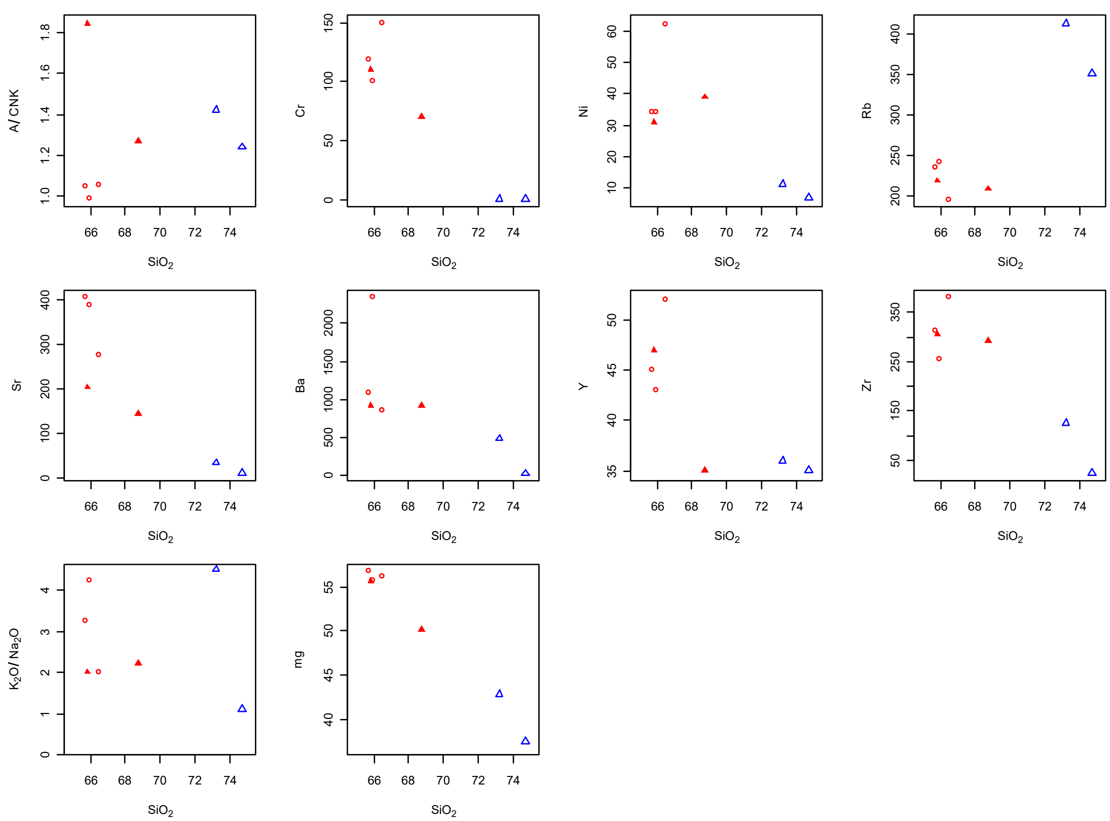


Figure (19). Trace elements (ppm) versus SiO_2 Harker variation diagrams of some granitoid rocks of the study area.

Table (4). A comparative study of the significant chemical character in I-type and S-type granitoid rocks of Kyaing Tong Area.

Sp.No.	Type	SiO2	K2O/ Na2O	A/(C+N+ K)	Sr(Goldschmidt)	Rb/Sr	Normative Corundum	Petrogenesis
KZW-3	S	74.73	1.09	1.24	<300ppm	35.2	>2	Subduction related Supracrustal
KZW-12	S	73.23	4.5	1.42	<300ppm	12.17	>3	Sedimentary source
KZW-18	S	65.83	2.01	1.84	<300ppm	1.07	>12	
S-1	S	68.77	2.23	1.27	<300ppm	1.45	>8	
KZW-7	I	64.91	2.01	1.052	<300ppm	0.71	>1	Subduction related Infracrustal
KZW-10	I	63.7	3.24	1.05	>300ppm	0.58	>1	Igneous source
KZW-54	I	64.4	4.24	0.99	>300ppm	0.62	<1	

Conclusions

This research is focus on the significant role of SiO_2, Al_2O_3, Na_2O, K_2O and CaO proportions in plutonic igneous rock classification and genetic type classification of granitoid rocks. Kyaing Tong granitoid rocks are believed to be derived from calc-alkaline magma series, these are two different genesis of both subduction related infracrustal igneous origin I - type & subduction related supracrustal sedimentary origin S-type. Most samples show peraluminous source and Sr composition show above 300 ppm. Zn, V, Cr, Ni, Mo (ppm) contents in I-type granite is more abundance than in S-type granite. Rb/Sr (ppm) contents in S-type granite are more abundance than in I-type granite. According to the variable classification diagrams, leucogranite samples fall in granite composition clan, biotite granite samples fall in granodiorite composition clan and granodiorite samples fall in slightly difference classification types of tonalite, adamellite, quartz monzonite and quartz diorite composition clan. This different may be depend on calculation system of the variable proportions in limited values of SiO_2, Al_2O_3, Na_2O, K_2O and CaO weight percent depend on the several authors' definitions and considerations . Because of the using the variable classification modal are to comparative study and to significantly identify for the important role of quartz and feldspar proportions in plutonic igneous rocks. So, the exposed some rocks named of the Kyaing Tong batholith are granite, quartzmonzonite, quartz diorite, adamellite, tonalite and granodiorite which are differ from the variable components of SiO_2, Na_2O, K_2O and CaO proportions by the several authors' standard limitation values.

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References

Chappell B. W. & White A. J. R. (2001), Two Contrasting Granite Types: 25 years later. *Australian Journal of Earth Sciences. 48*,pp.489-499.

Cox, K.G., Bell, L.D., & Pankhurst,R.J., 1979. The interpretation of igneous rocks. George, Allen and Unwin, London, 464p.

De La Roche, H., et al, 1980. A classification of volcanic and plutonic rocks using R_1-R_2 diagrams and major element analyses-its relationships with current nomenclature. Chem. Geol., 29;183-210.

Debon. F. & Le Fort. P.1983 A chemical-mineralogical classification of common plutonic rocks and associations. Transactions of the Royal Society of Elinburgh: Earth Sciences 73, 135-49.

Gardiner, N.J. et al, 2015. The Closure of Palaeo-Tethys in Eastern Myanmar and Northern Thailand: New Insights from Zircon U-Pb and Hf Isotope Data.2015 International Association for Gondwana Research. Published by Elsevier B.V.

Hutchison, C.S. (1973): Tectonic evolution of Sundaland: A Phanerozoic synthesis. *Geol. Soc.Malaysia, Bull*.6, p.61-86.

Harker, A., 1909. The natural history of igneous rocks. *Methen,* London.

Irvine, T.N., & Baragar, W.R.A., 1971. A Guide to the chemical classification of the Common Volcanic Rocks. Can. Jour.

Khin Zaw (1990): Geological, petrological and geochemical characteristics of granitoid rocks in Burma: with special reference to the associated W-Sn mineralization and their tectonic setting. Jour. *SE Asian Earth Sciences* 4 (4), p.293-335.

Middlemost, E.A.K., 1985, Magmas and Magmatic rocks, Longman, London.

Miyashiro, A. (1974). Volcanic rock series in island arcs and active continental margins. *Amer. J. Sci.,* 274, 321-355.

O'Connor, J.T.,1965. Classification of quartz rich igneous rocks based on feldspar ratios. U.S.G.S. Prof.Paper 528B, p.79-84

Pececrillo, A., & Taylor, S.R., 1976. Geochemistry of Eocene calc alkaline rocks from the Kastamonu area, Northern Turkey. *Contriburion to Mineralogy and Pet rology*. 58, p. 68-81.

Rollinson, H. R., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation. 1st Ed. Longman Group UK Limited 1993.

Shand, S.J., 1943. Eruptive Rocks. T. Murby and Co., London, 444pp.

Thornton, C.P., & Tuttle, O. F, 1960. Chemistry of igneous rock; I. Differentiation Index, Am. J. Sci., vol. 258, p.664-684.

Villaseca, C. et al, 1998. Crustal origin of Hercynian Peraluminous granitic batholiths of Central Spain: petrological, geochemical and isotopic (Sr.Nd) constraints Lithos 43, 55-79.

Win Swe, 2012. Outline Geology and Economic Mineral Occurrences of the Union of Myanmar. Journal of the Myanmar Geosciences Society: Special publication No. (1)

Wolfrat, R. et al. (1984): Stratigraphy of the Western Shan Massif, Burma, *Geol. Jb: Reihe B*, Heft.57. 92.