PETROGENESIS OF THE GRANITOIDS OF MOKPALIN-KYAUKTANLAY QUARRIES, MON STATE USING TRACE ELEMENT AND RARE EARTH ELEMENT GEOCHEMISTRY

Myo Thiri Sandar Aung[1], Mi New Ni Aung[2], Su Myat Aung[2],
War War Kyaw[2], Aye Pyae Phyo[3]

Abstract

The Mokpalin-Kyauktanlay area occurs in the southern part of Mogok Metamorphic belt and belongs to the central granitoid belts of Myanmar. The trace elements and rare earth elements geochemistry data are used for the formation of granitoids of the study area. Geochemically, the whole rock of silica ratios varies from 64.55 to 75.31%, Al_2O_3, Fe_2O_{3t}, CaO, MgO ranges from 14.02-17.85%. 1.00-7.87%, 1.16-6.81 and, 0.24-3.24%. The varying ratios of the incompatible elements of Rb/Sr ratios (0.1-0.5), Ba/Sr ratios (0.4-2.9), and Ba/Rb ratios (4-16.3) in granitoids. The granitoid rocks have enrichment in the Light Rare-Earth Elements (LREE) and depletion in Heavy Rare-Earth Elements (HREE) and with negative europium anomalies and they come from the same origin. The age of quartz diorite was about 90.8±0.8 Ma (Mitchell et al. (2012). Tectonically they fall volcanic arc granite fields and were products of volcanic arc magmatism. These granitoids were generated from the partial melting of the shallow crust.

Keywords: Granitoids; Volcanic arc granite; Calc-alkaline; Magma mixing

Introduction

The Mokpalin-Kyauktanlay area is mainly composed of igneous rocks. In the middle part of the area, it is composed of Mergui Group. Eastern part of the area has porphyritic biotite granites. Fresh samples of rock are only exposed in quarries. Most of the study areas are covered by lateritic soil and vegetation. The study area has more than twenty quarries. The quarries have made up of granitic and dioritic rocks. In Mokepalin Quarrry no-1 is located at the side of the Eastern part of Yangon-Mawlamyine Highway line (Fig.1). The size of the quarry is about 1300' from East to West. The major rock units are diorite and granodiorite. Some are micromeladiorite and microdiorite. Several of dykes and veins are occurred as aplite, pegmatite, rhyolite, dacite porphyry, lamprophyre, quartzofeldspathic and quartz veins injected into the country rocks of the quarry no-1. Xenoliths and enclaves are observed in granitic and dioritic rocks. In Mokepalin Quarry no-2, located at the flank of the western part of the Yangon-Mawlamyine Highway line. The wide of the quarry is about 1500' from East to West. The wholly of the quarry no-2 is dominantly composed of diorite. In Kyauktanlay and Kann-ni Quarries, they are located in the western part of the area, most are more than 1000' wide. The quarries have mainly composed of granitic rocks. Lamprophyre and epidote veins are intruded in it. Many workers have been studied in this area. So the present study detailed on igneous intrusion, petrogenesis, trace elements and rare earth elements of the granitoid rocks.

[1] Dr, Associate Professor, Department of Geology, Myeik University
[2] Assistant Lecturer, Department of Geology, Myeik University
[3] Demonstrator, Department of Geology, Myeik University

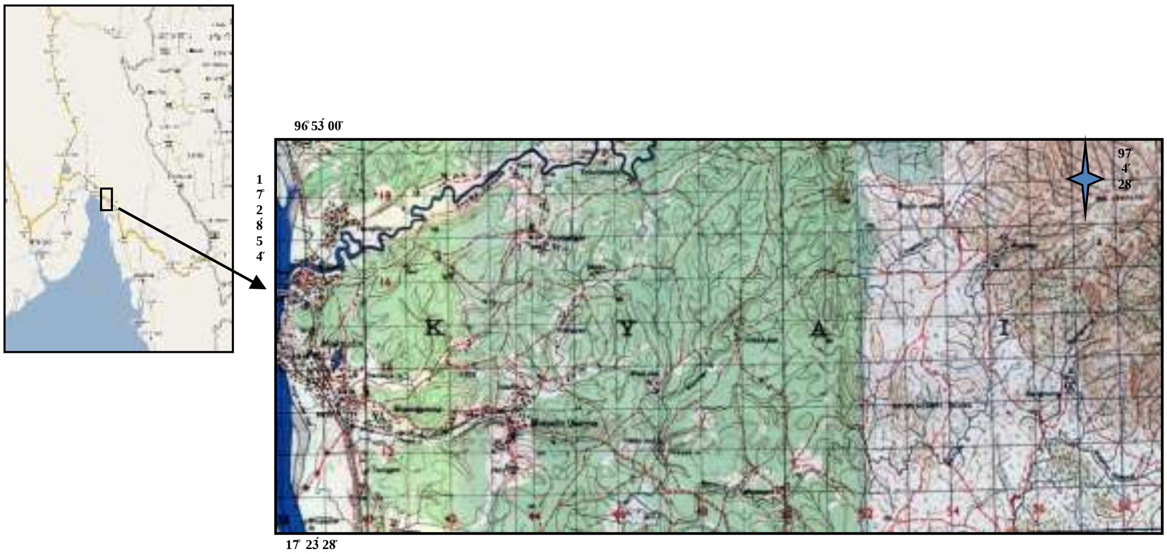

Figure 1 Location map of the Mokpalin-Kanni-Kyauktanlay area.

Regional Geology and Study Area

The general regional geologic setting southern part of Mogok Metamorphic belt and within Slate belt (Fig.2). It consists of rhyolitic tuff, meta-sedimentary rocks, probably of Carboniferous age close to the Mesozoic granite of Chhibber (1926). The Western granite belt of South East Asia and this belt are associated with eastward subduction of the Oceanic Indian plate (Pitcher, 1962). The study area lies in the northern part of western Tin Belt of South East Asia Tin province (Mitchell, 1977 and Nyan Thin, 1984) and lies within part of the Mogok Belt (Searle and Haq, 1964). Maung Thein (1983), regarded the central granitoid belt of Burma were developed in the tectonic setting of subduction related magmatic arc. The area belongs to the central granitoid belts of Myanmar (Khin Zaw, 1990). The area is structurally bounded by two major faults which are the Papun Fault system in the north and the Three Pagoda Fault in the south. The Sagaing fault was 1000Km to south and lies west of Mogok Metamorphic belt.

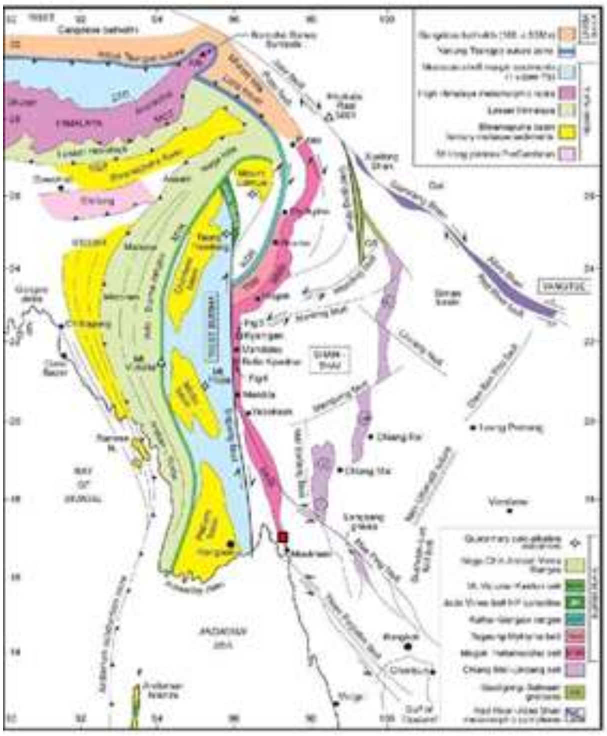

Figure 2 Geological map of SE Asia, Myanmar and the Andaman sea region north to southern Tibet, showing the major suture zones , faults, and terrain boundaries (Searle *et al*., 2007).

Materials and Methods

Eight representative samples were sent to ALS laboratory of Geological Survey of Japan, AIST and the Acme analytical laboratories of Vancouver-Canada. In this study, most relevant methods available to determine contents of major, trace, and rare earth elements of the lamprophyres were applied for major and trace elements analysis were carried out using techniques of X-ray fluorescence spectrometry (XRF), inductively coupled plasma-mass spectrometry and inductively coupled plasma-atomic emission spectrometry. The analyzed data are presented in Table-1. Standard C.I.P.W norms and C.I.P.W norm with biotite and hornblende are calculated according to the rules of Hutchison, 1975. Triangular plots of some analyses results were carried out by Tridraw 2.6 software. For tectonic discrimination diagrams (Pearce et.al., 1984), differentiation index diagram, major oxides and trace elements variation diagrams, ternary diagrams, binary diagrams and triangular plots diagrams were drawn by using SPSS-16 software, GCD kit 3.0, Tri-draw software and Microsoft excel.

Field Study and Petrography of Granite

Representative samples were collected from several locations throughout the Mokpalin, Kanni and Kyauktanlay quarries. Granodiorite and diorite are coarse-grained, and displays light grey on fresh and dark grey on weathered surfaces. It is widespread in occurrence and wherever exposed these are in sharp contact and gradational contact. In addition, thin veins of quartz and epidote sometimes occur and some joint faces coated with pyrites are noticeable. At Kanni quarries, highly weathered on top and fresh rocks beneath are observable. In some places, bands of dark and light-colored minerals in the form of stratification of intrusions are encountered. The reverse xenoliths (i.e the inclusion of granodiorite in diorite) suggest a short time span between each intrusion (Fig.3-a).

Near the sharp contacts with diorite the xenoliths are mostly angular to surrounded in form indicating that these xenoliths were derived not afar from the plutons (Fig.3-b). Magma mixing and assimilation of felsic and mafic magma, in Mokpalin quarry is peculiar (Fig.4). Petrographically, the granodiorite and quartz diorite contain mainly plagioclase, quartz, biotite, hornblende, alkali feldspar and opaque minerals and apatite as accessory (Fig.5).

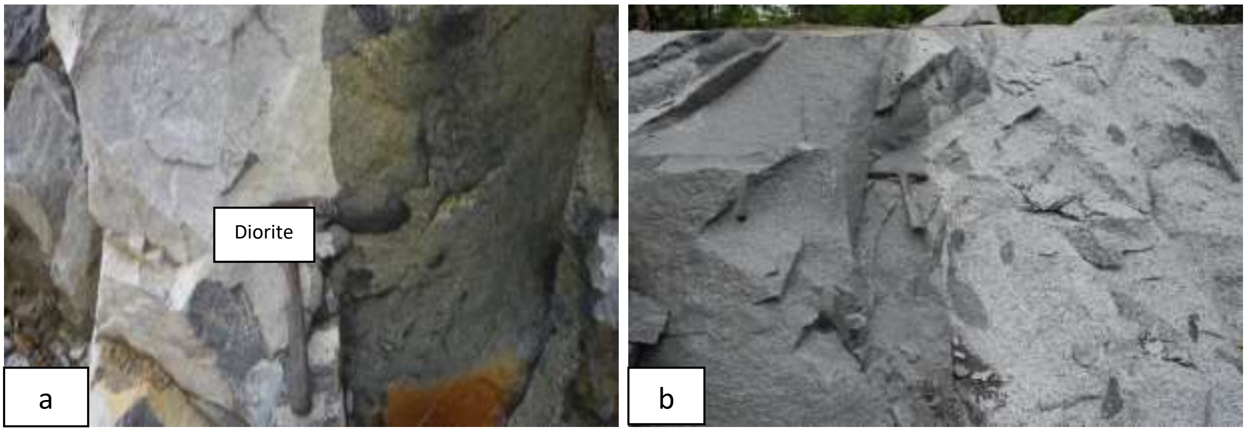

Figure 3 Field photo shows (a) Diorite xenoliths observed in granodiorite (left). A sharp contact occurred between granodiorite and diorite at Kanni quarry. (b) small, medium and large-size microgranular mafic enclaves are sub-angular to surrounded in granodiorite at eastern part of the area.

Figure 4 Assimilation of diorite and granitic magma, at Mokpalin quarry.

The granodiorites are medium to coarse-grained in texture and it is made up of quartz (20-30 vol-%), K-feldspar (25-30 vol.-%), plagioclase (40-45 vol-%), biotite (2-10 vol-%) and amphibole (2-5 vol.-%). Plagioclase is fractured and bent, suggesting plastic flow and crystal breakage during crystallization. Fractured crystals later were filled by recrystallized quartz. Mafic enclave show hornblende replaced by biotite mineral. Quartz exhibits undulatory extinction. K-feldspar crystals are subhedral in form containing small inclusions of amphibole and apatite grains. In QAP trilinear diagram (after Streckeisen, 1973) falls in the granodiorite field (Fig.6).

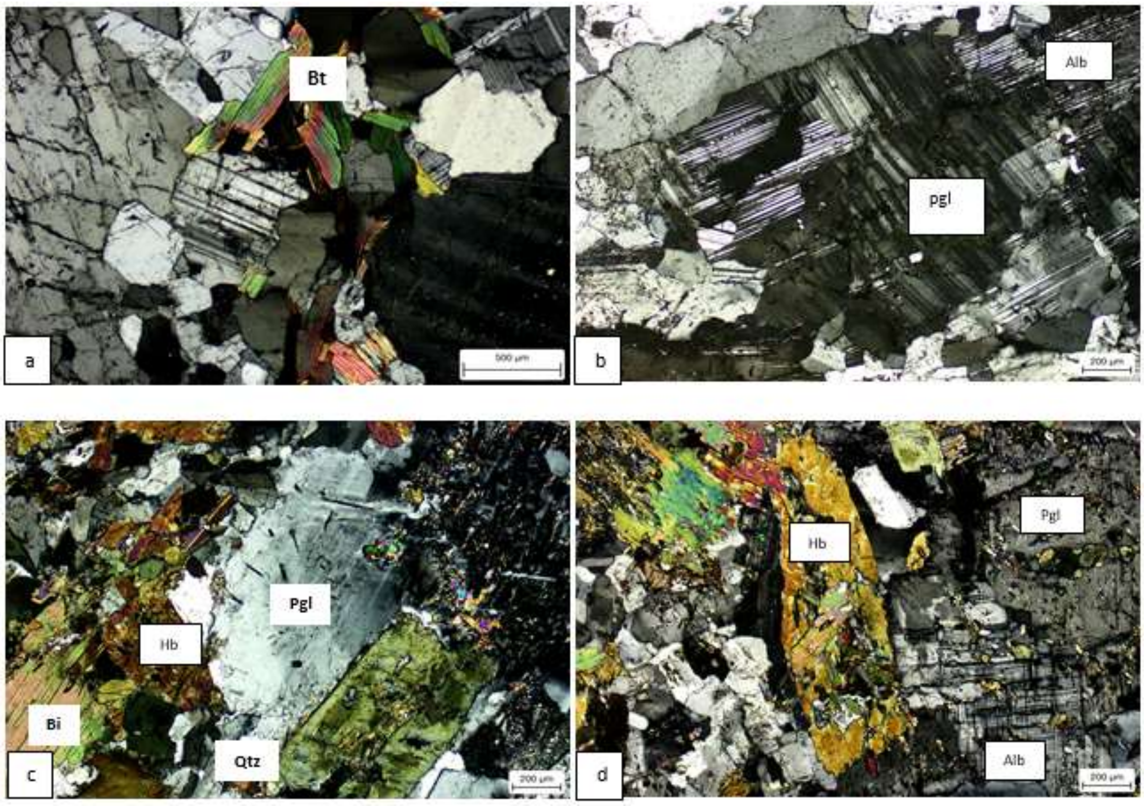

Figure 5 Photomicrographs of the igneous rocks of study area (a) Strong pleochroism of biotite (b) Bent plagioclase contact at right angle with albite in granodiorite (c) Quartz diorite consists of plagioclase, amphibole, biotite and quartz (d) Mafic enclave shows hornblende replaced by biotites with sieve texture between XN, at Mokpalin Quarry-1. Abbreviations: Hb = amphibole; Pgl = plagioclase; Bi = biotite; Alb = albite; Qtz = quartz.

Whole Rock Chemistry of Granitoids Rocks

The granitoids and quartz diorite are silica-rich, with SiO_2 =55.93–75.91 wt. %. They have high contents of alkalis, with K_2O=1.5-8.6 wt.%. Na_2O=3.6–4.0 wt.%, Al_2O_3 =11.9–15.8 wt.%, FeO (total Fe)=1.0–3.0 wt.%, MnO=0.0–0.1 wt.%, MgO=0.1–1.2 wt.%, TiO_2 =0.0–0.3 wt.%, and P_2O_5 =0.0–0.2 wt.% (Table-1). The granitoid rocks in the study area fall in the calc-alkaline and partially tholeiitic field (Fig. 7-a). A/NK (molecular AL_2O_3/Na_2O+ K_2O) vs A/CNK (molecular $Al_2O_3/CaO+K_2O+Na_2O$) diagram (Fig.7-a) showing the subalkaline and metaluminous of peraluminous character of igneous rock of the study area (after Shand 1943). In RB-Ba-Sr diagram (Fig.8-a) with the field corresponding to I-normal granite, II- anomalous granite, III-strongly differentiated granite, IV-granodiorite, V-diorite based diagram after El Bouseily *et al*., (1975), they fall granodiorite and diorite field. The positions of the data points in the Q-Ab-Or ternary diagram (Fig.8-b) indicate that the pluton crystallized at a water pressure between 0.5 kb and 1 kb.

On SiO_2 –K_2O diagram, the entire rocks within in the medium to partially high-K calc-alkaline series field (Fig.9-a). The chondrite-normalized REE patterns of the Mokpalin-Kyauktanlay granites (Fig.9-b) show light REE enrichment with low La_n/Yb_n (6.51–8.53) and moderately negative Eu anomalies (0.33–0.90). The differences between individual granitoid patterns are relatively slight, but most of all patterns are nearly similar. Rb, Ba, Th, Nb and K increase consistently from diorite to granodiorite to granite consistent with fractional crystallization. The steeper slopes could reflect lower degree of partial melting in calc-alkaline magma. Slightly negative Eu anomalies (Eu/Eu* = 0.88-1.06) and $(La/Yb)_N$ =7.7-15.3 show slightly fractionated**.** In Fe_2O_{3t}- MgO diagram (After Zorpi et al,1989) all the granitoid show partial melting and magma mixing (Fig.10-a). Geotectonically, according to Pearce et.al (1984) diagrams they fall in the field of volcanic arc granite field (VAG) (Fig.10-b).

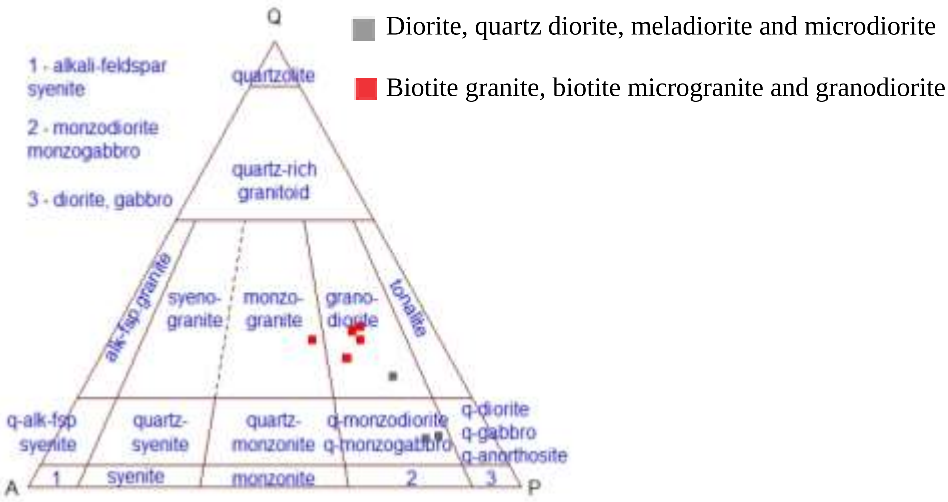

Figure 6 QAP plot for the studied granitoids (fields are after Streckeisen, 1973).(Q= Quartz, A= Alkali feldspar and P= Plagioclase)**.**

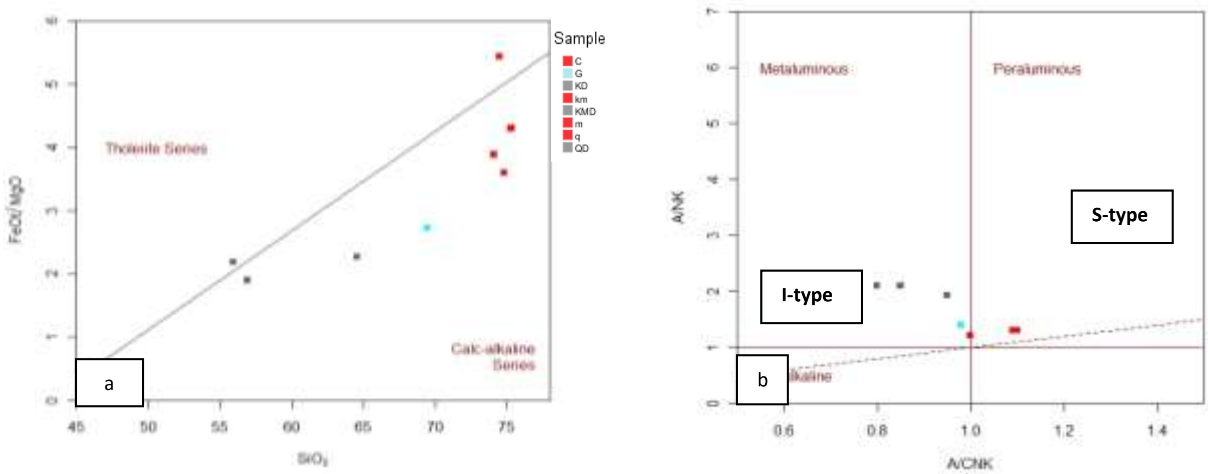

Figure 7 (a) FeOt/MgO vs SiO_2 diagram subdividing the subalkaline magma series to Tholeiitic and Calc-alkaline series (After Miyashiro 1974). (b) A/NK (molecular AL_2O_3/ Na_2O+K_2O) vs A/CNK(molecularl$_2O_3$/CaO+K_2O+Na_2O) diagram showing the subalkaline and metaluminous of peraluminous character of igneous rock of the study area (after Shand 1943).

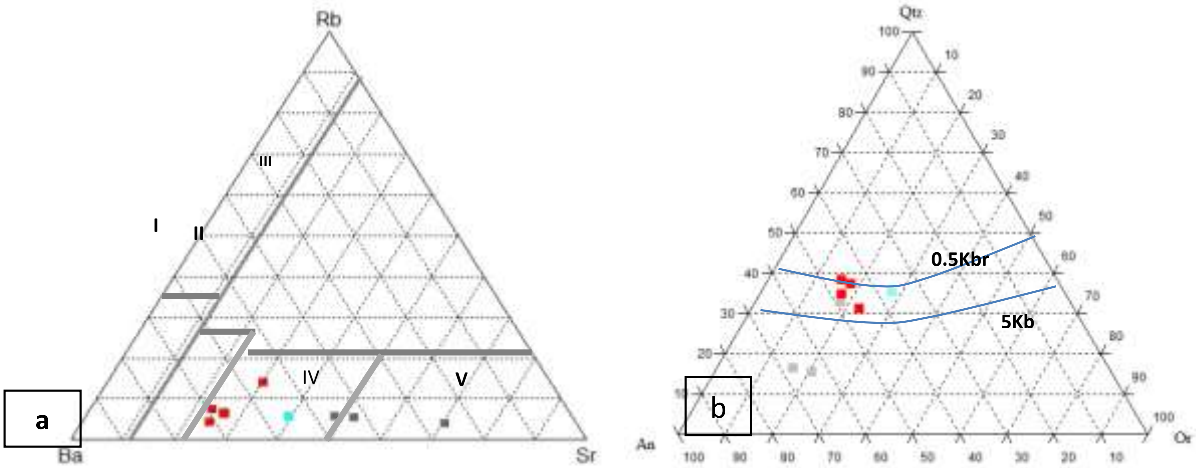

Figure 8 (a) RB-Ba-Sr diagram with the field corresponding to I-normal granite, II- anomalous granite, III-strongly differentiated granite, IV-granodiorite, V-diorite based diagram after El Bouseily *et al*., (1975). (b) Normative data plot of the granitic rocks of the study area showing that most of the granitic rocks were formed below 0.5kb of water vapour pressure, after Tuttle and Bowen (1958).

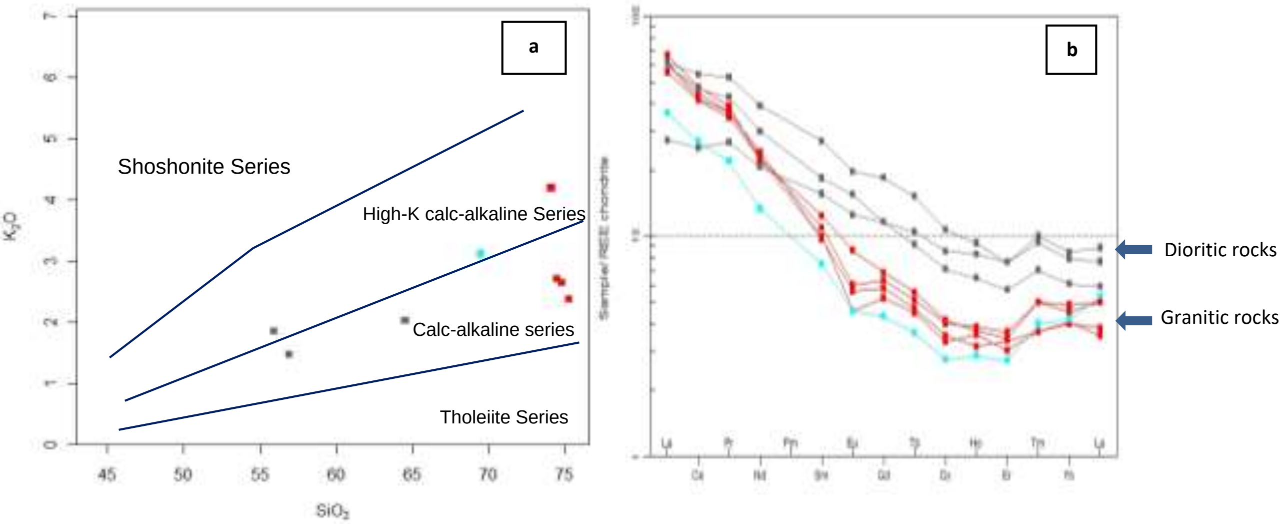

Figure 9 (a) Plots of wt%. K_2O versus wt%. SiO_2 for lamprophyres from Mokepalin-Kanniarea (after Peccerillo and Taylor 1976). (b) Chondrite-normalized REE diagram for granitoid rocks from the Mokepalin-Kanni area, normalizing values from (Nakamura 1974).

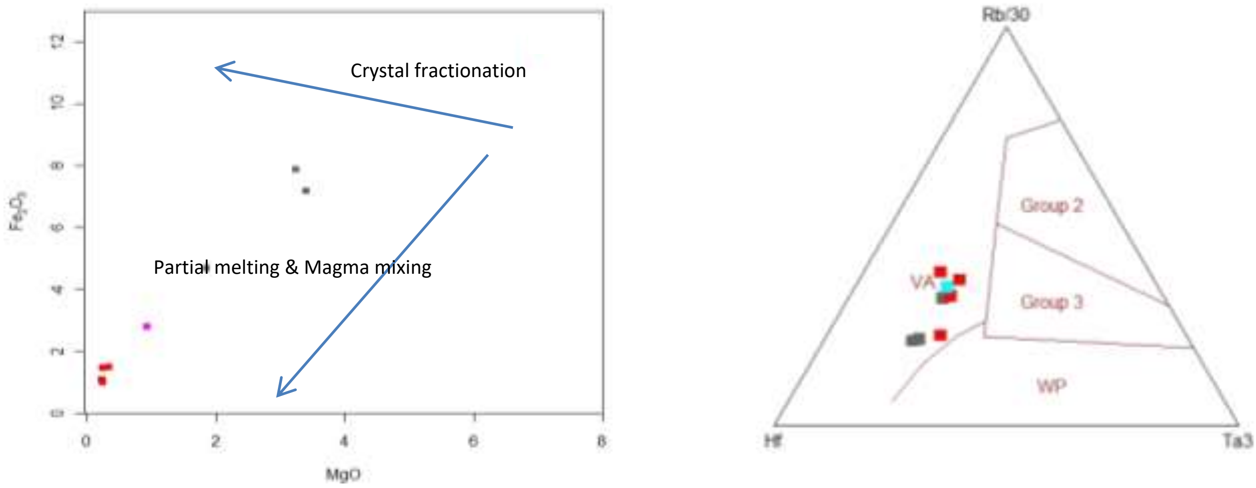

Figure 10 (a) Fe_2O_{3t}- MgO diagram (After Zorpi et al, 1989). (b) Plot of igneous rocks on geotectonic classification of volcanic arc granite (Pearce *et al* .1984).

Table 1 Representative selected whole-rock analysis for major and trace element from granitoid rocks.

Rock type	Tholeiitic		Calc-alkaline					
Sample	KD	QD	KMD	m	C	km	G	q
SiO2	64.55	56.90	55.93	74.5	74.8	74.12	69.46	75.31
TiO2	0.521	0.783	1.046	0.1	0.13	0.147	0.029	0.109
Al2O3	16.45	17.85	17.85	14.02	13.78	13.67	15.21	14.02
Fe2O3	4.69	7.18	7.87	1.45	1	1.48	2.8	1.08
MnO	0.09	0.12	0.12	0.07	0.04	0.06	0.07	0.03
MgO	1.857	3.402	3.24	0.24	0.25	0.343	0.926	0.226
CaO	4.785	6.805	6.566	1.16	1.37	1.412	2.711	1.189
Na2O	3.85	4.26	4.04	4.79	5.13	3.92	4.36	4.91
K2O	2.02	1.46	1.85	2.7	2.63	4.18	3.11	2.37
P2O5	0.13	0.29	0.23	0.06	0.06	0.07	0.12	0.06
LOI	0.45	0.54	0.49	0.73	0.5	0.1	0.22	0.27
Total	99.40	99.58	99.23	99.82	99.69	99.50	99.27	99.57
A/CNK	0.95	0.85	0.86	1.1	1	1	0.98	1.1
Ba	388	267	385	558	560	413	759	667
Ce	21.8	40.4	47.1	36.5	38.6	23.2	35.9	41.2
Cs	1.07	2.48	1.57	1.2	1	2.81	3.04	0.78
Dy	2.93	2.42	3.66	1.21	1.13	0.94	1.42	1.37
Er	1.71	1.28	1.71	0.75	0.68	0.61	0.77	0.81
Eu	0.96	1.19	1.51	0.43	0.35	0.35	0.66	0.46
Ga	17.6	20.8	21.9	13.5	12	15.9	17.8	15.5
Gd	3.2	3.2	5.1	1.6	1.4	1.2	1.9	1.7
Hf	4.2	2.1	4.6	2.3	2.5	4	3.2	3.4
Ho	0.58	0.45	0.65	0.22	0.25	0.20	0.26	0.27
La	9	20	20.4	20	20.4	12	18.4	22
Lu	0.3	0.2	0.3	0.13	0.12	0.18	0.17	0.17
Nb	4.4	4	6.6	5	5.6	5.2	4.8	5.6
Nd	13	18.9	24.7	14.2	15.2	8.4	14	14.4
Pr	3	4.8	5.9	4.1	4.1	2.5	3.9	4.4
Rb	47	42	49	60	53	103	78	41
Sm	3.16	3.72	5.48	1.96	2.01	1.51	2.51	2.22

Rock type	Tholeiitic		Calc-alkaline					
Sample	KD	QD	KMD	m	C	km	G	q
Sr	408	739	475	192	221	225	545	233
Ta	0.5	0.3	0.5	0.4	0.4	0.5	0.5	0.5
Eu/Eu*	0.93	1.06	0.88	0.75	0.63	0.8	0.93	0.72
Tb	0.49	0.43	0.71	0.22	0.21	0.17	0.26	0.24
Th	4.63	6.38	4.93	5	4.9	12.9	8.56	5.7
TI	<0.5	<0.5	<0.5	0.1	<0.1	0.5	<0.5	<0.5
Tm	0.3	0.2	0.3	0.11	0.11	0.12	0.15	0.15
U	1.54	1.74	1.91	1.1	1	3.17	3.25	1.21
V	99	181	199	<8	<8	22	48	<5
W	<1	1	<1	1.3	4.2	<1	<1	1
Y	16.8	12.7	18.5	7.5	7.4	6.5	8.1	9.7
Yb	1.86	1.33	1.73	0.88	0.89	0.92	0.99	1.07
Zr	127	63	138	76.9	82.7	103	100	92
Rb/Sr	0.1	0.1	0.1	0.3	0.2	0.5	0.1	0.2
Ba/Sr	0.9	0.4	0.8	2.9	2.5	1.8	1.4	2.9
Th/U	3	3.7	2.6	4.5	4.9	4	2.6	4.7
K_2O/Na_2O	0.5	0.3	0.5	0.6	0.5	1.1	0.7	0.5
ΣREE	131.5	62.44	114.82	72.78	66.66	101.28	51.25	214.46

Discussion and Conclusion

According to their geochemical composition these granitoids are occupied with metaluminous and slightly peraluminous character. They are high SiO_2, Na_2O+K_2O, calc-alkaline to partially tholeiitics series. Major and trace element data of the Mokpalin-Kyauktanlay granitoids are typical of fractionated, crustal contaminated (e.g., low Mg#, and negative Nb and Ti anomalies). Field evidence, major and trace elements chemistry data of the diorite and granitic rocks may come from a partial melting and mixing of felsic and mafic magma. The trace element supports that a variable degree of partial melting. Their tectonic setting belongs to volcanic arc granite field.

Acknowledgements

The author thanks to the Journal of Myanmar Academy of Arts and Science for editing on my research. Special acknowledge to Dr. Ni Ni Oo, Acting Rector of the Myeik University, and Dr. Soe Moe Lwin (Professor and Head of Department of Geology, Myeik University) for their permission to carry out this research. Finally, she also sincerely gratitude to Dr. Khin Zaw, University of Tasmania, Australia who provided valuable helps XRF data during the preparation of this manuscript.

References

Chhibber, H.L., (1926) Hornblende lamprophyres and associated rocks of Mokpalin Quarries, Thaton District: *Jour. Burma*. Soc. V.xvi,p. 167-168.

El Bouseily. A.m., and AA. El Sokkary, (1975). The relation between Rb, Ba and Sr in granitic rocks, *Chem Geol* 16,p 207-209.

Hutchison, C.S., (1975). Ophiolite in Southeast Asia. Geological Society of America Bulletin, 86, 797–806. 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. Of Southeast Asian Earth Sciences*, v.4. no.4. p.293-335.

Maung Thein, (1983). *The geological evolution of Burma, Department of Geology, Mandalay University,Mandalay, Burma*, (Unpublish), 89p.

Mitchell, A.H.G., Chung, S.-L., Thura Oo, Lin, T.-H. & Hung, C.-H. (2012). Zircon U–Pb ages in Myanmar: magmatic–metamorphic events and the closure of a neo-Tethys ocean? Journal of Asian Earth Sciences, 56, 1–23.

Miyashiro, A. (1974). Volcanic rock series in island arcs and active continental margins. *Am. Sci*. 274, 321-55.

Nakamura, N., (1974,) Determination of REE, Ba, Fe, Mg, Na and K in carbonaceous and ordinary chondrites, *Geochimica et Cosmochimica Acta*, vol. 38, no.5, p.757-775

Nyan Thin, (1984). *Some aspects of granitic rocks of Tenesserian Division, Department of Geology, Rangoon University, Rangoon, Burma (Unpublished),* 125p.

Peccerillo. A & Taylor. SR, (1976). Geochemistry of Eocene Calc-alkaline volcanic rocks from the Kastamonu area, Northern Turkey. Contributions to Mineralogy and Petrology. 58: p. 63-81.

Pearce.J.A., Harris, N.W., Trindle, A.G., (1984.) Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *Journal of Petrology* 25. P.956-983.

Pitcher, W.S., (1962). Granite type and Tectonic Environment, *Mountain Building Process*, p- 19-37.

Searle, D.L., and Haq, B.T., (1964, 2007). The Mogok Belt of Burma and its relation to the Himalayan Orogeny. *22nd. Intern. Geol. Congress. India* (in press).

Shand, S. J. (1943). *Eruptive Rocks. Their Genesis, Composition, Classification, and Their Relation to Ore-Deposits with a Chapter on Meteorite.* New York: John Wiley & Sons.

Streckeisen, A.L. (1973). Plutonic rocks Classification and nomenclature recommended by IUGS sub commission of systematic of igneous rocks. Geotimes, 18, pp.26-30.

Tuttle, O.F., and N. L., Bowen (1958): Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O, *Geol, Soc, am, Mem, 74.*

Zorpi MJ, Coulon C, Orsini JB, Cocirta C (1989) Magma mingling, zoning and emplacement in calc-alkaline granitoid plutons. Tectonophysics 157:315–329