Geochemistry of Plutonic Igneous Rock Exposed at Kantha-Aungthaya Area, Thabeikkyin Township, Mandalay Region

May Thet Aye[1], Myo Min Tun[2] and Min Aung[3]

Abstract

Kantha-Aungthaya area lies in Thabeikkyin Township, Mandalay Region. It is located about 122 km north of Mandalay and about 6.5 km east of Thabeikkyin. It is bounded by North Latitude 22^{o} 51' 15" to 22^{o} 58' 00" and East Longitude 96^{o} 01' 00" to 96^{o} 06' 00" in one inch topographic map 93B/1. This area is mainly composed of metasedimentary rocks such as white marble, phlogopite marble, diopside marble, graphite marble and calc-silicate rocks and igneous rocks such as biotite microgranite. These plutonic rock is intruded into older meta-sedimentary rocks. The geochemical characteristic of plutonic igneous rock is identified for its rock chemistry, rock type and tectonic setting in the research area. This paper documents the geochemistry of plutonic igneous rock of research area by geochemical studies. The granitic rocks associated with ore mineralization from the study area show peraluminous characters and are identified as S-type granite and the tectonic setting of the studied granites are discriminated as orogenic granitoids.

Keywords: Geochemistry, Plutonic igneous rock, Tectonic setting.

Introduction

Location, Size and Accessibility

The research area is located about 6.5 km east of Thabeikkyin and 122 km north of Mandalay. It is bounded by the North Latitude 22^{o} 51' 15" to 22^{o} 58' 00" and the East Longitude 96^{o} 01' 00" to 96^{o} 06' 00" in one inch topographic map 93 B/1. It extends for about 8 km from North to South and 8 km from East to West. It covers an area extent of approximately 64 square kilometer. The study area is accessible by car throughout the year. The location map and three-dimensional map of the study area shown in figures (1) and (2).

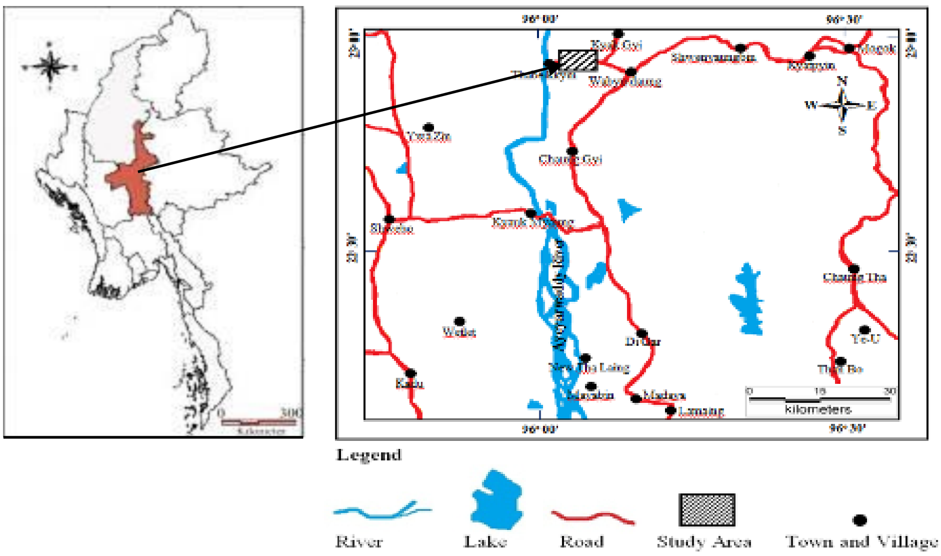

Figure (1). Location map of the study area, Thabeikkyin Township, Mandalay Region.

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Purpose of study

The principle purposes of the present research area are;

-to identify the rock classification of igneous rock,

-to describe the tectonic environments for the granites of the study area.

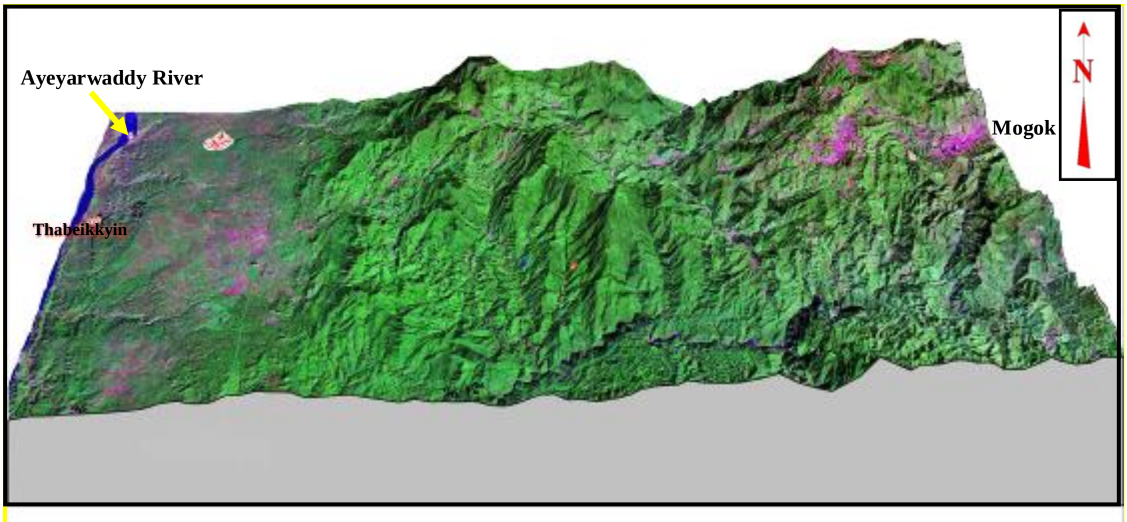

Figure (2). Three-dimensional view of the topography of the study area and its environs.

Previous Works

Various workers studied the Mogok Metamorphic Belt. They mentioned their views on the geology, metamorphism and tectonism of the Mogok Metamorphic Belt. La Touche (1913) described the principal rock types of the area in the memoir of the Northern Shan State. The term ‘Mogok Gneiss’ was firstly introduced by him. Clegg (1941) proposed the rocks to be metamorphosed Paleozoic and Mesozoic rocks. He published a geological report for north of Thabeikkyin and east of Ayeyarwaddy. Searl and Haq (1964) described that the Mogok Series comprises stratigraphical groups ranging from Precambrian to Upper Paleozoic and that the metamorphism must have been post Paleozoic and related to the Himalayan Orogeny. Ali Akbar Khan (1985) reported that the metasedimentary rocks are intruded by Tertiary igneous rocks on the geology of Wabyudaung-Ondan area. Myint Naing (1987) explained the geolgy of Chaunggyi-Zayetkwin area, Thabeikkyin Township. He stated that Lower to Upper Paleozoic metasedimentary rocks were intruded by Late Creteceous to Paleocene igneous rocks. Myint Lwin Thein et al., (1990) studied the main rock units of the Mogok-Thabeikkyin-Singu-Madaya area. They described the stratigraphic consideration on marble as well as other metamorphic rock units and associated igneous rocks. Zaw Win Ko (1997) also studied the gelogy of Kwinthonze-Onzon area. Bertrand et al., (1999, 2001 and 2003) proposed the Oligocene to Mid-Miocene age of the Mogok metamorphism. Myo Thant (2002) studied the geology and ore deposits of Kwinthonze-Leikkya area, Thabeikkyin Township. Tin Aung Myint (2009) has studied precious and base-metal mineralization in the Chaunggyi-Kandaung-Kwinthonze area. This is just south of the research area. Zar Oo San (2010) also studied the petrology and genetic aspects of gem minerals in the Kyetsaung Taung-Kyaukkyi area, Thabeikkyin Township. This area is south of the study area. Zaw Win (2015) also contributed the petrology and gold mineralization of the Kyaukbalu-Donwe area.

Regional Geologic Setting

The research area lies within the north-south trending narrow strip of the Mogok Metamorphic Belt of Searle and Haq (1964) and Mitchell (1993). It is situated between the Shan Scarp to the east and Sagaing Fault (Win Swe, 1970), a north-south trending right lateral strik-slip fault to the west. The Shan Scarp marks the boundary between the central plain to the west and Shan plateau to the east. The Mogok Metamorphic Belt extends for over 1500 km along the western margin of the Shan-Thai Block, from Andaman Sea to the eastern Himalayan Syntaxis. This belt is made up of intrusive igneous and high grade metamorphic rocks mainly gneiss, marble, schist and quartzite. Lithologically and structurally, Mogok Metamorphic Belt is very complex. Towards the west of the study area, Sagaing Fault, north-south trending right lateral strike-slip fault of Win Swe (1970) is dissecting the Mogok Group and Irrawaddy Formation.

To the east of the area, the Mogok Group is bounded as overthrust by the Precambrian Chaung Magyi Group. Tourmaline granite intrusive bodies are emplaced. In the east of the area, Paragneisses (garnet-biotite gneiss, biotite gneiss and leucogneiss) of ? Precambrian age, the metasedimentary rocks (foliated marbles and marbles) Mogok Group of Upper Paleozoic age, meta-igneous rocks (granodioritic gneiss and monzonitic gneiss) of ? Upper Cretaceous to Lower Eocene and syenitic rocks, Kabaing granite, leucogranite, pegmatite and aplite of ? Tertiary age are exposed (Ali Akbar Khan, 1985). Towards the south of the area, metamorphic rocks (gneisses and marble), igneous rocks (basalt, syenitic rocks, biotite microgranite, leucogranite, pegmatite and aplite) are present (Tin Aung Myint 2009).

Distribution of the Rock Units

The main rock units exposed in the study area are meta-sedimentary and igneous rocks. The meta-sedimentary rocks are various marbles such as white marble, phlogopite marble, diopside marble, graphite marble and calc-silicate rocks. The geological ages of these rock units are regarded as most probably Late Paleozoic to Mesozoic. The igneous rock is the Eocene to Middle Miocene based on the dating of biotite microgranite. The meta-sedimentary rocks are widely distributed in the study area. Diopside marble is interbedded with calc-silicate rocks in the eastern part of the research area. Large exposures of biotite microgranite boulders are well-observed at the eastern and northern parts of the area. The garnet skarn was probably produced by intrusions of igneous bodies into the marble and calc-silicate rocks, especially in the northern part of the Chan-tha village (Fig. 3).

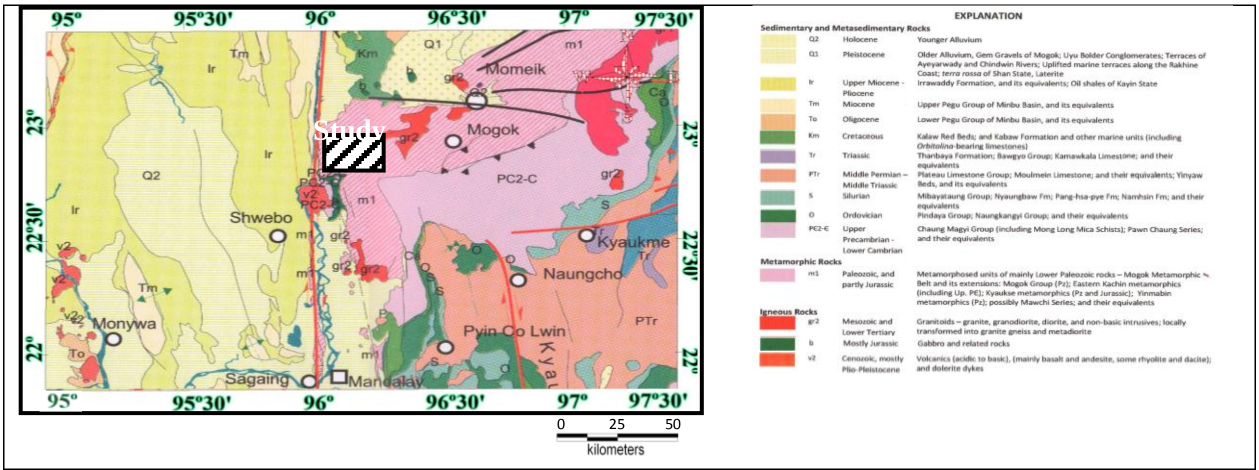

Figure (3). Regional Geologic Setting of the study area and its environs (Source: The Geological Map of Myanmar, 2014; by Myanmar Geo-science)

Analytical Methods

This research is based on the field investigation of Kantha-Aungthaya area. The major and trace elemental composition of rock(s) and mineralized rocks/veins was analyzed by X-Ray Fluorescence (XRF) under pressed pellets using a RIGAKU RIX-3100 (Series VR 25006) X-ray Fluorescence spectrometer. This laboratory analysis were performed at Faculty of Engineering, Kyushu University, Japan.

Geochemistry of Plutonic igneous rock

In general, biotite-microgranite is generally related to ore mineralization and alteration. Seven biotite microgranite samples were selected for detailed geochemical studies. Major and trace elemental compositions of the samples were analyzed by X-Ray Fluorescence (XRF).

Representative geochemical compositions for granite samples are shown in table (1). In the present study, XRF whole-rock analysis was used to supplement petrographic analysis in the rock classification, and discrimination of tectonic setting. Standard CIPW norms were calculated in a way to work out the mineralogy of the rocks and classification from the chemical data. The resulting normative mineralogical compositions of the igneous rocks samples are presented in table (2).

Based on the result of XRF analysis, the granites have the chemical composition as follows: SiO_2 (65.34-74.2 wt. %), Al_2O_3 (13.23-17.19 wt. %), Na_2O (0.35-2.39 wt. %), K_2O (4.12-5.44 wt. %), CaO (1.42-2.87 wt. %), FeO (2.0-2.57 wt. %), MgO (0.54-2.76 wt. %), MnO (0.01-0.07 wt. %), P_2O_5 (0.04-0.07 wt. %) and TiO_2 (0.23-0.43 wt. %)

The total alkali versus silica (TAS) diagram subdivided the igneous rocks into ultrabasic, basic, intermediate and acid, on the basics of silica content. Plot on the TAS diagram (Cox *et al*., 1979) indicates that the bulk compositions of intrusive rocks fall within the fields of granite and granodiorite (Fig. 4).

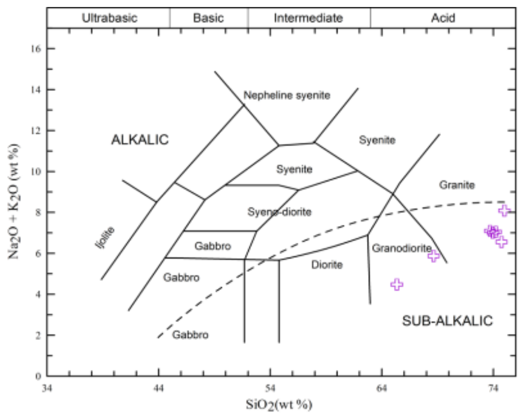

Figure (4). Plots of granitic rocks from Kantha- Aungthaya area in the total alkali versus silica, (TAS) diagram of Cox *et al*. (1979).

Table (1) Chemical compositions of biotite microgranite samples from Aungchanthar Area.

Sample ID	Sc-SMSE-Oc	Sc-SMSE-alt	Nca-C-055	OTG-021	Llk-gw-alt	Gr	Sc-033
SiO_2	73.952	68.633	74.203	73.696	65.343	74.976	74.726
TiO_2	0.228	0.256	0.233	0.275	0.436	0.086	0.234
Al_2O_3	13.369	15.189	13.257	13.231	17.192	13.274	13.078
FeO	2.003	2.579	2.041	2.152	1.431	1.39	1.913
MnO	0.072	0.031	0.031	0.042	0.002	0.093	0.053
MgO	0.543	1.196	0.541	0.582	2.766	0.3666	0.574
CaO	1.474	2.057	1.421	1.63	2.874	0.596	1.696
Na_2O	2.357	0.436	2.398	2.168	0.352	2.735	2.539
K_2O	4.651	5.44	4.651	4.927	4.121	5.351	4.017
P_2O_5	0.05	0.039	0.039	0.044	0.077	0.007	0.061
LOI	1.09	3.88	0.98	1.07	5.3	1.0	0.93
V	16	19	16	25	32	7	25
Cr	bdl	Bdl	Bdl	bdl	bdl	bdl	bdl
CO	46	39	32	57	34	39	8
Ni	8	5	8	7	6	14	5
Cu	40	10	20	30	50		
Zn	500	150	90	470	370		
Pb	370	380	370	410	390		
As	bdl	bdl	bdl	bdl	bdl	bdl	bdl
Mo	6	6	9	3	8	4	7
Rb	206	187	188	189	193	523	164
Sr	259	130	267	230	30	25	252
Ba	1114	1663	1119	1078	138	138	838
Y	31	24	27	37	15	141	25
Zr	213	248	207	238	351	89	205
Ta	bdl	Bdl	bdl	bdl	bdl	bdl	bdl
Nb	16	11	14	14	7	17	13

* Concentrations of major and minor oxides and S in wt. %, elements are in ppm; bdl-below detection limit

Table (2) CIPW normative compositions of granites of the study area calculated from the major and minor oxides composition.

Sample ID	Sc-SMSE-Oc	Sc-SMSE-Alt	Nca-C-055	OTG-021	Llk-Gw-alt	Gr	Sc-033
Q	37.06	37.18	37.16	36.35	36.64	35.63	38.78
Or	27.48	32.15	27.48	29.13	24.35	31.62	23.76
Ab	19.97	3.72	20.31	18.36	2.96	23.19	21.49
An	6.97	9.96	6.78	7.83	13.72	2.91	8.04
C	1.9	4.93	1.79	1.46	7.13	1.9	1.6
Hy	4.75	7.33	4.75	4.98	8.76	3.41	4.64
Il	0.44	0.49	0.44	0.53	0.84	0.17	0.44
Ap	0.12	0.09	0.09	0.09	0.19	0.02	0.14
Pr	0.02	0.02	0.02	0.02	0.02	0.07	0
AN	25.86	72.29	25.04	29.88	82.24	11.16	27.23

Granitic rocks of the study area are also classified according to their normative composition in the An-Ab-Or triangular diagram (O'Corner, 1965). On the An-Or-Ab triangular plot, all granitic rock samples fall in the field of the granite (Fig. 5).

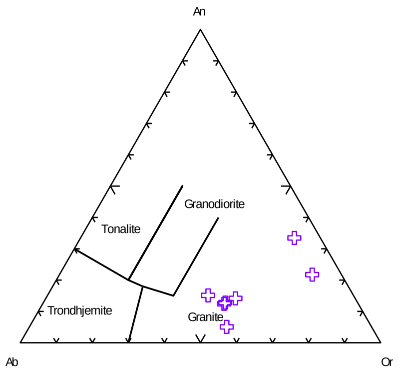

Figure (5). Ternary plot diagram in normative albite-orthoclase-anorthite digram for the granitic rocks of the study area. Division lines in the diagram are taken from O' Corner (1965).

Shand proposed the useful terms metaluminous and peraluminous to refer to rocks that are respectively under- and oversaturated in Al. Shand (1927) grouped igneous rocks based on the total molar alkali vs. alumina content as either **peralkaline** [Al_2O_3 < (Na_2O + K_2O)], **peraluminous** [Al_2O_3 > (CaO + Na_2O + K_2O)], and **metaluminous** [Al_2O_3 < (CaO + Na_2O + K_2O) but Al_2O_3 > (Na_2O + K_2O)], a classification that is useful mostly for very felsic rocks. Alumina saturation is generally determined by using Shand's Index (1949). The granitic rock samples from the research area are plotted on N+K/A vs A/C+N+K diagram (Fig. 6). The granitic rocks show peraluminous character based on the plot on this diagram and the mole percent alumina greater than the sum of lime, soda and potash (Al_2O3>CaO+Na_2O+K_2O).

When the elements in a rock are recast as hypothetical minerals in a CIPW norm, metaluminous rocks contain normative diopside (di) and peraluminous rocks contain normative corundum (C). These normative minerals will correspond to the presence of specific Al-poor or Al-rich minerals in the rock. CIPW normative compositions for the granites of the study area are calculated from the major and minor oxides composition and indicate that the granites contain normative corundum (C) ranging from 1.6 to 7.13%. Thus, the granitic rocks from the study show peraluminous characters oversaturated with Al_2O_3 contents. The peraluminous character is also reflected by the occurrences of relatively abundant biotite in the modal composition observed from the microscopic observation.

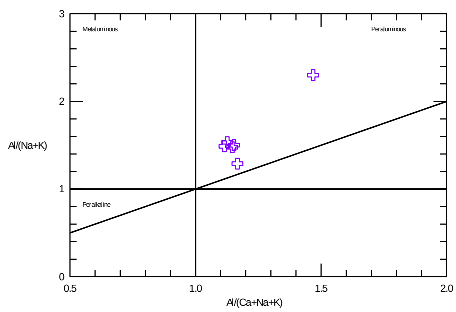

Figure (6). Al/(Ca+Na+K) versus Al/(Na+K) diagram determining metaluminous, peraluminous and peralkaline granitoid (Shand, 1927).

Alumina saturation of the rocks is also defined by using the Al_2O_3-CaO-(Na_2O+K_2O) classification diagram (Fig. 7). The granitic rocks of the study area fall within the field of peraluminous.

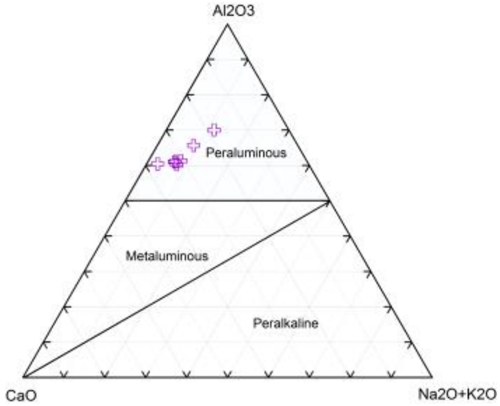

Figure (7). Al_2O_3-CaO-(Na_2O+K_2O) classification diagram for the granitic rocks of the study area (after Hyndman, 1985).

Chappell and White (1974) classified the granitoid rocks into two main types, I type and S type. I-type granitoid (for a given value of SiO_2) has higher Na, Ca, Sr, Fe^{3+} /Fe^{2+}, $^{87}Sr/^{86}Sr$, and $\delta_{18}O$ and lower Cr, Ni, and $^{143}Nd/^{144}Nd$. The common oxide is magnetite, the rocks are hornblende-rich, and are either metaluminous or weakly peraluminous. They are chemically similar to the continental arc granitoids. The chemical composition suggests that they are derived by partial melting of a mafic mantle-derived igneous source material (probably of a sub-crustal underplate, but subducted-slab crust or older high-level pluton sources cannot be excluded) (Winter, 2001).

The second suite has the opposite chemical trends to those listed above, and is always peraluminous (often strongly so). The common oxide is ilmenite, and the rocks are biotite-rich, and normally contain cordierite. They may also contain muscovite, andalusite, sillimanite, and/or garnet. These rocks have been called S-type gran-itoids, and the chemical composition suggests that they are produced by partial melting of already peraluminous sedimentary source rocks imprinted by weathering at the Earth's surface. These rocks correspond to the crustal melts (Winter, 2001).

For classification of granitic rocks, various plots are used to distinguish I- and S-type. One of the most importance diagrams is ACF (A-Al_2O_3+Na_2O+K_2O; C-CaO; F-Fe_2O_3+MgO) diagram. Plots of the granitic rocks sample from the research area on ACF diagram indicates that they belong to S-type granite (Fig. 8). Peraluminous character of the granites samples, such as the higher contents of Al-minerals as well as the occurrence of normative mineral corundum also point to the S-type for the granites of the study area.

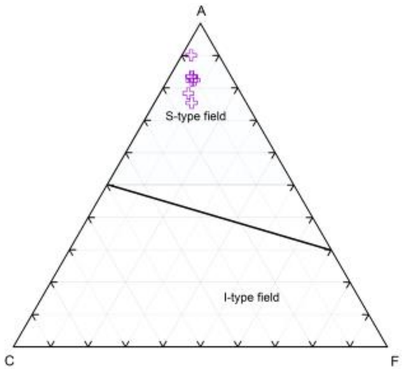

Figure (8). ACF diagram for the granitic rocks of the study area. Molar ratios: A-Al_2O_3+ Na_2O+K_2O; C-CaO; F-Fe_2O_3+MgO (after Hydman, 1985).

Tectonic Discrimination

The tectonic environments for the granites are usually discriminated by means of major and minor elements chemistry. In this scenario, a variety of discrimination diagrams are applied in order to discriminate various tectonic environments of granitic rocks. Biotite microgranite is mainly the focus of this study for the determination of tectonic environments of the research area.

In this study, discrimination of tectonic environments for granites follow the works of Maniar and Piccoli (1989):

Orogenic Granitoids

- Island Arc Granitoid (IAG)
- Continental Arc Granitoid (CAG)
- Continental Collision Granitoid (CCG)
- Post Orogenic Granitoid (POG)

Anorogenic Granitoids

- Rift-Related Granitoids (RRG)
- Continental Epirogenic Uplift Granitoids (CEUG)
- Oceanic Plagio-granite (OP)

K_2O versus SiO_2 diagram discriminates the IAG+CAG+CCG+ RRG+ CEUG and OP field. In this diagram, biotite microgranite samples from the study area are plotted in the IAG+CAG+CCG+ RRG+ CEUG field (Fig. 9).

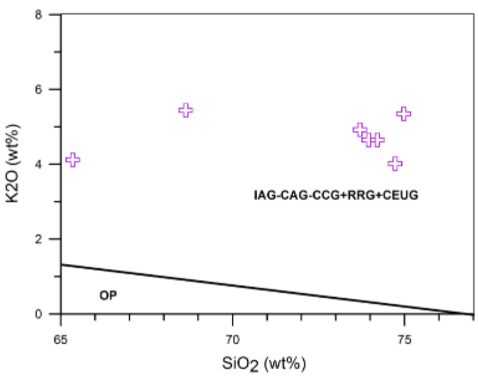

Figure (9). K_2O versus SiO_2 diagram for granitic rocks of the study area; division line between tectonic environments is taken from Maniar and Piccoli (1989).

Al_2O_3 versus SiO_2 diagram (Fig. 10) attempts to plot the biotite micrograni tes into IAG+CAG+CCG, RRG+CEUG and POG fields. According to this diagram, all of the granite samples plot within the IAG+CAG+CCG and POG fields. On MgO versus SiO_2 variation diagram (Fig. 11), biotite microgranite samples fall in the IAG+CAG+CCG field.

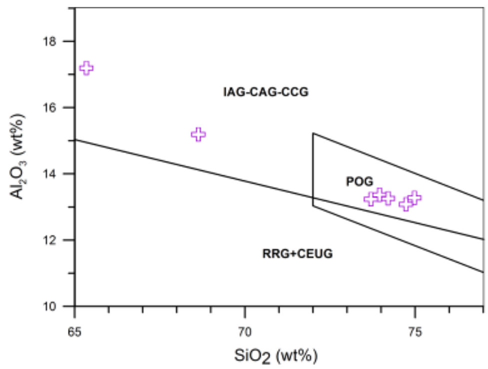

Figure (10). Al_2O_3 versus SiO_2 diagram for granites of the study area (after Maniar and Piccoli, 1989).

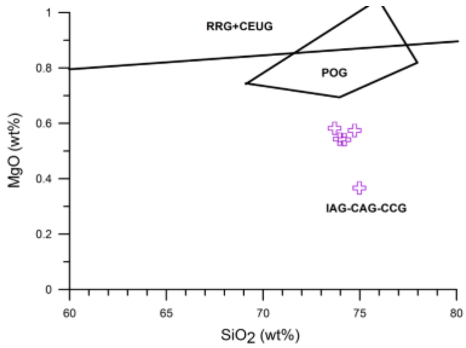

Figure (11). Plot of MgO vs SiO_2 for granite of the study area (Maniar and Piccoli, 1989).

Based on the plot on various discrimination diagrams, it can be concluded that biotite microgranite from the study area falls in the IAG+CAG+CCG field which discriminates the tectonic setting of the studied granites as orogenic granitoids.

In the Shand's index diagram, all the granites samples from the research area are confined to CAG and CCG field (Fig. 12). In this case, the igneous rocks of the study area may be regarded as continental arc granitoids as well as continental collision granitoid. Hence it seems reasonable to conclude that the granite was formed in the continent in relation with the subduction of an oceanic plate beneath the continent. ACF diagram (Fig. 8), and other chemical criteria suggest that the granites of the study area are of S-type.

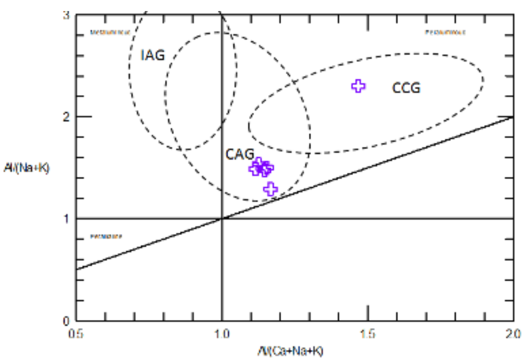

Figure (12). Shand's index diagram for granitic rocks of the study area (after Maniar and Piccoli, 1989).

This is also supported by the occurrence of aluminium rich characters as well as by the mineralogy of the granite composition. Normative corundum of the granite is also greater than 1%. Therefore, it can be concluded that biotite microgranite was formed in the continent due to the subduction of an oceanic plate beneath the continent.

Trace element data can also provide a means to determine the tectonic setting. Trace element analyses were used in this study to investigate the tectonic origins of intrusive rocks from the study area. Y, Nb, and Rb are utilized in tectonic discrimination diagrams and are generally considered immobile under most metamorphic conditions. According to Pearce *et al.*, 1984, the granites can be classified into oceanic-ridge (ORG), volcanic arc (VAG), within-plate (WPG) and collisional types (COLG).

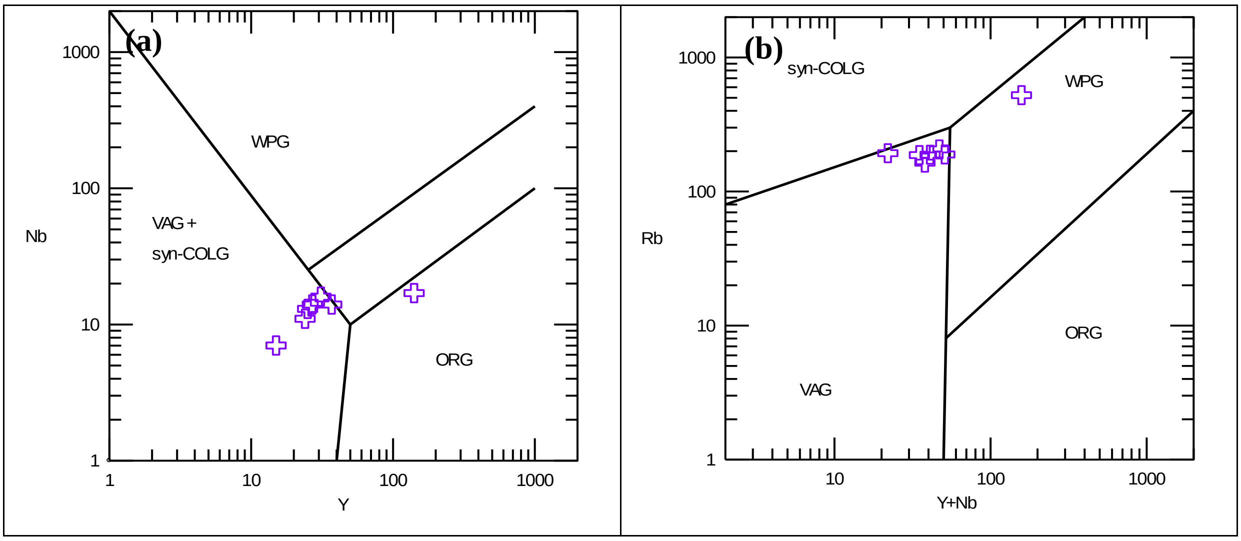

Figure (13). (a) The Nb-Y discrimination diagram for granite (after Pearce *et al.*, 1984) and (b) The Rb-(Y+Nb) discrimination diagram for granite (after Pearce *et al.*, 1984); syn-collisional granites (syn-COLG), within-plate granite (WPG), volcanic-arc granite (VAG) and ocean-ridge granite (ORG).

On the tectonic discrimination diagram using (Y vs Nb) (Pearce *et al.*, 1984), the granitic rocks are plotted in the fields of the volcanic arc and syn-collisional fields (Fig. 13.a). On the tectonic discrimination diagram (Y + Nb vs. Rb; Pearce *et al.*, 1984), they are plotted in the volcanic arc field (Fig. 13.b) and have trace element characteristics of a volcanic-arc setting.

Conditions for the crystallization

As illustrated in Fig. (5), the bulk composition of igneous rocks of the study area falls in the granite field. Almost all of the analyzed rocks of the study area possess >40% normative Ab+Or+Qtz and >40% normative Or+An+Qtz. These ratios are plotted in ternary diagrams (Fig. 14).

In the diagram, the quartz-feldspar boundaries at water pressure of 1kb, 2kb, 5kb, 1Gpa, 2Gpa and 3Gpa are shown projected onto the anhydrous base of the tetrahedron, after Tuttle and Bowen (1958). With reference to figure (14), biotite microgranite lies win the field with pressure <1kb.

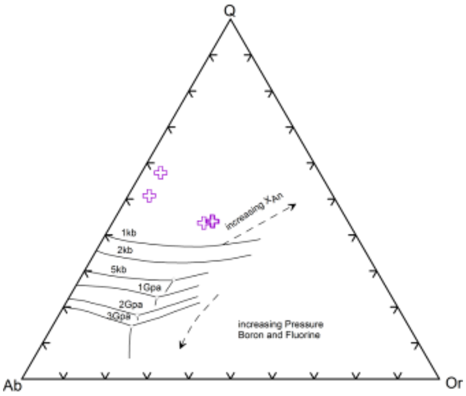

Figure (14). Normative Qtz-Ab-Or-H_2O diagram for the granitic rocks of the study area. Diagram showing H_2O saturated liquidus field boundaries and isobaric temperature in the system Qtz-Ab-Or-H_2O for various water pressures (after Tuttle and Bowen, 1958).

Summary and Conclusions

The Kantha-Aungthaya area is located in Thabeikkyin Township, Mandalay region, central Myanmar. The major rock units of the research area are metasedimentary and igneous rocks. The igneous rock is mainly biotite microgranite. The current research is intended to focus on the geochemistry of plutonic igneous rock and its tectonic setting in the study area. The granitic rocks associated with ore mineralization from the study area show peraluminous characters and can be identified as S-type granite. Based on the plots on various discrimination diagrams, it can be concluded that granite from the study area fall in the IAG+CAG+CCG field which discriminates the tectonic setting of the studied granites as orogenic granitoids. On the tectonic discrimination diagram (Y vs Nb), the granitic rocks are plotted in the volcanic arc and syn-collisional fields and On (Y + Nb vs. Rb) diagram, they are plotted in the field of the volcanic arc and have trace element characteristics of a volcanic-arc setting.

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