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PETROLOGICAL SIGNIFICANCE ON GRANITOID ROCKS EXPOSED IN MYA YEIK- TA YAW GYIN AREA, MONYWA-SALINGYI SEGMENT OF WESTERN MYANMAR ARC

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Abstract

The present area is situated in the Monywa-Salingyi segment of Western Myanmar Arc that is composed of diverse igneous rocks during early Cretaceous to Quaternary age. Although the plutonic rocks having mafic to felsic composition are exposed, the present research emphasize only on granite and granophyre as granitoid rocks. Mineralogically, these granitoid rocks are mainly composed of quartz, orthoclase, plagioclase, hornblende, and biotite. The textures of granitoid rocks indicate in terms of volatile rich composition, highly differentiate and magma mixing condition of magma. Moreover, the mineral composition and textures strongly supports to interpret I-type, calc-alkaline magma. Petrochemically, these rocks belong to the calc-alkaline suite and I-type granitoid. In addition, they can also be interpreted as the subduction related volcanic arc. Thus granitoid rocks were probably formed in an arc setting during subduction of Neo-Tethyan oceanic lithosphere.

Keywords: Western Myanmar arc, Monywa-Salingyi Segment, granitoid rocks, calc-alkaline, Neo-Tethyan

Introduction

Myanmar is situated at the eastern margin India-Asia collision that is characterized by the existence of 1200 km long Sagaing Fault (Lee *et al*., 2016). The western Myanmar geological province comprises all of Myanmar west of the Mogok Metamorphic Belt (MMB) that were formed with the Himalayan orogeny during Mesozoic to Cenozoic (Mitchell *et al*., 2012; Shi *et al*., 2014). Moreover, there are two principal Neo-Tethyan related magmatic belts in Myanmar: the Western Myanmar Arc (WMA) of western Myanmar, and the Mogok-Mandalay-Mergui Belt found in central and southern Myanmar (Gardiner *et al*., 2015). The WMA was widely considered as the Andean-type continental arc formed along the South Asian margin during the Neo-Tethyan oceanic subduction (United Nations, 1979; Bender, 1983; Mitchell *et al*., 2012; Wang *et al*., 2014; Lin *et al*., 2019). These rocks in the WMA can be correlated with (1) Cretaceous–Paleogene granitoids of the Gangdese batholith (Barley and Pickard, 2003; Gardiner *et al*., 2015; United Nations, 1979; Mitchell *et al*., 2012), and (2) a series of Miocene-Quaternary volcanoes along the Andaman–Sunda (Sumatra)–Banda subduction system in southeast Asia (Hutchison, 1989).

The WMA, located in the central part of the Burma terrane, is a N-S trending magmatic belt delineated by the Banmauk-Wuntho Batholith in the north, and the Monywa-Salingyi Segment in the south that intruded the Basement Complex (Figure 1) (Barber, 1936; Mitchell *et al*., 2012). In the Salingyi segment including present area, amphibolites, gabbros, diabases, and pillow basalts (Barber, 1936; United Nations, 1979) are interpreted as part of an ophiolite, overlying mica-schists, gneisses and pegmatites occurring in small inliers beneath conglomerates of similar materials (Mitchell,1993).

The Chindwin Basin including present area lies west of the WMA, and is regarded as the forearc basin of the WMA (Wandrey, 2006 in Wang *et al*., 2014). Moreover, the Chindwin Basin was filled by the upper Cretaceous-Eocene shallow marine or deltaic clastic rocks and carbonates, and the unconformably overlying Neogene fluvial sediments (Bender, 1983).

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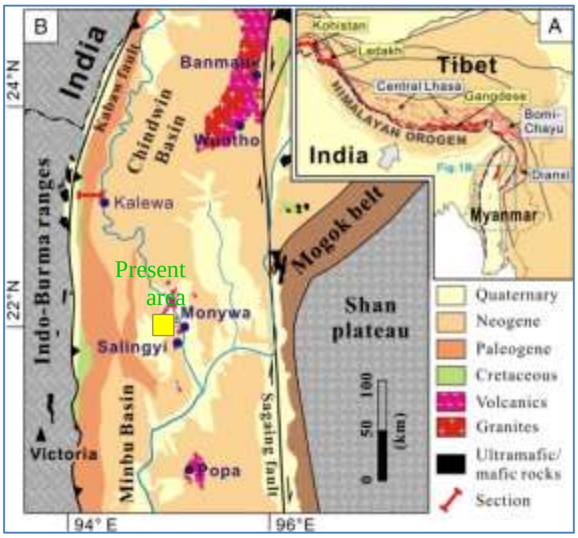

Figure 1 A: Simplified tectonic map of the Tibetan plateau and adjacent regions, B: Geological Map of northern Myanmar. Western Myanmar Arc is delineated by the Banmauk - Wuntho - Monywa - Popa magmatic belt (Wang *et al*.., 2014)

This research emphasizes petrographical data and petrochemical data of the granitoid rocks in the area, and all results can examine the petrogenesis and tectonic implications to better understand the magmatic evolution of the part of WMA. Because the granitoid rocks are important to deduce the origin, evolution, and geodynamics condition due to the main component of continental crust (Barbarin, 1999). This research also postulates the findings of oceanic plate fragments to ensure the island arc setting.

Method of Investigation

Detailed field work was carried out in order to perform the geologic mapping at 1: 50,000 scale of UTM map, and geological map of United Nations (1979). The field observations were carried out along car-road, cart-tracts, food-paths, and quarries where good exposures are appeared. 30 samples were collected for petrography and 6 representative samples of different plutonic rocks were selected for geochemical analysis of major elements.

The 30 thin sections are examined by using polarizing microscope for mineral identification according to Kerr (1959), for mineral composition according to William *et al.*, (1982) and for textural analysis according to Winter (2014). The whole rock geochemical analyses were performed at Department of Chemistry, Monywa University by using XRF (X-ray Fluorescence). From these major oxides, the classification of rocks according to Cox *et al.*, (1979) for plutonic rocks; identification of magma series according to Ivrine and Bragar (1971), Pearce *et al*. (1984), Chappel and White (2001), Frost *et al.* (2001); and then possible tectonic settings are interpreted.

Lithologic Units

The study area is mainly composed of igneous rocks forming as intrusive and extrusive. These igneous rocks are the southern part of WMA that have been formed from the Mesozoic to Quaternary. Moreover, the basement of the study area was recognized as Monywa-Salingyi Volcanics and Crystalline Complex for green rock, diorite intruding the green rock, and granophyre of middle Cretaceous (Barber, 1936; Bender, 1983; Min Aung, 1994). The present research subdivided this basement complex into Ophiolitic rocks with limestone and chert, siliceous mudstones, Yinbochaung Granite and Granophyre as Granitoid Rocks (Figure 2). In addition, Tertiary and Quaternary volcanic rocks are extruded contemporaneously with Magyigon Formation of Miocene-Pliocene age.

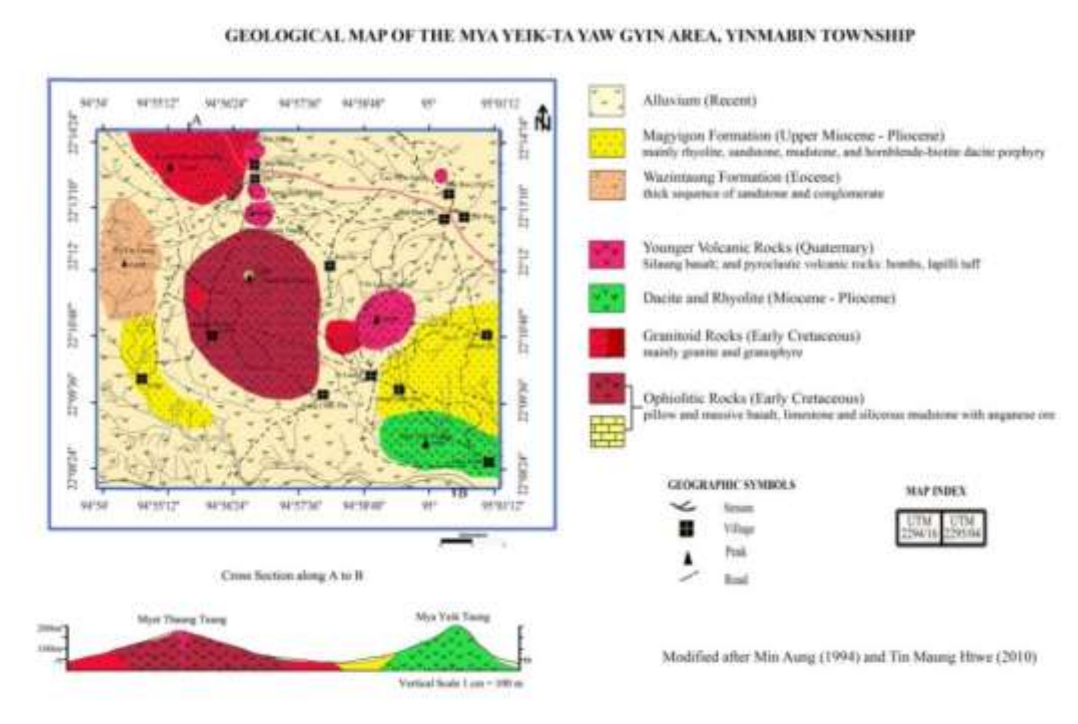

Figure 2 Geological Map of the study area

Ophiolitic Rocks

Basaltic rock units are exposed in the stream just west of Ta Yaw Gyin village, west of Kan Su village and vicinity of Taungbu Taung. The volcanic rocks are exposed as massive with bed like jointing and as pillow structures (Figure 3). These rocks mostly display green color and constitute mainly of olivine, pyroxene and plagioclase which are more or less altered. Some rocks are very fine-grained as basalt whereas some are medium-grained size as dolerite. These basaltic rocks were intruded by quartz veins at the margin of this unit in which zeolite and actinolite minerals were found. Diorite was also intruded these volcanics at the Powin taung (Min Aung, 1994). Some residual manganese ores are also found in this unit (Figure 4).

In addition, these units are overlain by the medium-to thick-bedded micritic limestone unit in which chert nodule are also noted (Figure 5 and 6). This limestone may be deposited during or after Early Cretaceous in age due to stratigraphic position. Moreover, the siliceous mudstones are also intercalated within the limestone units (Figure 7). Fossil evidences have not been yielded from limestone whereas some radiolarians have been found in the siliceous mudstone.

This unit is equivalent to those in the Mawgyi Volcanics in the Wuntho-Banmauk arc segment to the north (Mitchell, 2017). Mawgyi Volcanics were also intruded by the early Upper Cretaceous Kanzachaung Batholith and small diorite stocks of pre-Upper Cretaceous (United Nations, 1979). Moreover, the age of diorite at Salingyi had a zircon U-Pb age of 105.3±1.7 Ma (Mitchell *et al*., 2012), K/Ar determinations from hornblende ages on diorites of 106±7 Ma (United Nation, 1979). By the stratigraphic relationship with southern and northern continuation of Salingyi and Mawgyi Volcanics along the WMA, this unit can be assumed as Upper Cretaceous in age.

Granitoid Rocks

Yinbochaung Granite

This unit is well exposed along the Yinbochaung and at Kyauk Sabyone Taung that intruded the ophiolitic rocks. They have dark-grey on weather surface and little pinkish to white color on fresh surface (Figure 8). They are composed mainly of coarse-grained quartz, plagioclase, orthoclase and biotite with xenoliths of basalt (Figure 9). Some granite rocks along the road of Monywa-Alaungdawkathapha and at Kyauk Sabyone Taung are highly weathered and are only remained quartz grains.

Granophyre

Granophyres are exposed on a small hill southwest of Silaung Taung that form as NNE striking dyke with about 300 feet wide (Figure 10). The granophyre intruded the volcanic rocks of the ophiolitic rocks at the northwest of Myayeik taung. They are composed of coarse-grained quartz, feldspar and accicular form of amphibole minerals (Figure 11). The granophyre was assigned as the part of the Yinbochaung Granite because it also intruded the ophiolitic rocks.

The granite in the study area is compositionally and texturally similar to that of Baingdaung granite in Salingyi-Shinmataung Area (United Nations, 1979). A K/Ar radiometric determination on a biotite concentrate from the granite at the Salingyi yielded an age of 103±4 m.y., indicating a probable age of intrusion of late Upper Cretaceous (United Nations, 1979). Moreover, the granites from the Wuntho-Banmauk Segment assigned the oldest age as 98±1 at Wuntho and 103±1 Ma based on the U-Th-Pb (Lin *et al*., 2019). It can be recognized that granitoid rocks were intruded during Upper Cretaceous.

Figure 3 Basalt showing pillow structure exposed at the east of Taungbu Taung (N 22°12' 1" and E 94° 56' 39")

Figure 4 Residual manganese ore exposed at the east of Taungbu Taung (N 22°12' 1" and E 94° 56' 39")

Figure 5 Limestone with karst features exposed at the east of Taungbu Taung (N 22°12'7" and E 94°56'43")

Figure 6 Chert layer and nodules in limestone exposed at the east of Taungbu Taung (N 22°12'7" and E 94°56'43")

Figure 7 Intercalated siliceous mudstone exposed at the east of Taungbu Taung (N 22°12' 1" and E 94° 56' 39")

Figure 8 Granites with joints exposed at Yinbochaung (N 22°14'6"and E 94°56'16")

Figure 9 Xenolith of basalt in granite exposed at Yinbochaung (N 22° 14'6"and E 94°56'16")

Figure 10 Dyke like nature of granophyre exposed just southwest of Silaung Taung (N 22°11'1" and E 94°58' 17")

Figure 11 Accicular amphibole minerals in granophyre exposed just southwest of Silaung Taung (N 22°11'1" and E 94°58'17")

Mineralogical an Textural Significance

Yinbochaung Granite

This rock is mainly composed of quartz (20-40%), orthoclase (10-20%), plagioclase (10-20%), hornblende (~10%), biotite (10%) and microcline (3-5%) showing hypidiomorphic to allotriomorphic texture (Figure 12 and 13). The hornblende minerals are suggested as I-type granitoid (Chappel and White, 1992; Winter, 2014) as well as amphibole-rich calc-alkaline granitoid (ACG) (Barbarin, 1999). Quartz minerals are mostly anhedral forms and show wavy extinction that fill interstitial spaces between other minerals. The multiple twinned plagioclases with interstitial quartz and orthoclase (Figure 12) that is the characteristic feature of calc-alkaline granodioritic plutonic rock (Wilson, 2007).

In addition, cross-hetched twinned microclines are also included in granites (Figure 14) which occurred in most differentiated stage of the volatile-rich conditions (Wilson, 2007). Moreover, the euhedral plagioclase contain within the orthoclase (Figure 15). A mineral is included only in the core areas of another mineral indicate the strongest evidence for one mineral ceasing to crystallize before the other forms (Winter, 2014).

Quartz and feldspar intergrowth show myrmekitic texture that appear to have grown from the plagioclase–K-feldspar boundary into the K-feldspar (Figure 16). As the plagioclase replaces the K-feldspar, SiO_2 is released (the anorthite component of plagioclase contains less SiO_2 than the K-feldspar), thereby producing the quartz (Winter, 2014). Myrmekite commonly forms during cooling of granitic rocks (Winter, 2014; Collins and Collins, 2013).

Alkali feldspars are present as orthoclase, albite and microcline. Plagioclase crystals are subhedral to euhedral in shape that show zoning (Figure 17). These zoning are formed when a mineral change in composition as it grows during cooling (Gill, 2010). This irregular compositional change may indicate magma mixing, unstable crystallization or both (Aslan, 2005).

Granophyre

They are composed of quartz (20-45%), plagioclase (30-50%), hornblende (~7%), orthoclase (3-10%) and biotite (~3%) minerals (Figure 18). The intergrowth texture of quartz minerals and alkali feldspar displaying a granophyric texture (Figure 19) is possibly reflecting eutectic crystallization of the final residual melt, shows cunei form and rod-like form (Winter, 2014). In addition, if the H_2O is suddenly lost, the melting point will rise quickly, resulting in undercooling (even at a constant temperature) and rapid simultaneous crystallization of the alkali feldspar and quartz (Winter, 2014). Moreover, Granophyric intergrowths are formed from the highly differentiated of the most volatile-rich magmas (Wilson, 2007).

Petrochemical Significance

The major, minor and trace elements of the granitoid rocks are described in Table (1). The granitoid rocks in the study area belong to the granite clan of subalkaline field based on the total alkalis and silica content (Figure 20) (Cox *et al.*, 1979). In the AFM diagram of the (Na_2O+K_2O), FeO and MgO, subalkaline series of granites and granophyres fall in the field of calc-alkaline (Figure 21) (Irvine and Baragar, 1971 in Rollinson, 1993). Calc-alkaline magmas are essentially restricted to subduction related plate tectonic processes (Winter, 2014).

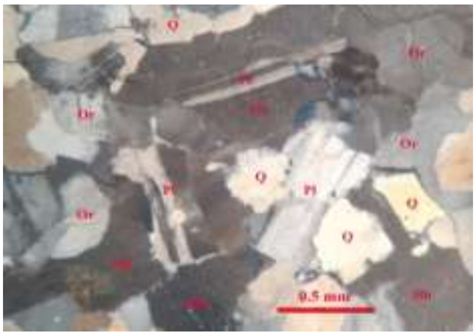

Figure 12 Granite composed of quartz (Q), plagioclase (Pl), orthoclase (Or), hornblende (Hb) showing allotriomorphic texture (XN, 4x)

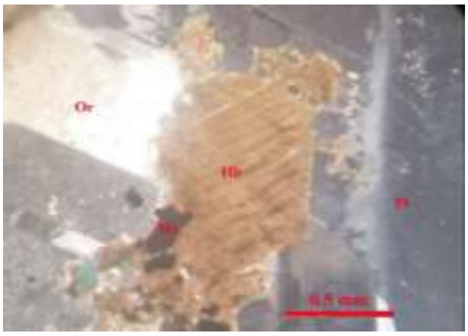

Figure 13 Hornblende minerals with two sets of cleavage in granite (XN, 4x)

Figure 14 Cross-hetched twin microcline in granite (XN, 4x)

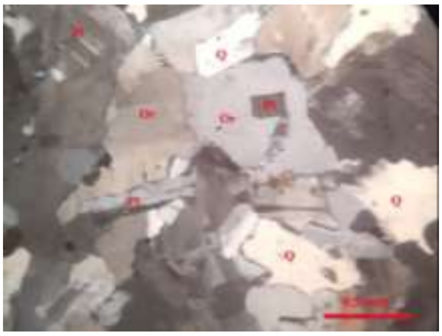

Figure 15 Euhedral plagioclase within the orthoclase in granite (XN, 4x)

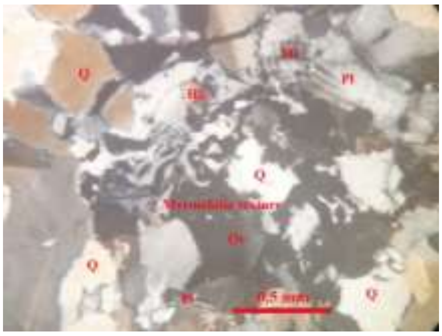

Figure 16 Quartz and feldspar intergrowth of myrmekitic texture and interstitial quartz grain (Q) in granite (XN, 4x)

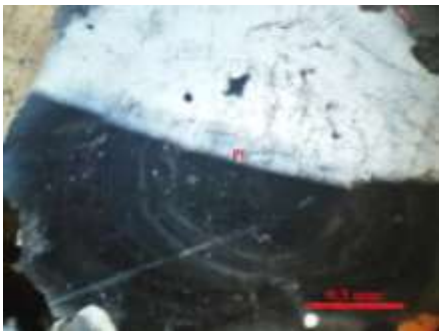

Figure 17 Zoning and twinning plagioclase in granite (XN, 4x)

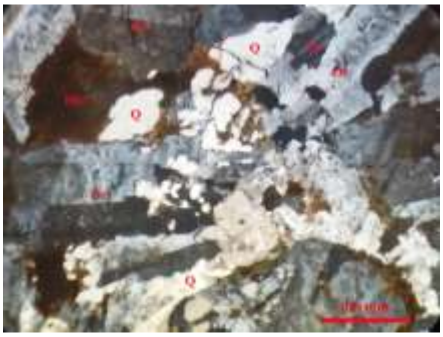

Figure 18 Granophyre composed of quartz (Q), orthoclase (Or), hornblende (Hb) and plagioclase (Pl) (XN, 4x)

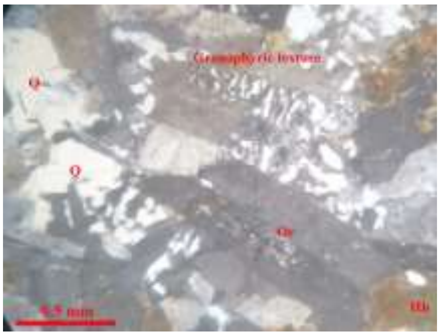

Figure 19 Quartz and alkali feldspar showing granophyric texture in granophyre (XN, 4x)

To classify the I-type and S-type granitoid, when plotted on the ACF (Al_2O_3-Na_2O+K_2O, CaO, and FeO+MgO) diagram on the basis of major oxides, it is found that these plutonic rocks fall in the I-type field (Figure 22) (Chappell and White, 1992).

Frost *et al.* (2001) had classified according the geochemical data for granitoids based on Fe-number ratio of the rock to classify the ‘ferroan’ (Tholeiitic) and ‘magnesian’ (Calc-alkaline); based on modified alkali-lime index (MALI); and is based on aluminum saturation index (ASI). The samples fall within the slightly ferroan field except one sample of granite; and within calcic to alkali-calcic field. The granophyres fall within metaluminous whereas the granite within slightly peraluminous field (Figure 23) that also indicates the I-type granitoid (Winter, 2014).

The granitoid rocks are further discriminated by using trace element Rb, Y, and Nb according to Pearce *et al*. (1984). Most of the samples fall within the volcanic arc granite (VAG) except one sample based on Rb-(Y+Nb) as well as fall within the volcanic arc granite and collision granite (VAG+syn-COLG) except one sample based on Nb-Y(Figure 24).

Table 1 Major, minor, and trace element contents of the granitoid rocks

Sample No	**3-a**	**3-a1**	**3-a2**	**5-g**	**5-g1**	**5-g2**
Rock types	Granite	Granite	Granite	Granophyre	Granophyre	Granophyre
Localities	Yinbochaung	Yinbochaung	Yinbochaung	S of Silaung Taung	S of Silaung Taung	S of Silaung Taung
Major oxides (wt%)						
SiO_2	71.885	76.267	80.821	70.368	69.071	71.59
TiO	0.142	0.045	0.113	0.338	0.345	0.39
Al_2O_3	16.564	14.278	11.285	15.654	15.982	14.937
Fe_2O_3	0.942	0.209	0.689	2.062	2.234	1.892
MnO	0.027	0.01	0.018	0.082	0.088	0.076
MgO	0.114	0.064	0.177	0.39	0.357	0.307
CaO	3.046	2.312	1.963	3.158	3.763	3.221
Na_2O	5.457	4.871	3.686	7.043	7.096	6.535
K_2O	1.547	1.089	1.041	0.427	0.552	0.565
P_2O_5	0.034	0.017	0.071	0.219	0.229	0.22
			Trace element (ppm)			
Cr	62	48	34	246	109	164
Rb	37	37	37	9	9	9
Sr	135	85	76	186	211	186
Y	31	24	24	24	39	31
Zr	7	30	52	74	74	104
Nb	7	0	0	252	7	7
La	563	205	384	759	699	716
Ce	627	90	293	488	757	676
Hf	93	263	68	93	161	68
Ta	229	205	139	221	270	197

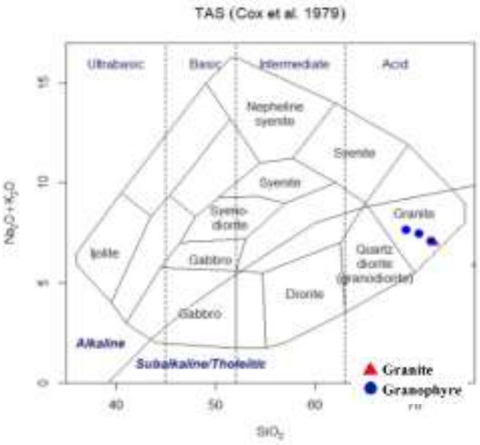

Figure 20 The chemical classification of plutonic rocks based on total alkalis (Na_2O+K_2O) and silica (SiO_2) (Cox *et al.*, 1979) (Drawing from GCDkit 5)

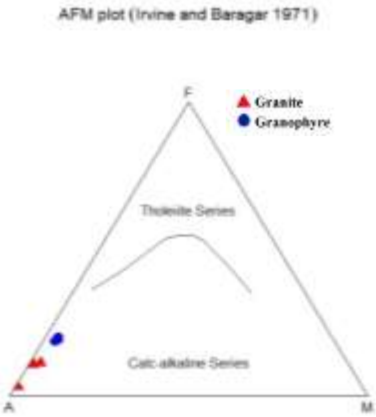

Figure 21 AFM diagram for plutonic rocks of the study area showing the discrimination between tholeiitic and calc-alkaline suite (Ivrine and Bragar, 1971) (Drawing from GCDkit 5)

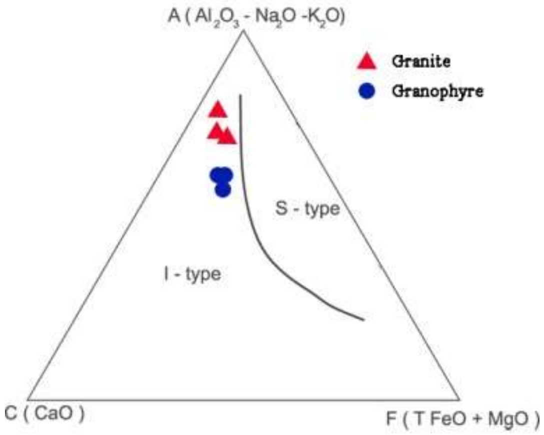

Figure 22 ACF diagram for the granite rock of the study area compared with the typical I- type and S-type (Chappel and White, 2001)

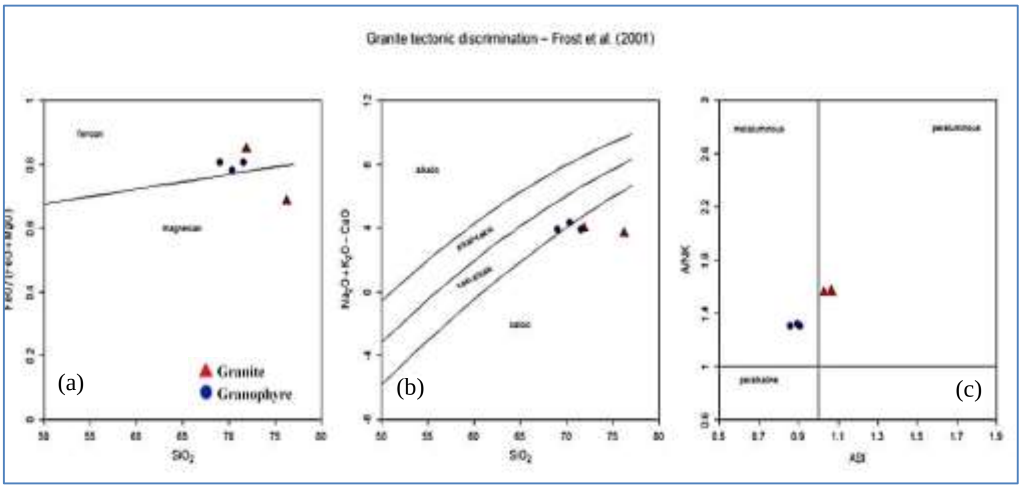

Figure 23 Granite tectonic discrimination (Frost *et al.*, 2001)

(a) Fe-number [FeO/(FeO + MgO)]

(b) Modified alkali-lime index (MALI) (SiO_2 vs $Na_2O + K_2O – CaO$)

(c) Aluminum saturation index (ASI)

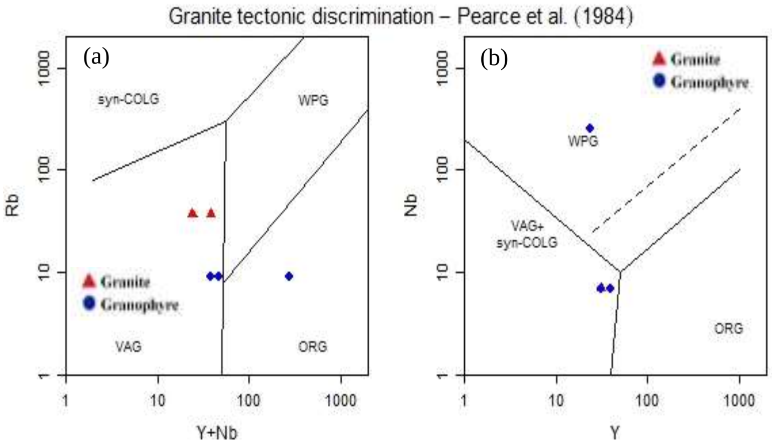

Figure 24 Granite tectonic discrimination (Pearce *et al.*, 1984) (a) Rb vs (Y+Nb) (b) Nb vs Y

Discussion

The granitoid rocks are examined systematically by using field occurrence, mineralogical and textural parameters, and geochemical parameters. From the field relationship, the basalt xenoliths are found in the granitoid rocks that indicate the granitoid rocks intruded the ophiolitic rocks.

All these rocks are mainly composed of quartz, plagioclase, orthoclase, hornblende and biotite in which hornblende is the indicator of I-type granitoid (Chappell and White, 1992; Winter, 2014) and amphibole-rich calc-alkaline granitoid (ACG) (Barbarin, 1999).

The presence of interstitial quartz and orthoclase, and microcline suggest the highly differentiated volatile rich calc-alkaline magma. The granophyric textures in all granophyres also indicate the highly differentiated volatile rich magma. Moreover, euhedral plagioclase within the orthoclase provides the temperature condition and changes of magma composition. In addition, zoning plagioclases suggests that the changing of composition of magma as magma mixing or unstable crystallization during cooling of magma.

All the granitoid rocks fall within the granite field based on the total alkalis and silica content as well as calc-alkaline field according to (Na_2O+K_2O), FeO and MgO. Moreover, these samples also belong to calcic to calc-alkalic based on the modified alkali-lime index. This geochemical data supports the petrographical result to identify calc-alkaline magma.

Considering I-type or S-type, all samples belong to I-type according to ACF diagram. In addition, these samples fall within the metaluminous and weakly peraluminous of aluminum saturation index which also suggest the I-type character (Winter, 2014).

The paleotectonic environment of these granitoids is interpreted as volcanic arc granite (VAG) from the trace elements Rb, Y, and Nb. Moreover, the low Nb contents (<11 ppm) is a characteristic of the arc setting above subduction zone (Pearce *et al.*, 1984). In addition, the VAG can vary in setting from oceanic to continental and in composition from tholeiitic through calc-alkaline to shoshonitic (Peccerillo & Taylor, 1976 in Pearce *et al.*, 1984).

The following facts can be pointed out with the regional tectonics along WMA,

(1) The basaltic rocks of the ophiolitic rocks can be correlated with the Mawgyi Volcanics along the northern continuation of WMA due to the occurrences of pillow basalts with local

limestone. Moreover, these basaltic rocks were extruded in deep marine environments (United Nations, 1979; Mitchell, 2017).

(2) Moreover, the age of ophiolites from igneous rocks and chert throughout Myanmar indicated Middle Jurassic-Early Cretaceous (Liu *et al.*, 2016; Teza Kyaw *et al.*, 2019; Suzuki *et al*., 2020; Tin Tin Naing *et al.*, 2020). Thus, Tethyan ocean was existed in the Western Myanmar during that time.

(3) The granitoid rocks also intruded the basaltic rocks in the present area. Most of the intrusions along WMA were hosted by the Pre-Albian Mawgyi Volcanics (Mitchell, 2017).

(4) The WMA is the N-S trending magmatic-volcanic arc with numerous mafic-felsic plutons. In addition, ACG is also the characteristic plutons of the subduction related volcanic arcs that form vast batholiths, elongate parallel to the trench (Barbarin, 1999).

(5) Moreover, the Cretaceous mafic-felsic magmatism along WMA was generated during subduction of the Neo-Tethyan oceanic lithosphere (Mitchell *et al*., 2012; Li *et al*., 2020)

It can be concluded that the granitoid rocks in the present area were intruded from the calc-alkaline, I-type magma at volcanic arcs during subduction of the Neo-Tethyan oceanic lithosphere.

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References

Aslan, Z., (2005). Petrography and Petrology of the Calc-Alkaline Sarihan Granitoid (NE Turkey): An Example of Magma Mingling and Mixing, *Turkish J. Earth Sci.*, vol.14, pp.185-207.

Barbarin, B., (1999). A review of the relationships between granitoid types, their origins and their geodynamic environments, *Lithos*, 46, pp.605-626.

Barber, C. T., (1936). The Intrusive and Extrusive Rocks of the Salingyi Uplands and Linzagyet, *Memoir of the Geological Survey of India*.

Barley, M. E., Pickard, A. L., Khin Zaw, Rak, P., Doyle, M. G., (2003). Jurassic to Miocene magmatism and metamorphism in the Mogok metamorphic belt and the India-Eurassia collision in Myanmar, *Tectonics*, vol. 22, No. 3, 1019, TC001398.

Bender, F., (1983). *Geology of Burma*, Gebruder Brontraeger, Berlin.

Chappell, B.W. and White, A.J.R., (1992). I and S-type granites in the Lachlan Fold Belt. Transactions of the Royal Society of Edinburgh: *Earth Sciences* 83, 1-26.

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

Collins, L. G. and Collins, B. J., (2013). Origin of myrmekite as it relates to K-, Na-, and Ca-metasomatism and the metasomatic origin of some granite masses where myrmekite occurs, www.csun.edu/~vcgeo005/*Nr56Metaso.pdf.*

Cox, K. G., Bell, J. D. and Pankhurst, R. J., (1979). *The interpretation of igneous rocks*. Boston, George Allen and Unwin London.

Frost, B.R., Barnes, C.G., Collins, W.J., Arculus, R.J., Ellis, D.J., Frost, C.D., (2001). A Geochemical Classification for Granitic Rocks, *Journal of Petrology*, V.42, No.11, p.2033-2048.

Gardiner, N.J., Searle, M.P., Robb, L.J., Morley, C.K., (2015). Neo-Tethyan magmatism and metallogeny in Myanmar-An Andean anglogue?, *Journal of Asian Earth Sciences*, vol. 106, p.197-215.

Gill, R., (2010). *Igneous Rocks and Process: A Practical Guide*, Wiley-Blackwell, A John Wiley & Sons, Ltd., Publication, U. K.

Hutchison., C. S., (1989). *Geological Evolution of South-East Asia*, 2nd ed., Art Printing Works Sdm. Bhd., Malaysia.

Irvine, T. N., and Baragar, W. R. A., (1971). A guide to the chemical classification of the volcanic rocks, *Canada Journal of Earth Science*, Vol. 8, pp 523-548.

Kerr, P.F., (1959). *Optical Mineralogy*, 3rd Edition, McGraw-Hill Book Company Inc., New York.

Lee, H.Y., Chung, S.L., Yang, H.M., (2016). Late Cenozoic volcanism in central Myanmar: Geochemical characteristics and geodynamic significance, *Lithos*, 245, pp. 174-190.

Li, J.X., Fan, W.M., Zhang, L.Y., Peng, T.P., Sun, Y.L., Ding, L., Cai, F.L., Kyaing Sein, (2020). Prolonged Neo-Tethyan magmatic arc in Myanmar: evidence from geochemistry and Sr-Nd-Hf isotopes of Cretaceous mafic-felsic intrusions in the Banmauk-Kawlin area, International Journal of Earth Sciences, https://doi.org/10.1007/s00531-020-01824-w .

Lin, T.H., Mitchell, A.H.G., Chung, S.L., Tan, X.B., Tang, J.T., Thura Oo, Wu, F.U., (2019). Two parallel magmatic belts with contrasting isotopic characteristics from southern Tibet to Myanmar: zircon U-Pb and Hf isotopic constraints, *Journal of the Geological Society*, London, vol. 176, pp. 574-584.

Liu, C.Z., Chung, S.L., Wu, F.Y., Zhang, C. Xu, Y., Wang, J.G., Chen, Y., (2016). Tethyan suturing in Southeast Asia: Zircon U-Pb and Hf-O isotopic constraints from Myanmar ophiolites. *Geology*, Geological Society of America, 44, pp.311–314.

Min Aung, (1994). Geology of the Powintaung-Silaung area, Yinmabin Township, *M. Sc. Thesis*, University of Mandalay, unpub.

Mitchell, A. H. G., (1993). Cretaceous-Cenozoic tectonic events in the western Myanmar (Burma) – Assam region in *Journal of the Geological Society of London*, vol. 150, p. 1089-1102.

Mitchell, A., Chung, S. L., Thura Oo, Lin, T. S., 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*,Vol. 56, pp. 1-23.

Mitchell, A., (2017). *Geological Belts, Plate Boundaries, and Mineral Deposits in Myanmar*, Elsevier Inc., United States.

Pearce, J.A., Harris, N.B.W., Tindle, A.G., (1984). Trace element discrimination diagrams for the tectonic interpretation of granitic rocks, *Journal of Petrology*, vol. 25, part-4, pp. 956-983.

Rollinson, H. R., (1993). *Using Geochemical Data: Evaluation, Presentation, Interpretation*, Longman, P. 352.

Shi, G.H., Lei, W.Y., He, H.Y., Nok Ng, Y., Liu, Y., Liu, Y.X., Yuan, Y., Kang, Z.J., Xie, G., (2014). Superimposed tectono-metamorphic episodes of Jurassic and Eocene age in the jadeite uplift, Myanmar, as revealed by ^{40}Ar/^{39}Ar dating. *Gondwana Research*. 26, pp. 464–474.

Suzuki, H., La Ja, Maung Maung, Aung Kyaw Thin, Kuwahara, K., (2020). The first report on Early Cretaceous Radiolaria from Myanmar, *Paleontological Research*, 24, pp. 103-112.

Teza Kyaw, Maung Maung, Suzuki, H., (2019). Upper Jurassic Radiolarians from Bedded Chert of Tagaung Area in Tagaung-Myitkyina Belt, *Myanmar, 3rd International Conference on Substantial Scientific Collaborations of Ocean & Earth Sciences*, Conference Proceeding, pp. 27-33.

Tin Tin Naing, Robinson, S., Searle, M., Henderson, G., Millar, I., (2020). Age, Depositional History and Tectonics of the Indo-Burman Ranges, *Geomyanmar 2020 International Congress Plus IGCP 668 & IGCP 679,* Oral Presentation.

United Nations, (1979.)Geology and Exploration Geochemistry of the Salingyi-Shinmataung Area, Central Burma, *Technical report 5,* New York.

Wang, J. C., Wu, F. Y., Tan, X. C., Liu, C. Z., (2014.)Magmatic evolution of the Western Myanmar Arc documented by U-Pb and Hf isotopes in detrital zircon, *Tectonophysics*, 612-613 (2014), p. 97-105.

Williams, H., Turner, F. J., Gilbert, C. M., (1982). *An Introduction to the Study of Rocks in Thin Sections*, 2nd Edition, W. H. Freeman and Company, New York.

Wilson, M., (2007). *Igneous Petrogenesis: A Global Tectonic Approach*, Springer, Netherlands.

Winter, J. D., (2014.)*An Introduction to Igneous and Metamorphic Petrology*, Prentice-Hall Inc., Upper Saddle River, New Jersey.