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PETROGRAPHY AND GEOCHEMISTRY OF VOLCANIC ROCKS IN THE WIN GYI AREA, WUNTHO-BANMAUK GOLD REGION, MYANMAR

Than Tun Win[1], Aung Zaw Myint[2], Htay Win[3]

Abstract

Win Gyi area is located in the south-eastern part of Wuntho Massif and characterized by the lithologic units of (i) plutonic rocks of Kanzachaung Batholith, (ii) volcanic rocks of Mawgyi Volcanics, and (iii) volcanoclastics and volcanic rocks of the Mawlin Formation. Gold mineralization in the study area is mainly confined to the andesitic unit of Mawgyi Volcanics and, hence, we study the petrography and geochemistry of Mawgyi Volcanics to determine petrogenesis and tectonic setting. Mawgyi Volcanics mainly consist of porphyritic andesite and basalts. A geochemical study indicates that the volcanic rocks possess of SiO_2 (48.5- 57.9 %), Na_2O (1.21-6.55%), K_2O (0.13-0.5%), MgO (4.5-7.18%), Fe_2O_3 (9.27-11.2%), and TiO_2 (0.74-1.08%), mostly show calc-alkaline characteristics. Chondrite-normalized REE patterns and primitive mantle-normalized spider diagram reveal that the volcanic rocks are derived from slab-derived fluids, resulting from partial melting of the metasomatized mantle wedge. The volcanic rocks were formed by the subduction of the Neo-Tethyan oceanic lithosphere to the Eurasia plate during Cretaceous.

Keywords: Wuntho-Banmauk segment, Mawgyi Volcanics, Win Gyi area, petrogenesis, tectonic setting

Introduction

Wuntho-Banmauk Gold Region is located in the Popa-Loimye magmatic arc of Myanmar. This region is famous for the Kyaukpazat gold deposit, Shangalon porphyry-like copper-gold deposit, and other gold and copper occurrences. The Win Gyi area is one of the high-grade gold occurrences in the Wuntho-Banmauk Gold Region (Fig. 1). Gold-bearing quartz veins are hosted by the Mawgyi Volcanics. There was no systematic record regarding the geochemical characteristics of the Mawgyi volcanics. Thus, we conduct the petrography and geochemistry of the volcanic rocks of Mawgyi Volcanics to determine their petrogenesis and tectonic setting.

Geological Background

Popa-Loimye magmatic arc is related to the later tectonic events associated with the subduction of the Neo-Tethys oceanic lithosphere (Cobbing et al., 1992; Gardiner et al., 2018). The Popa-Loimye magmatic arc comprises Cretaceous to Oligocene dioritic to granodioritic rocks, Cretaceous to Miocene volcanic rocks, and Quaternary basalts (Gardiner et al., 2018; Mitchell, 2018). Win Gyi area is located in the southeastern part of Wuntho Massif (Noetling, 1894), also known as the Wuntho-Banmauk segment of the Popa-Loimye magmatic arc (Mitchell and McKerrow, 1975). Wuntho-Banmauk segment is built up with (i) plutonic rocks of Kanzachaung Batholith and Pinhinga Plutonic complex, (ii) volcanic and volcanoclastic sediments of Maingthon dacite, Mawlin Formation, Mawgyi Volcanics, and Shwedaung Formation, and (iii) sedimentary units of Kangon Formation, Ketpanda Formation, and Wabo

[1] Department of Geology, University of Yangon

[2] Department of Geology, Dawei University

[3] Department of Geology, University of Yangon

Chaung Formation (United Nations, 1979). The origin of Mawgyi Volcanics (105- 93Ma) coincident with the formation of many Neotethyan supra-subduction zone ophiolites and intraoceanic arcs along orogenic strikes in the eastern Mediterranean, Middle East, Pakistan, and Southeast Asia (Zhang et al., 2022).

The geology of the Win Gyi area is represented by the lithologic units of (i) plutonic rocks of Kanzachaung Batholith, (ii) volcanic rocks of Mawgyi Volcanics, and (iii) volcanoclastics and volcanics rocks of Mawlin Formation (Fig. 1). Mawgyi Volcanics are widely exposed in the Win Gyi area.

Analytical Methods

Fifty samples of igneous rocks were collected from the environs of the Win Gyi for petrography and geochemical analysis. Among them, six fresh samples of volcanic rocks are analyzed with X-Ray Fluorescence Spectrometry (XRF) at the Geological Department, Yangon University. At ALS, Australia, five samples are analyzed with Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) for major and minor oxides. Then, four samples are analyzed with Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) for trace elements and Rare Earth Elements. The whole rock geochemical data are listed in Table (1) and (2).

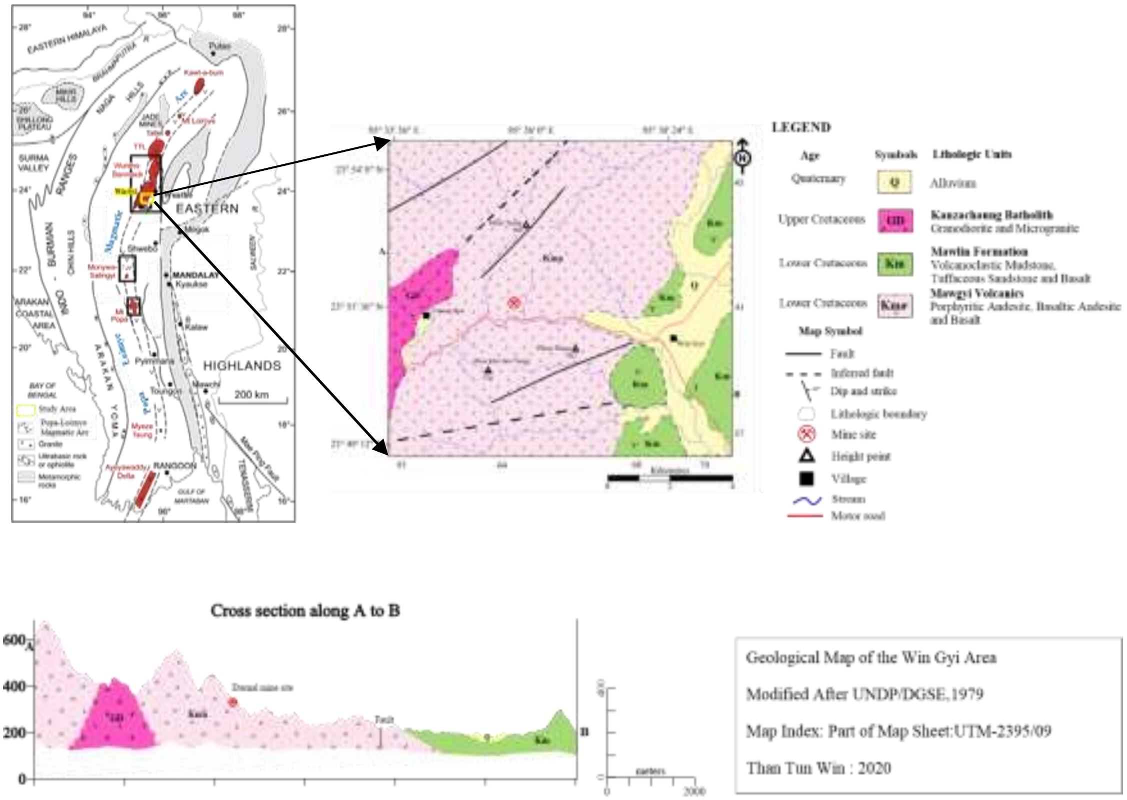

Figure 1 Popa-Loimye magmatic arc, (Mitchell and McKerrow, 1975) and geological map of the study area

Petrography

Porphyritic Andesite

It is well exposed in the north and northeastern part of the study area, displaying dark-brown to light grey, fine-grained, porphyritic, massive, and highly weathered (Fig. 2a). It is composed essentially of feldspar, pyroxene, and hornblende. It comprises 25% of phenocrysts (plagioclase, pyroxene, and quartz) and 75% of groundmass (plagioclase, epidote, and opaque minerals). The penetration-twinned plagioclase phenocrysts, 0.2 to 0.7 mm in diameter, are embedded in the groundmass (Fig. 3a). Alteration minerals are epidote, chlorite, sericite, and actinolite. Some plagioclase phenocrysts are altered partially to sericite. The large phenocryst of euhedral orthopyroxene is altered to strongly pleochroic actinolite, which shows yellowish-green, long prismatic form, and nearly parallel extension (Fig. 3b). Chlorite occurs as radial aggregates (Fig. 3c).

Basalt

It is well exposed in the southern part of the study area (Fig. 2b). It essentially consists of feldspar, pyroxene, and hornblende. It comprises 80% of groundmass (glassy matrix, feldspar laths, pyroxene, and opaque minerals). The plagioclase phenocrysts, 0.3 to 0.5 mm in diameter, are embedded in the groundmass (Fig. 3d). Pyroxene occurs as subhedral to anhedral micro-phenocrysts and high interference color (Fig. 3d &3e). Some plagioclase laths show flow texture (Fig. 3f).

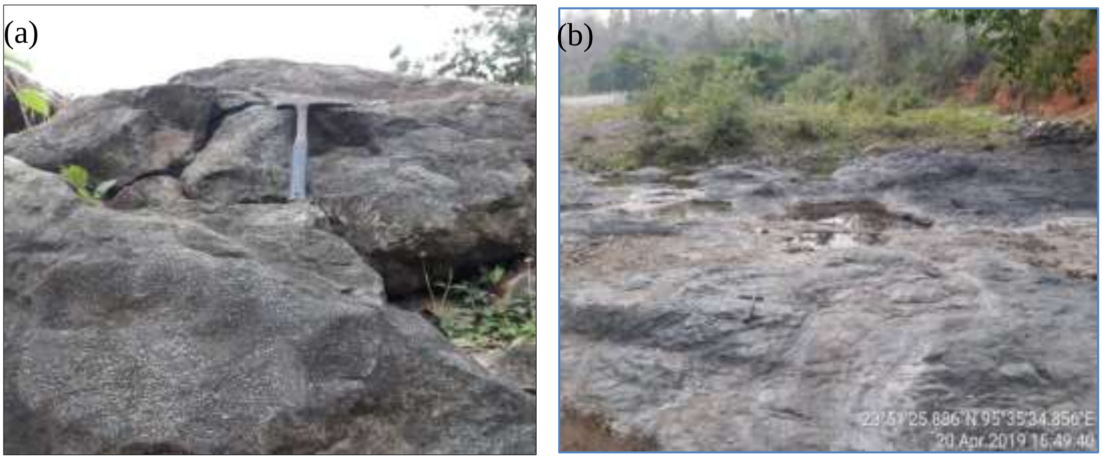

Figure 2 Field exposures of Mawgyi Volcanics (a) Nature of porphyritic andesite exposed near the mine site, (b) Basalt exposed at stream bed of Kyauk Kyi Chaung

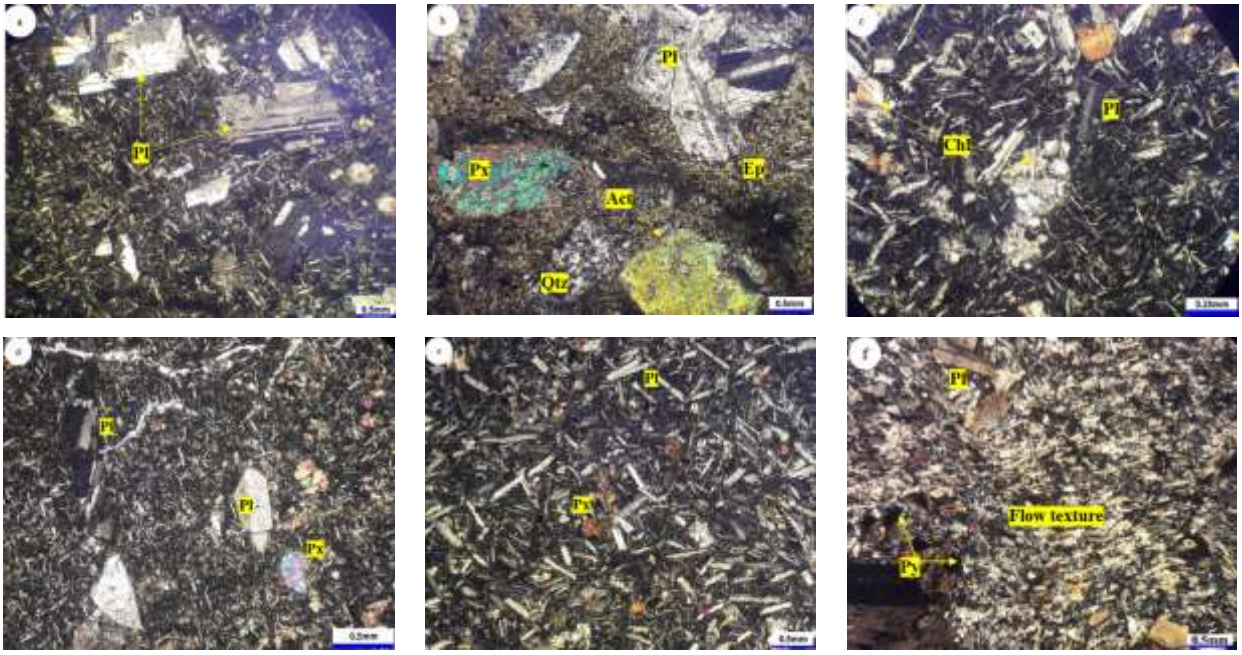

Figure 3 Photomicrographs showing the mineral composition of (a, b, c) Porphytic andesite, (d, e, f) basalt of the Mawgyi Volcanics. Abbreviation; Qtz, quartz; Pl, plagioclase; Or, orthoclase; Bt, biotite; Hb, hornblende; Ep, epidote; Act, actinolite; Px, pyroxene; Chl, chlorite; Py, pyrite

Geochemical Characteristics

Major Elements Geochemistry

The chemical composition of Mawgyi volcanics show SiO_2 (48.5- 57.9 %), Al_2O_3 (15.6-18.6%), Na_2O (1.21-6.55%), K_2O (0.13-0.5%), CaO (3.7-9.35%), MgO (4.5-7.18%), MnO (0.18-0.74%), Fe_2O_3 (9.27-11.2%), and TiO_2 (0.74-1.08%). The abundances of Al_2O_3, Fe_2O_3, and MgO are negatively correlated with the value of SiO_2. CaO, Na_2O, and K_2O do not markedly increase with SiO_2, and TiO_2 is slightly positively correlated with SiO_2. All volcanic samples belong to the basalt, basaltic andesite, andesite, and basaltic trachy andesite (mugearite). Most of the samples show a subalkaline/ tholeiitic nature (Fig. 4a). The volcanic rocks are better classified using the AFM diagram of (Irvine and Baragar, 1971) shown in figure (4c) within the field of calc-alkaline series except for three samples that fall in the tholeiitic series.

Table (1) Major elements (wt %) concentration in the volcanic rocks of Win Gyi area

Method	ICP-OES					XRF					
Sample No	E-002	E-065	E-066	E-068	E-089	E-067	WG-002	WG-003	WG-018	LPK-4	WG-001
SiO_2	50.9	51	54	54.2	48.5	48.8	53.7	53.6	55.5	53.2	57.9
Al_2O_3	16.95	18.6	15.65	15.6	17.8	15.8	16.1	16.1	16.2	17.3	17.4
Fe_2O_3	9.38	10.25	12.2	10.85	11	12.5	10.1	11.2	8.49	9.27	10.1
CaO	4.45	7.76	4.62	3.7	9.35	6.44	5.29	7.11	12.9	14.4	5.25
MgO	5.6	6.23	4.96	4.73	5.01	7.53	7.18	6.96	4.5	4.72	5.03
Na_2O	5.19	4.55	5.01	6.55	3.91	1.54	2.85	1.63	5.69	1.21	2.31
K_2O_3	0.49	0.13	0.2	0.09	0.22	0.45	0.57	0.186	0.49	0.335	0.4
TiO_2	0.79	0.73	0.97	0.74	1.08	1.16	1	1.05	0.992	0.98	1.61
MnO	0.18	0.18	0.2	0.2	0.25	0.73	0.141	0.209	0.063	0.097	0.34
P_2O_5	0.09	0.06	0.13	0.05	0.14	0	0	0	0	0	0
LOI	3.7	1.7	2.62	1.98	1.03	0	0	0	0	0	0
Total	97.72	101.2	100.56	98.69	98.3	95	96.931	98.045	104.825	101.5	100.34

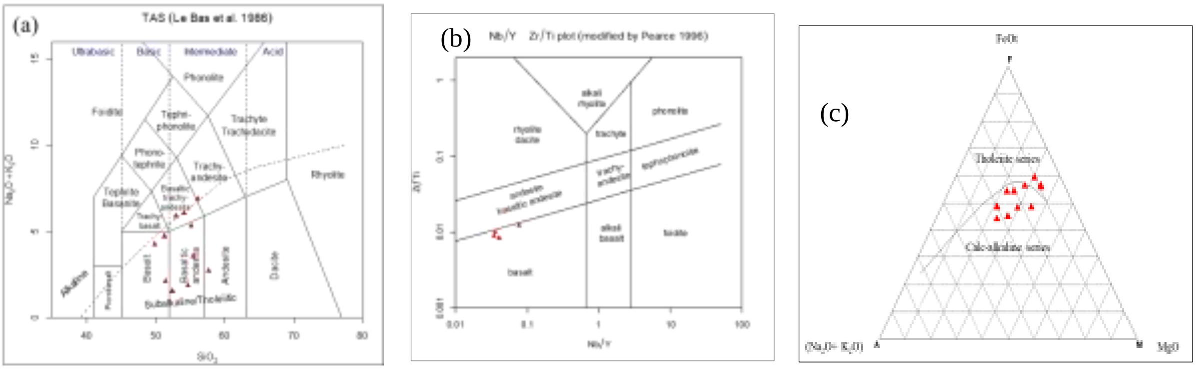

Figure 4 (a) TAS (total alkalis ($Na_2O + K_2O$) and silica (SiO_2)), diagram (Le Bas et al, 1986), **(b)** Nb/Y vs. Zr/Ti variation diagram (Winchester & Floyd, 1977; Pearce, 1996), **(c)** AFM diagram (Irvine and Baragar, 1971) for the volcanic rocks of the Win Gyi area

Table (2) Abundances of trace and rare earth elements in the Mawgyi Volcanics

Sample	Ba	Ce	Cr	Cs	Dy	Er	Eu	Ga	Gd	Hf	Ho	La	Lu	Nb	Nd	Pr	Rb	Sm	Sn	Sr	Ta	Tb	Th	Tm	U	V	W	Y	Yb	Zr	Ni
E-002	47	16	70	0.27	4.50	2.9	0.79	12.8	4.01	2.01	0.95	5.7	0.46	1.8	10.3	2.86	5.2	3.04	5	158	0.8	0.68	1.31	0.43	2	272	8	23.6	2.48	58	1
E-065	32	7.7	80	0.61	2.91	1.9	0.65	15.6	2.47	1.2	0.64	3.2	0.28	0.6	5.8	1.2	2	1.88	1	128	0.1	0.43	0.7	0.3	0.19	369	4	17.6	1.83	39	12
E-066	40	11	50	0.26	4.26	2.83	0.92	16.8	3.6	1.9	0.95	4.4	0.4	0.8	8.6	1.72	3.5	2.62	3	187	0.2	0.65	0.93	0.39	0.3	378	2	22.5	2.52	58	22
E-068	45	5.8	40	0.17	2.84	1.9	0.77	12.2	2.46	1.1	0.63	2.1	0.25	0.6	4.9	0.88	1.3	1.64	1	112	0.1	0.42	0.55	0.25	0.08	349	4	14.8	1.71	37	29

Trace and Rare Earth Elements Geochemistry

Nb/Y vs. Zr/Ti diagram indicates that volcanics are mainly basaltic composition (Fig. 4b). The degree of fractionation of an REE pattern can be expressed by the ratio of the normalized concentration of a light REE (La or Ce) divided by the normalized concentration of a heavy REE such as (Yb) or the trace element (Y). The ratio of the HREE (Yb) divided by the LREE (La) would be a good indicator of the slope of the REE diagram. Volcanic samples display slight enrichments of light rare earth element (LREE) with $(La/Yb)_N$ ratios of (0.99–1.16) and $(La/Sm)_N$ ratio of (0.8-1.17). The $(Tb/Yb)_N$ ratios (1-1.16) show slight fractionation of HREE. The Eu anomalies (Eu/Eu* = 0.66–1.18) show weakly negative and positive anomalies (Fig. 5a). Primitive mantle-normalized spider diagram of Mawgyi volcanics shows high Ba/Th values (36.18 - 45.3), high Ba/La ratios (8.32-21.33), and low Th/Nb ratios (0.55-1.17) (Fig. 5b).

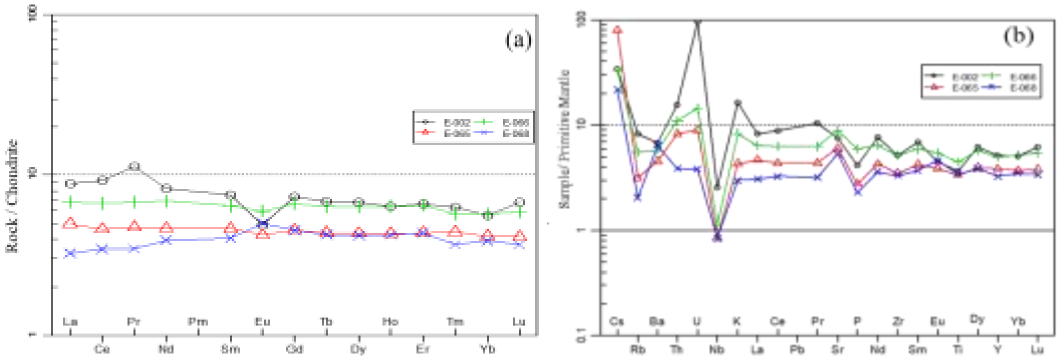

Figure 5 (a) Chondrite normalized REE diagram (Sun and McDonough, 1995) and, (b) Primitive mantle-normalized spider diagram (Sun and McDonough, 1989) of Mawgyi Volcanics

Discussion

Petrogenesis

Volcanics rocks from the Win Gyi area contain MgO (4.5-7.53 wt%), Cr of (40-90 ppm), and Ni (0.00-29.2 ppm) that are lower than the values of mantle-derived primary melts (i.e., MgO > 8 wt%, Cr > 1000 ppm, and Ni > 400 ppm; Best, 2003). The Mawgyi Volcanics display a slight variation from andesitic to basaltic composition. They mostly belong to the medium-K, calc-alkaline series with a few plotting in the tholeiite field. In the REE spider diagram, the HREE portion of all the curves is shown relatively flat indicating no relation with deep fractionation processes. The LREE-enriched patterns with weakly negative Eu anomalies resemble subduction-related aqueous fluids or melts (Pearce et al., 1992, Pearce and Peate, 1995). Primitive mantle-normalized spider diagram shows enrichments in LILE (Cs, K, and Sr) and depletion of HFSE (Nb, P) are compatible with arc-type magmas and their mantle sources were likely affected by slab-derived fluids/melts (Hawkesworth et al. 1993; Pearce and Peate 1995). High Ba/Th (36.18-45.3) values, high Ba/La (8.32-21.33), and low Th/Nb (0.55-1.17) ratio indicate their mantle sources were mainly metasomatized by the slab-derived fluids (Hawkesworth et al. 1993; Pearce and Peate 1995; Kesselet al. 2005). In addition, high Ba/Th values indicate the addition of hydrous fluids from shallow levels of subducted oceanic crust (Elliot, 2003). Thus, the Mawgyi volcanics were likely formed by the magma generated from the slab-derived fluids, which may be mixed with hydrous fluids.

Tectonic Setting

According to the triangular plot of Zr/4, 2×Nb, and Y (Meschede, 1986), the volcanic rocks from the study area fall within the N-type MORB and volcanic arc basalts field (Fig. 6a). By using Cr versus Y plot (Pearce, 1996), volcanic samples of the study area are located in the volcanic arc basalt (VAB) field (Fig. 6c). The Nb/Yb versus Th/Yb diagram (Dilek and Furnes, 2011) diagram shows Mawgyi Volcanics fell within the field of oceanic arc (Fig. 6b).

Based on the geochemical data, the parent magma of the volcanic rocks was generated from a subduction-related fluid metasomatized mantle source. It was probably related to the high-angle subduction of the Neo-Tethyan oceanic lithosphere to the Eurasia plate.

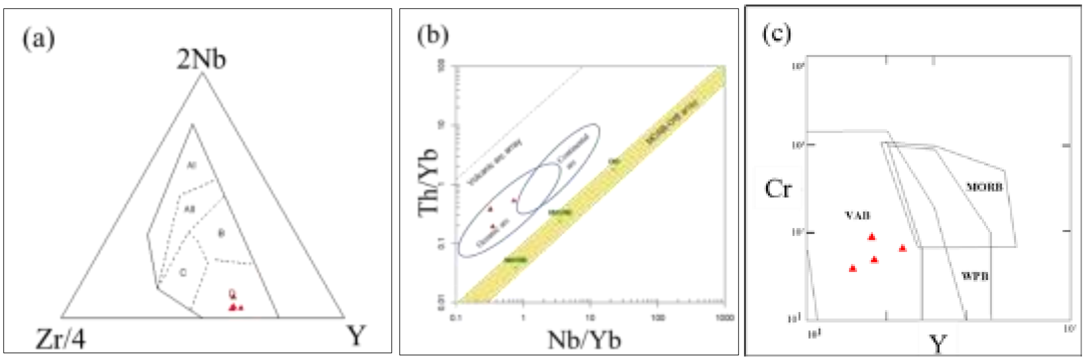

Figure 6 (a) Zr-Nb-Y diagram for basalts, (Meschede, 1986), (b) oceanic arc and continental crust (Dilek and Furnes, 2011), (c) Cr-Y discrimination diagram for basalts (Pearce, 1996)

Conclusions

A combination of petrographic study and geochemical data indicate that the volcanic rocks of the Mawgyi Volcanics have a slight variation in composition, ranging from basalt to andesite. Chondrite-normalized REE patterns and primitive mantle-normalized spider diagram reveal that the volcanic rocks are derived from partial melting of the metasomatized mantle wedge by slab-derived fluids. The present study suggests volcanic rocks are likely related to the subduction of the Neo-Tethyan oceanic lithosphere to the Eurasia plate during the Cretaceous (~110-90 Ma).

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References

Best, MG., (2003), *Igneous and Metamorphic Petrology*. Blackwell Publishing, Oxford.

Cobbing, E.J., Pitfield, P.E.J., Darbyshire, D.P.F., and D.I.J. Mallick, (1992), The granites of the South-East Asian tin belt. *Overseas Memoir 10*, British Geological Survey.

Dilek, Y., & H., Furnes, (2011), Ophiolite genesis and global tectonics: Geochemical and tectonic fingerprinting of ancient oceanic lithosphere. *Geological Society of America Bulletin*.

Elliott, T., (2003), Tracers of the slab, in Eiler, J. ed., Inside the subduction factory. American Geophysical Union, *Geophysical Monograph*, Washington DC. 138: 23–45.

Gardiner, N.J., Searle, M.P., Morley, C.K., Robb, L.J., Whitehouse, M.J., Roberts, N.M., Kirkland, C.L., Spencer, C.J., (2018), The crustal architecture of Myanmar imaged through zircon U-Pb, Lu-Hf and O isotopes:

Tectonic and metallogenic implications. *Gondwana Res*. 62, 27–60.

Hawkesworth CJ., K., Gallagher, JM., Hergt, F.Mcdermott, (1993), Mantle and slab contributions in arc magmas. *Annu Rev Earth Planet Sci* 21:175–204.

Irvine, T.N., &Baragar,W.R.A.,1971. A guide to the chemical classification of the common Volcanic rocks. Can. *Jour.Earth.Sci*.Vol.8,p.523-548.

Kessel R., MW., Schmidt, P., Ulmer, T. Pettke, (2005), Trace element signature of subduction-zone fluids, melts and supercritical liquids at 120–180 km depth. *Nature* 437:724–727.

Le Bas, M.J., R.W. Lemaitre., A.L. Streckeisen., and B. Zanettin., (1986), A chemical classification of volcanic rocks based on the total alkali-silica diagram, *Journal of Petrology*, Vol. 27, pp 745-750.

Meschede, M., (1986), A method of discriminating between different types of mid-oceanic ridge basalts and continental tholeiites with the Nb2-Y diagram, *Chemical- Geology*, Vol. 56, pp. 207-218.

Mitchell, A.H.G., W.S., McKerrow, (1975), Analogous evolution of the Burma orogen and the Scottish Caledonides. *Geological Society of America Bulletin* 86, 305e315.

Mitchell, A.G.H., (2018), *Geological belts, plate boundaries, and mineral deposits in Myanmar*. Elsevier, Amsterdam, p. 509p.

Noetling, F., (1894), *Note on the Geology of Wuntho, Upper Burma*.

Pearce, J. A., (1996), A user's guide basalt discrimination diagrams. In Wvman, D.A (fd) Trace element geochemistry of volcanic rocks. Applications for massive sulphide exploration Vol. 12. *Geological Association of Canada short Course Notes*, pp. 79.113.

Pearce, J.A., (2008), Geochemical fingerprinting of oceanic basalts with applications to ophiolite classification and the search for Archean oceanic crust. *Lithos*. 100(1–4):14–48.

Pearce JA., DW., Peate, (1995), Tectonic implications of the composition of volcanic arc magmas. *Annu Rev Earth Planet Sci* 23:251–285.

Pearce, J.A., Van Der Laan, S.R., Arculus, R.J., Murton, B.J., Ishii, T., Peate, D.W., and Parkinson, I.J., 1992, Boninite and harzburgite from Leg 125 (Bonin-Mariana forearc): A case study of magma genesis during the initial stages of subduction: *Proceedings of the Ocean Drilling Program, Scientific Results*, v. 125, p. 623–659, https://doi .org/10.2973/odp.proc.sr.125.172.1992.

Sun, SS., McDonough, WF., (1995), The composition of the Earth. *Chemical Geology* 120, 223–253.Cross Ref Google Scholar.

Sun SS., McDonough WF., (1989), Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. Geological Society, London, *Special Publications* 42:313–345.

United Nations, (1979), Geology and Exploration Geochemistry of the Pinlebu-Banmauk Area, Sagaing Division, Northern Myanmar. *Technical Report* No. 2. United Nations Development Programme, *UN/BUR-72 002/6* United Nations, New York, 69 p.

Winchester, J. A., P. A., Floyd, (1977), Geochemical discrimination of different magma series and their differentiation products using immobile elements, *Chemical Geology*, Vol. 20, pp. 325-342.

Zhang, L., Fan, W., Ding, L., Pullen, A., Ducea, M. N., Li, J., Wang, C., Xu, X., & Sein, K. (2022). Forced subduction initiation within the Neotethys: An example from the mid-Cretaceous Wuntho-Popa arc in Myanmar. *Bulletin of the Geological Society of America*, 134(3–4), 849–870. https://doi.org/10.1130/B35818.1