

Petrochemical Study on the Volcanic Rocks from the Different Lava Flows of the Popa Area, Kyaukpadaung Township, Mandalay Region

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Abstract

The study area falls in the Central Volcanic Arc of the Central Cenozoic Belt, and consists of andesite, basaltic andesite, basalt and volcanoclastic rocks. There are eight major petrographic units distinguished based on their petrographic character and evidence of superposition. Geochemical data has been used to specify and characterize the volcanic rocks in this study area. Major oxides are used in rock types and rock series. TAS diagram pointed out that the volcanic rocks are mainly fallen in basalt, basaltic andesite, trachy basalt, basaltic trachyandesite and trachy andesite fields. In K_2O-SiO_2 (alkali versus silica) diagram, Mt. Popa lavas define a series ranging from prominent medium-K to high-K calc-alkaline, except for the some basaltic compositions which span the high-K and shoshonitic boundary. In the AFM plot, all volcanic rocks fall in the calc-alkaline field. Minor and trace element data can provide means to determine the tectonic setting. Plot of the studied lavas in the Cr-Y discrimination diagram shows eleven sample fall in the VAB (volcanic-arc basalt). From the plot of $TiO_2-K_2O-P_2O_5$ triangular diagram, the basaltic rocks of the study area fall in the continental field. In the $TiO_2-MnO-P_2O_5$ discrimination diagram, the volcanic of the study area fall within calc-alkali basalt. From Ti vs. Zr trace element discrimination diagram, it is clear that all basalt samples of the study area fall in the field of volcanic-arc. This characters are corresponded with volcanism of this area might be regarded as subduction related.

Keywords: Calc-alkaline, Volcanic Arc, VAB (Volcanic-arc basalt)

Introduction

The study area is located in Kyaukpadaung Township of Mandalay Region. The area investigated, lying in the part of UTM map sheet no 2095 01 and 05 of Survey Department, Ministry of Forestry is situated between north latitude $20^{\circ} 45'$ and $21^{\circ} 00'$ and east longitude $95^{\circ} 10'$ and $95^{\circ} 20'$. It covers about 67.5 square kilometer. The study area falls in the Central Volcanic Arc of the Central Cenozoic Belt, and consists of andesite, basaltic andesite, basalt and volcanoclastic rocks. There are eight major petrographic units distinguished based on their petrographic character and evidence of superposition. Andesite is the most widely distributed rocks type, and is composed predominantly of plagioclase, brown hornblende and augite. The geological map of the study area is shown in (Fig.1). The main composite cone consists of alternate layers of basalt, basaltic andesite and andesite flows, coarse pyroclastic flows and rework volcanoclastic deposits.

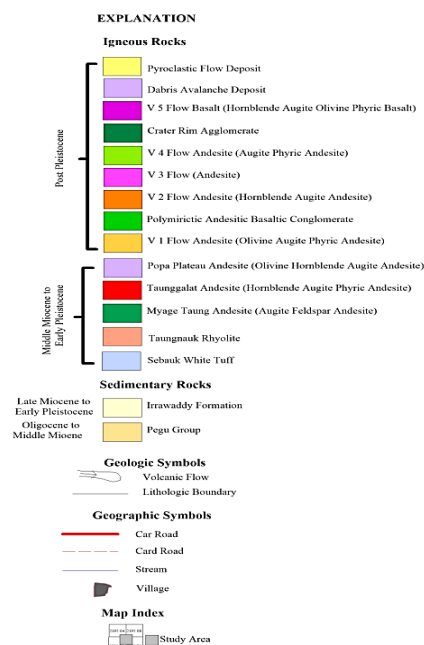
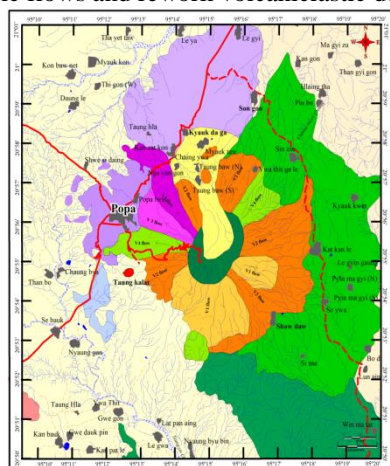


Figure 1. Geological Map of the study area. Geology by Hla Min, 2015. (after Aung Moe,1980)

Method of Study

The modified geological map of this area is the outcome of the field work carried out for about 15 days from 28 March to 12 April, 2013. More than 15 samples were carefully selected for chemical analysis to avoid the effect of secondary alteration from the study area. Major elements whole rock analysis were determined by X-ray fluorescence spectrometry (XRF) at the MURC, Department of Geology, Mandalay

University. The analysis of representative major and minor elements analysis of volcanic rocks of the study area is shown in table (1) and trace element analysis is shown in table (2).

Result

Petrochemical Characteristics of Volcanic Rocks

Geochemical data has been used to specify and characterize the volcanic rocks in this study area. Geochemical analysis of major oxides was used with petrographic analysis and hand sample examination in the determination of rock types, rock series and petrochemical characteristics.

Table 1. XRF analysis of major oxide compositions (wt%) of the lavas in the study area.

Sample no	TP-4	6V-2	8V	9V	12V-2T	12V-2	Myage
SiO ₂	51.35	50.23	50.96	51.94	50.12	53.14	57.97
TiO ₂	0.67	0.73	0.80	0.65	0.65	0.64	0.60
Al ₂ O ₃	18.59	21.03	21.03	18.67	21.03	22.35	18.41
Fe ₂ O ₃	6.84	7.75	7.31	6.93	6.28	6.04	3.29
MnO	0.12	0.12	0.10	0.11	0.12	0.12	0.03
MgO	4.32	4.82	3.71	3.82	2.65	2.74	0.55
CaO	9.52	9.91	9.28	8.67	8.27	8.35	4.60
Na ₂ O	3.31	3.62	3.97	3.70	3.70	3.96	3.85
K ₂ O	1.44	1.25	2.32	1.36	2.13	2.27	3.09
P ₂ O ₅	0.19	0.20	0.27	0.22	0.22	0.24	0.20
ZrO ₂	0.03	0.02	0.03	0.03	0.03	0.03	0.03
SrO	0.11	0.09	0.12	0.12	0.10	0.10	0.06
Total	96.5	99.8	99.9	96.2	95.3	100.0	92.7
Sample no	M-1	KT-4	5V-12	C-1	KT-6	TG-1	YE-3
SiO ₂	53.06	52.23	57.45	50.04	48.28	49.71	52.99
TiO ₂	0.57	0.68	0.48	0.81	0.82	0.84	0.70
Al ₂ O ₃	18.84	20.50	19.84	22.17	20.47	20.04	20.06
Fe ₂ O ₃	5.28	7.10	5.54	7.76	7.67	7.49	6.74
MnO	0.10	0.12	0.13	0.12	0.11	0.13	0.11
MgO	2.63	4.11	1.94	3.40	3.37	4.80	2.78
CaO	7.39	9.98	7.30	9.50	9.16	10.52	8.45
Na ₂ O	3.69	3.47	4.22	4.15	3.85	3.68	3.81
K ₂ O	2.73	1.28	2.36	1.60	2.01	2.04	1.68
P ₂ O ₅	0.25	0.24	0.35	0.29	0.31	0.26	0.20
ZrO ₂	0.03	0.03	0.04	0.03	0.03	0.03	0.02
SrO	0.07	0.10	0.11	0.10	0.10	-	0.08
Total	94.6	99.8	99.8	100.0	96.2	99.5	97.6

The total alkali-silica diagram (TAS) is one of the most useful schemes available for the volcanic rocks. The (TAS) classification scheme is intended for the more common, fresh volcanic rocks. It should not be normally used with weathered, altered or metamorphic rocks because alkalis are likely to be mobilized. In the total alkali-silica diagram (TAS) after Le Bas et al., (1986), the volcanic rocks are mainly fall in basalt, basaltic andesite, trachy basalt, basaltic trachy andesite and trachy andesite fields (Fig.2). They are better classified using K₂O-SiO₂ (alkali versus silica) diagram (Pecceirillo and Taylor, 1976) shown in (Fig.3). In this figure, Mt. Popa lavas define a series ranging from prominent medium-K to high-K calc-alkaline basalt,

basaltic andesite and andesite, except for the same basaltic composition which span the high -K and shoshonitic boundary (Fig.3).

Table 2. Trace element analyses of selected lavas from the Mt. Popa area (ppm) (D.Stephenson & T. R. Marshall, 1984).

Analysis by IGS, London. Li, Br, Cr, Co, La by optical emission spectrometry; other by XRF

	10179	10218	40095	10177	10229	70176	10223	10151
Ba	432	680	522	784	583	1069	640	650
Sr	795	865	1005	711	935	1050	508	562
Rb	12	22	18	37	21	37	116	108
Y	16	19	18	24	13	21	24	21
La	19	28	34	48	26	62	54	75
Ce	36	40	50	49	41	71	67	70
Nb	3	6	4	4	6	5	6	7
Li	6	6	6	8	7	7	28	26
B	0	1	1	0	0	0	22	25
U	2	0	0	0	0	0	6	5
Th	9	6	6	11	7	13	21	23
Mo	5	1	4	0	2	2	2	2
Pb	14	22	9	14	12	8	28	23
Zn	58	65	81	64	59	61	66	70
Cu	126	114	129	92	56	73	52	51
Ni	18	19	21	27	30	17	12	16
Cr	41	69	56	37	155	46	28	66
Co	36	49	50	50	42	36	18	20
Zr	76	85	90	103	82	120	180	165

Volcanic rocks may be subdivided into two major magma series-the alkaline and subalkaline (originally termed tholeiitic) series. Alkali-silica plot after Irvine and Baragar (1971) separates the field of alkaline and subalkaline. In the discrimination diagram, the volcanic rocks of the study area fall in the alkaline and subalkaline fields Fig. (4). AFM plot proposed by Irvine and Baragar (1971) separating fields of tholeiitic and calc-alkaline rocks. In this plot, all volcanic rocks fall in the calc-alkaline field (Fig. 5).

Some of the major elements (Na₂O, K₂O, Fe₂O₃, MgO, CaO, TiO₂ and Al₂O₃) are plotted against SiO₂ as a differentiation index (Fig.6). In the Harker variation diagram, K₂O, Al₂O₃ show positive correlation with SiO₂ although Na₂O remain unchanged content. On the other hand, CaO, Fe₂O₃, MgO are negatively correlated with SiO₂. When TiO₂ is plotted against SiO₂, the content of TiO₂ shows no significant variation.

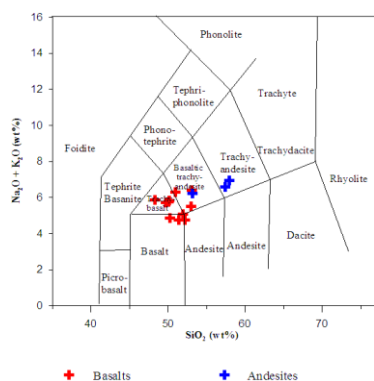


Figure 2. A chemical classification of volcanics based on the total alkali versus silica ("TAS"). After Le Bas et al, 1986

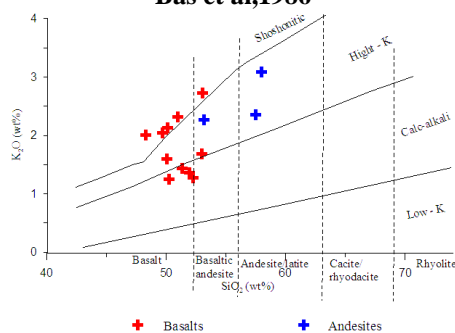


Figure 3. Plot of studied lava in the classification diagram K_2O vs SiO_2 (Peccerillo and Taylor, 1976)

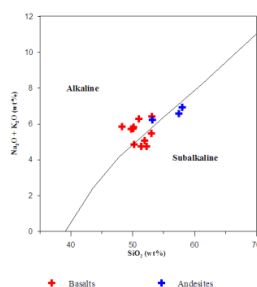


Figure 4. Alkali silica plot showing both alkaline and subalkaline nature of the volcanics in the study area (after Irvine and Baragar, 1971)

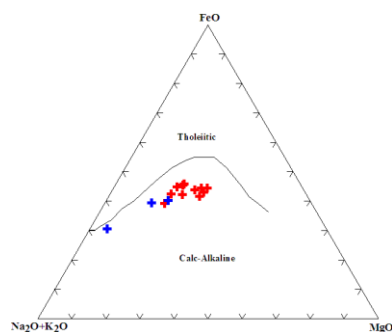


Figure 5. Total alkali vs. silica plot for lavas from the Mt. Popa area. Division of rock-series from Kuno (1966) (In Rollison, 1995)

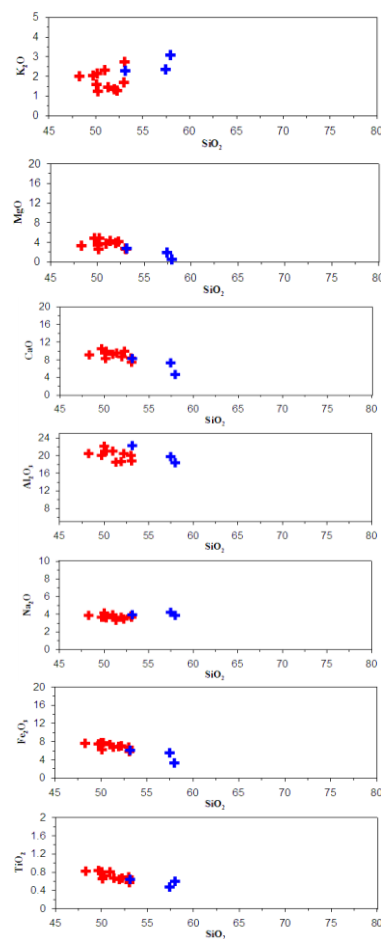


Figure 6. SiO_2 versus major oxide (%) variation plot of the lavas from the study area.

Tectonic Significance of Volcanic Rocks

To trace the tectonic significance (i.e. tectonic environment) the minor and trace elements are used. These minor and trace element data can provide means to determine the tectonic setting. Therefore, minor and trace element analysis have been used in this study to investigate the tectonic origin of basalts and andesites from the area investigated. Ti, Zr and Y (HFSE) and Cr (transitional) are utilized in tectonic discrimination diagrams as they are thought to be relatively immobile under condition of hydrothermal, sea floor weathering and up to medium metamorphic grades. The effects of metamorphism, however, can be minimized by choosing trace elements generally considered to be immobile during metamorphism (usually including Ti, Cr, Zr, Hf and Y). The effect of fractional crystallization, assimilation, and mixing can be minimized by applying the technique to mafic volcanic rocks only.

The configuration of tectonic settings for the volcanic rocks of the study area was made by using minor elements data. Pearce et.al (1973) discriminates between oceanic and non oceanic basalts with a single straight boundary line on a TiO_2 - K_2O - P_2O_5 triangular diagram. In this diagram, the basaltic rocks of the study area fall in the continental field (Fig.7). Fresh samples of volcanics are analysed by using TiO_2 - MnO - P_2O_5 discrimination diagram. In the TiO_2 - MnO - P_2O_5

discrimination diagram, the fields are MORB; OIT;-ocean-island tholeiite or seamount tholeiite; OIA-ocean-island alkali basalt or seamount alkali basalt; CAB- Island-arc calc-alkaline basalt; IAT-island arc tholeiite; Bon-boninite. The boninite field occupies the MnO-rich sector of the CAB field. the volcanic of the study area fall within calc-alkali basalt except one andesite sample fall in the oceanic island arc tholeiite field (Fig.8). The Ti versus Zr diagram (Fig.9) shows the field of volcanic-arc basalts, MORB and within plate basalts. From this trace element discrimination diagram, it is clear that all basalt samples of the study area fall in the field of volcanic-arc. The Zr/Y – Ti/Y discrimination diagram (Fig.10) for basalts is based upon Zr/Y and Ti/Y variations to discriminate between within plate basalts and the other types of basalt. All samples of the volcanic rocks of the study area fall in the field of plate margin basalt. The Zr/Y-Zr diagram (Fig.11) can be used to subdivide arc basalts into those belonging to oceanic crust and arc developed at active continental margins. In this diagram, most of the volcanic rocks in the study area fall in continental arc. From these two diagrams, it is known that the volcanic rocks of this area were formed by extrusion of mafic lavas onto the continental crust at continental margins. Plot of the studied lavas in the Cr-Y discrimination diagram (Fig.12) shows eleven sample fall in the VAB (volcanic-arc basalt).

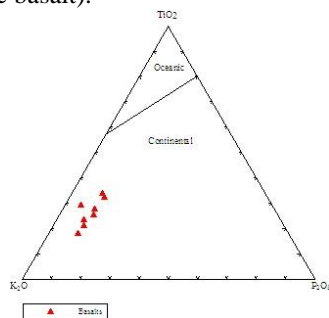


Figure 7. TiO_2 - K_2O - P_2O_5 discrimination diagram for basalts of study area (After Pearce et al., 1973)

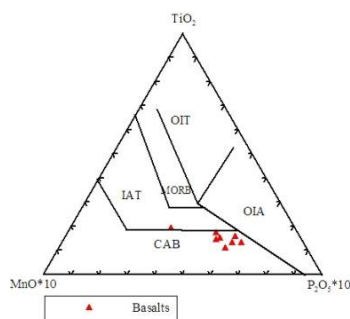


Figure 8. The MnO - TiO_2 - P_2O_5 discrimination diagram for the volcanic rocks of the study area (after Mullen, 1983).

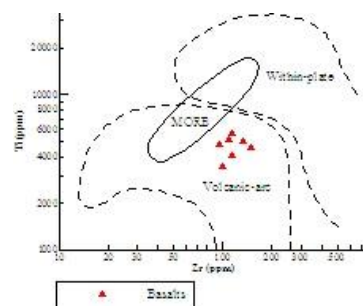


Figure 9. Plot of studied lava in the discrimination diagram for basalts based upon Ti-Zr variation (after Pearce, 1982 in Rollinson, 1993)

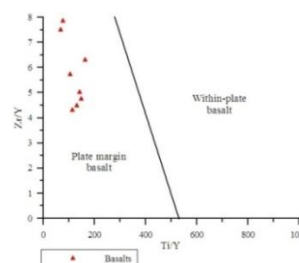


Figure 10. Plot of the studied lava in the Zr/Y – Ti/Y discrimination diagram for basalts showing the fields of within plate basalt and plate margin basalts (i.e all other basalt type stated area is field of overlap (after Pearce and Gale, 1977 in Rollinson, 1993)

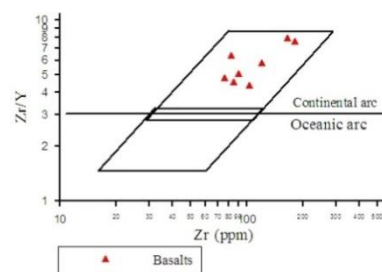


Figure 11. Plot of the studied lava in the diagram showing continental and oceanic arc basalts separated on the basis of a Zr/Y value of 3. (after Pearce, 1983 in Rollinson, 1993)

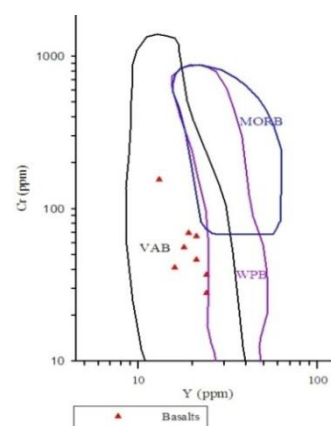


Figure 12. Plot of the studied lava in the Cr- Y discrimination diagram for basalts showing MORB, VAB and WPB (after Pearce, 1982 in Rollinson, 1993).

Discussion and Conclusion

The volcanism in this area might be regarded as subduction related. Maung Thein (2000) postulated the subduction of the Indian Plate under the overriding Burma Plate, might continue, till the Holocene time, along the Rakhine off-shore region as suggested by the formation of an outer magmatic arc (central volcanic line) and renewed volcanism (mainly andesites and basalts) along central Igneous line, e.g. Mt. Popa and Twindaung during Pleistocene and Early Holocene. Mt. Popa and Twindaung overlie a well-defined Wadati-Benioff plane 120-140 km deep (Guzman-Spezials and Ni, 1996; Satyabala, 1998 in Maury et.al, 2004). Mt. Popa volcanic area (including the study area) occupies the rock association of basalt, basaltic andesite, latite and rhyodacite. (Aung Moe, 1980; Stephenson & Marshall, 1984). The two groups of lava (Kyaukpadaung and Mt. Popa) are regarded as a single petrographic suite in which several continuous and discontinuous mineral reaction series are recognized. Whole-rock analyses are characterized by relatively high K, Ba, Sr, Rb, and Zr. High $Mg/(Mg+Fe)$ ratios of 0.85 to 0.65 in both phenocrysts and whole-rock, high K/Rb (767) and low Sr 87/Sr86 (0.70431) and Rb/Sr (0.0155) ratios suggest that the basalts are relatively primitive, mantle-derived compositions, modified slightly by fractionation, with negligible crustal contamination. The more siliceous lavas as the study area may have been derived by fractional crystallization of such magmas at crustal levels. The magmatism is attributed to the waning stages of orogeny as eastward subduction of the Indian plate beneath China gave way to strike-slip movement, associated with the Andaman Sea spreading center. Within the tectonic model, magmas were probably generated by hydrous mantle melting above dehydrating oceanic crust of the subduction zone (Stephenson & Marshall, 1974). In the Harker variation diagram, K_2O , Al_2O_3 show positive correlation with SiO_2 although Na_2O content. On the other hand, CaO , Fe_2O_3 , MgO are negatively correlated with SiO_2 . It indicates that the igneous rocks formed in the course of magmatic differentiation. In the AFM plot, all volcanic rocks fall in the calc-alkaline field. After analyzing of the major elements, the tectonic environment of the volcanic from the study area is continental volcanic arc. In the TiO_2 - MnO - P_2O_5 discrimination diagram, the volcanics of the study area fall within calc-alkali basalt. From Ti versus Zr trace element discrimination diagram, it is clear that all basalt samples of the study area fall in the field of volcanic-arc. Plot of the studied lavas in the Cr-Y discrimination diagram shows eleven sample fall in the VAB (volcanic-arc basalt). From the plot of TiO_2 - K_2O - P_2O_5 triangular diagram, the basaltic rocks of the study area fall in the continental field. In the TiO_2 - MnO - P_2O_5 discrimination diagram, the volcanic of the study area fall within calc-alkali basalt. From Ti vs. Zr trace element discrimination diagram, it is clear that all basalt samples of the study area fall in the field of volcanic-

arc. This characters are corresponded with volcanism of this area might be regarded as subduction related.

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