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Petrographic and geochemical characteristic of volcanic rocks from Tasik Kenyir and Kampung Awah, East Malaya Block, Peninsular Malaysia

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Abstract. Kampung Awah and Tasik Kenyir are geologically located in East Malaya Blocks. These block is also known as western margin of Indochina terrane. Apart from sedimentary formations, East Malaya Blocks is also dominated by plutonic and volcanic rocks of mafic to rhyolitic compositions. Petrography and geochemical data suggest that Kampung Awah and Tasik Kenyir are one of locations which consists of volcanic rocks of generally basaltic to basaltic andesite compositions. Volcanic rocks from both area consists of plagioclase, clinopyroxene, orthpyroxene as main mineral constituents with minor occurrences of hornblende. Geochemical data also indicate that volcanic rocks from both area were formed during subduction of the Paleo-tethys oceanic underneath the East Malaya Block or Indochina terrane. Most of the samples are metaluminous which indicate the volcanics are derived from igneous origin. This paper will contribute new geochemical data of mafic volcanics from Kampung Awah and Tasik Kenyir with the support of petrographic and field evidence to deduce the magma evolution and the tectonic setting.

INTRODUCTION

The East Malaya blocks consist of Central and Eastern Belt dominated by sedimentary formation which intruded by Early Permian to Late Triassic the arc related I-type magmatism [1 - 8]. The volcanic rocks in Peninsular Malaysia are mostly found on the East Malaya Blocks which have association with the sedimentary formation. The volcanic rocks have wide range of composition from mafic to felsic composition [1 - 9]. The focus of this research is the occurrences of volcanic rocks in Kampung Awah and Tasik Kenyir area which located in Pahang and Terengganu state respectively. They both are geologically located within the East Malaya Block of Peninsular Malaysia (Figure 1). The occurrences of volcanic rocks in Kampung Awah are mostly known as andesite agglomerate associated with Permian Limestone [10, 11]. This paper will present field evidence, petrographic and geochemical data of volcanic rocks within the Tasik Kenyir and Kampung Awah area. The new available geochemical data will be used to determine the types of the volcanic rocks, their fractional crystallization pattern as well as tectonic affinity.
FIELD RELATION AND PETROGRAPHIC ANALYSIS

Field relation of Kampung Awah volcanic

Volcanic rocks in Central Pahang are mostly found within the triangle area of Jerantut, Maran and Temerloh. The composition of the volcanic rocks ranging from basaltic to andesitic composition of pyroclastic and lava flow. The most notable mafic volcanic rocks outcrop within this area is Kampung Awah volcanics which located in an active quarry. The quarry can be readily accessed from the main road. The quarry consists of predominant mafic agglomerate of various size which can reach up to 50 cm in diameter. The agglomerate contained clasts of limestone and basaltic andesite. The difference of limestone clasts and basaltic andesite clasts can be easily determined by their mineral composition and colour. Limestone shows grey colour while basaltic andesite flow shows dark green colour. The rock contact between the limestone and volcanic lava are ranging from sharp to irregular. Most of the volcanic rocks formed as aphanitic to porphyritic texture. The phenocrysts are mostly dominated by dark colour pyroxene, hornblende and plagioclase which enclosed by glassy matrix. The size of the phenocryst can reach up to 3 cm in diameter. The occurrences of volcanic in Kampung Awah is shown in Figure 2a

Kampung Awah petrographic analysis

In microscopic scale, most of the Kampung Awah volcanics shows rather porphyritic texture. The mineral composition is composed of plagioclase, clinopyroxene and orthopyroxene mineral. Some of the samples shows small occurrence of calcite mineral which indicate limestone contamination. The phenocryst consists of clinopyroxene and orthopyroxene enclosed within calcic feldspatic groundmass. Most of the groundmass formed as glass which makes it impossible to identify them. Clinopyroxene mostly shows high interference colour which ranging from blue to yellow colour while orthopyroxene shows low interference colour of grey to light orange. Some of the pyroxene shows clear 2 sets of cleavage where the intersection of the angle between them is almost diagonal (~90°). There are no occurrences of embayment margin texture because this texture is more common in felsic volcanic rocks. Accessories mineral that present in the samples are mostly magnetite. Photomicrograph of volcanic rocks from Kampung Awah is shown in Figure 2b and Figure 2c

Field relation of Tasik Kenyir volcanic

Tasik Kenyir is located on the western part of Terengganu state. The occurrence of volcanic rocks in this area is quite common and can be readily accessed alongside of the between Gua Musang and Kampung Kuala Jeneris. The outcrop area consists of predominant volcanic rocks of both pyroclastic and lava flow type of basaltic andesite composition with subordinate of slightly metamorphosed limestone and argillaceous rocks (Figure 2). The volcanic rocks formation is in between of the plutonic rocks in the west and Semantan sedimentary formation on the east. Most of the volcanic rocks shows dark colour and formed as aphanitic to less common porphyritic texture. The phenocryst is consists of clinopyroxene, ortopyroxene and less common hornblende. The occurrences of volcanic in Kampung Awah is shown in Figure 2d

Kenyir petrographic analysis

In microscopic scale, most of the Kenyir volcanics shows porpyritic to aphanitic texture. The mineral composition is composed of plagioclase, clinopyroxene and orthopyroxene minerals. Some of the phenocrysts surrounded by calcium rich plagioclases and glassy matrix. Some samples show small occurrences of calcite mineral and replacement of pyroxene and hornblende to chlorite due to hydrothermal alteration. The phenocryst consists of clinopyroxene and orthopyroxene and less common plagioclase. Clinopyroxene and orthophyroxene can be distinguished by showing high birefringence and low birefringence respectively. Two sets of diagonal cleavages are occasionally present in some of the pyroxene mineral. Plagioclase mostly shows albite twinning and zoning extinction which might indicate of fractional crystallization. Accessories mineral that present in the samples are mostly magnetite. Some more evolved andesite contained embayed quartz which is commonly found in volcanics. Photomicrograph of volcanic rocks from Tasik Kenyir is shown in Figure 2e and Figure 2f
ANALYTICAL METHOD

A total of fresh 11 rock samples were selected for thin section petrographic study and geochemical analysis. The sample were crushed and pulverized into powder form by using tungsten carbide crusher and milling respectively for geochemical analysis. The geochemical analysis was conducted by using X-ray Fluorescence (Pan Analytical Axios) in Geology Department of University Malaya. Samples were prepared into fuse bead for major elements analysis. The ratio of the sample to flux is 1:10 by using lithium tetraborate flux (Li₂B₄O₇). The analytical procedures for major elements analysis follow the method described by [12]. Standard reference materials from USGS were used for standard calibration for igneous rocks. The results are given in Table 1. Accuracies and precision of the XRF analysis are estimated to be better than 2% for all major oxides and 5% for trace elements.

GEOCHEMISTRY

Based on geochemical classification the types of volcanic rocks from Kampung Awah are basalt to basaltic trachy-andesite (agglomerate) while volcanic rocks from Tasik Kenyir are from basalt – basaltic trachy-andesite -basaltic andesite of both lava and tuffaceous [15] (Figure 3a). The range of silica content of Kenyir and Kampung Awah are 44.4% to 54.5% and 42.7% to 48.7% respectively. The content of Al₂O₃ are generally overlap with same silica content. Most of the oxide elements (Al₂O₃, MgO and CaO) shows increasing and decreasing concentration with increasing silica content (SiO₂). Most samples from Kenyir and Kampung Awah are strongly metaluminous with 2 samples are weakly peraluminous characteristic ( Aluminium Saturation Index = 0.67 – 1.01). The content of MnO for all samples from both area ranging from 0.19% to 0.23%. Most of the samples are plotted into orogenic field in triangular plot discrimination diagram of [13].

STRATIGRAPHIC AND AGE CORRELATION.

The age of volcanic rocks in Kampung Awah has been established by both relative dating radiometric dating. The limestone in Kampung awah is relatively contemporaneous with the basaltic andesite in Kampung awah (Figure 2a). Presence of brachiopod (Karavankina sp.) in limestone at Kota Gelanggi strongly shows that the limestone is at least Middle Permian [14]. Kampung awah has been correlated with the limestone at Kota Gelanggi. This relative age has been supported by potassium-argon and argon-argon radiometric age of 269±49 ma [1, 16].

The age of volcanic rocks in Tasik Kenyir is still unknown. Presence of limestone or fossil in Kenyir area has not been reported in any of previous study (Figure 2d). The limestone and shale clasts which closely related to the andesite indicate the volcanics may have formed contemporaneous with the sedimentary formation. The similarity between Tasik Kenyir geological evidence and Kampung Awah shows that they are formed approximately at the same time despite of their high distance. The formation of the volcanic is possibly related to the either Gua Musang formation (Late Permian – Triassic) or Aring formation (Late Carboniferous – Early Triassic) due to their close distance. The Aring Formation contained predominant volcanics with subordinate basal dolomitic marble and calcareous argillite and the relative age ranging from Late Carboniferous to Early Triassic [17]. The Gua Musang formation is consists of predominant argillaceous and calcareous rocks interbedded with volcanic and arenaceous rocks and shows relative age of Late Permian to Triassic age [18 - 22]. However based on the field evidence it is more suitable to put the volcanics within Tasik Kenyir into Aring Formation. This is because the presence of limestone and shale within the Tasik Kenyir area is only minor with predominant volcanics. It is crucial to determine the types of the fossil inside the limestone clasts in order to determine relative age and which formation should volcanic rocks within Tasik Kenyir is belong to.
DISCUSSION AND CONCLUSION

Based on petrographic and geochemical data obtained from XRF analysis most of the major oxide elements shows close similarities between volcanic rocks from Kampung Awah and Kenyir. However it is clear that volcanic rocks from Kenyir area are more evolved compared to Kampung Awah Volcanic. Both of volcanic rocks may be derived from melting of igneous rocks due to their strong metaluminous characteristic. Based on discrimination plot and MnO content, most samples from both Kampung Awah and Kenyir area are formed within active continental margin (ACM) which related to subduction zone (Figure 3b). Any igneous rock samples that plot into ACM field (active continental margin) also are calc-alkaline characteristic [13]. Based on field relation and evidence of limestone clasts within volcanic rocks in both Kampung Awah and Kenyir area, it is safe to assume that the volcanic rocks are formed approximately at the same time (Middle Permian = ~266ma) during subduction of the Paleo-tethys oceanic crust under the East Malaya Block (Indochina Terrane). However trace elements and geochronology data are needed to support this conclusion.

FIGURE 1. Geological map shows the occurrences of volcanic rocks in Peninsular Malaysia (after Hutchison, 1973a). Note the box shows the location of the study area. Both Kampung Awah and Tasik Kenyir are geologically located in East Malaya Block (Indochina Terrane).
FIGURE 2. a) Photograph shows the occurrence of pyroclastic ignimbrite which contained clasts of limestone and basaltic rocks in Kampung Awah. b) Photomicrograph shows the occurrence of twinning of clinopyroxene mineral which enclosed by plagioclase and glass matrix (Kampung Awah). c) Photomicrograph shows the presence of orthopyroxene which also shows simple twinning (Kampung Awah). d) Field photograph shows the occurrence of limestone clasts within basaltic andesite volcanic (Kenyir). Note the limestone formed irregular contact with host volcanic. e) Photomicrograph shows the occurrence of simple twinned clinopyroxene (Kenyir). f) Photomicrograph shows the clinopyroxene has 2 sets of diagonal cleavages. Ad – Andesite clast, Lst – Limestone clast, Pl – Plagioclase, Cpx- Clinopyroxene, Cl – chlorite, Opx – Orthopyroxene, Mtx – Matrix.
**FIGURE 3.** a) Geochemical classification of volcanic rocks after Cox et al. (1979). Note volcanic rocks from Kampung Awah are plotted into basalt and basaltic trachy-andesite while Kenyir are plotted into basalt – basaltic trachy-andesite – basaltic andesite. b) Tectonic discrimination diagram after Pearce et al., (1977). Note most of the samples from Kampung Awah and Kenyir are plotted into orogenic field (active continental margin). FeO$^T$ = total iron (Fe$_2$O$_3$+FeO).

**TABLE 1.** a) Table shows major element data of volcanic rocks from Kampung Awah and Tasik Kenyir (KGA= Kampung Awah Kenyir = Tasik Kenyir). A/CNK stands from aluminium saturation index (mole of Al$_2$O$_3$/mole of (CaO + K$_2$O + Na$_2$O). L.O.I. stand for Loss On Ignition. All data are present in percent (%) unit.
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