Petrology and geochemistry of the volcanic rocks associated with the Darvel Bay Ophiolite, Lahad Datu, Eastern Sabah, Malaysia

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Introduction

The uppermost unit of the igneous stratigraphy of ophiolite complexes consists of sequences of volcanic rocks, mainly basaltic lava. The top of this lava pile is commonly covered by extruded rocks, such as tuff and volcanic breccia, and oceanic sedimentary rocks. The Darvel Bay Volcanic Rocks (DBVR) consist mainly of massive basalt, with minor layered basalt, pillow basalt, volcanic breccia and tuff. Volcanic rocks are only sparsely distributed and cover approximately 20% of the total studied area. They mainly crop out along road sections in the southern part of the complex. Some of the volcanic rocks are associated with the mélange outcrop and occur as loose blocks and sometimes are associated with pelagic sedimentary rocks. The DBVR can also be observed in several islands around the Darvel Bay.

The Darvel Bay Ophiolite Complex has been well described in the publications of the Geological Survey of Malaysia (Reinhard & Wenk, 1955; Fitch, 1955; Dhonau & Hutchison, 1966; Koopmans, 1967). The complex has been interpreted as a segment of ocean floor, either of a Proto-South China Sea (Holloway, 1981; Rangin *et al.*, 1990) or of the Celebes Sea (Hutchison, 1988). A wide range of K/Ar age dates have been obtained from the rocks of the Darvel Bay Ophiolite Complex from 210 Ma Early Jurassic (Leong, 1971) to 168 Ma 150 Ma Late Jurassic and 137 Ma Early Cretaceous (Rangin *et al.*, 1990; Aitchison, 1994).

This paper gives an account of the field relations, petrographic description and geochemistry of the DBVR and discusses their origin and significance in the tectonic evolution of Sabah. The work described here was presented as a thesis by Omang (1993) for the award of the PhD. degree of the University of London.

Field and Petrographic Descriptions

Based on field observation, petrography and geochemistry the DBVR are divided into three main groups: (1) Group I Darvel Bay volcanic rocks. (2) Group II Darvel Bay volcanic rocks and (3) Group III Darvel Bay volcanic rocks.

Group I Volcanic Rocks

Group I Darvel Bay volcanic rocks occur mainly as loose blocks in the mélange outcrop. To the south of the study area, they occur along the road section at km 101 of Jalan Silam and to the north of the study area near Kampong Sepagaya, about 6 miles west of Lahad Datu town. Group I Darvel volcanic rock crops out in the Kampong Sepagaya showing pillow structures. These pillows are always brownish in colour and sometimes greenish. Amygdaloidal or vesicular textures are well preserved. Basaltic dykes with size range between 5-10 cm also occur within the pillow basalt outcrop. In thin section, the pillow basalt is fine grained, showing interstitial and amygdaloidal textures. Most of the vesicles have been filled by carbonate and quartz. This rock contains microphenocrysts of plagioclase, clinopyroxene, olivine and Fe-Ti oxides.

Group II Volcanic Rocks

This group is mainly exposed along Jalan Silam (e.g. Localities JS8, JS118.5, JS121, JS123). The other localities are in the Sungai Sabahan (Locality SGB2), south of the study area in a disused quarry along the Jalan Sandakan (Locality JSN3) and in the north of the study area. The main feature of this group is characterized by massive structure. This basaltic rock is greenish and brownish colour. In thin section, the massive basalt is fine to medium grained and commonly shows intersertal textures but sometimes amygdaloidal/vesicular textures and also preserved. The rock consists mainly of plagioclase, clinopyroxene, olivine and Fe-Ti oxides.

Group III Volcanic Rocks

Group III Darvel Bay volcanic rocks consist of layered basalt and volcanic breccia. Layered basalt is mainly exposed on several islands south of Lahad Datu town. In thin section, the rocks consists of plagioclase, amphibole, epidote, chlorite and Fe-Ti oxides. Commonly show intersertal texture as well as amygdaloidal/ vesicular (less than 2%), including those from Pulau Sakar (southern part only) (sample PS9) and its surrounding (Pulau Katung Kalungan) (samples PK2C, PKN).

Volcanic breccia is exposed in one locality along Jalan Silam at km 113 (Locality JS113) and km 129 (sample JS129). Most of the clasts in the volcanic breccia are of basalt fragments. The size of the clasts varies from a few cm up to 5 cm across. In thin section these rocks consist of clasts of mainly basaltic fragments showing vesicular texture.

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Whole-rock Geochemistry

Twenty-two samples of volcanic rocks from the Darvel Bay Ophiolite Complex were selected for major and trace element analysis. Five samples of Group I volcanic rocks, seven samples of Group II volcanic rocks, seven samples of Group III volcanic rocks and three samples of Neogene volcanic are rocks from the Dent Peninsula, Sabah were analysed. Several covariation plots of major and trace elements were tested to determine if the volcanic rocks could be subdivided into geochemical compositional groups that might facilitate their genetic interpretation. Considered together, these plots clearly establish the DBVR can be divided into three groups, which do not appear to be related to a single fractionation trend and are therefore not co-genetic.

Tectonomagmatic Setting

Group I volcanic rocks fall in the within-plate basalt (WPB) field and Group II volcanic rocks fall in the MORB field respectively. The Group III volcanic rocks fall within the IAT field and those from Neogene volcanic arc of Sabah (samples TB, SgPgD, SgPgP) suggest an arc affinity.

Tectonic Significance

On the basis of the trace element geochemistry the data suggests the existence of the tectonic environments from major ocean basin to island-arc settings. Group I and II Darvel Bay volcanic rocks may be related to volcanic activity during formation of the oceanic crust. Group II Darvel Bay volcanic rocks (N-MORB affinity) may represent the spreading ridge-axis volcanism whereas the Group I Darvel Bay volcanic rocks (OIB/E-MORB affinity) represent the off-axis volcanism. Darvel Bay Group III volcanic rocks (LAT affinity) may be related to the Oligocene-Middle Miocene volcanic arc activity of the Dent Peninsula, SE Sabah. This magmatic arc formed either due to southeastward subduction of the Proto South China Sea oceanic crust beneath Sabah (Taylor & Hayes, 1983) or due to northward subduction of the Celebes Sea (Bangin *et al.*, 1990; Hutchison, 1992). Later late Neogene (Pliocene to Quaternary) volcanic arc of Sempurna-Tawau are superimposed on the older arc, relating to the southward subduction of the Sulu Sea beneath the Sulu arc (Hutchison, 1975, 1978; Rangin, 1989).