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Geochemical characteristics of the granitic rocks from Boundary Range Batholith, Peninsular Malaysia

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Abstract: Geochemical characteristics of Boundary Range granite are similar to those of the Eastern Belt Granite and not to those of the Western Belt Granite. Although, the majority of the rocks from the Boundary Range granite have SiO_2 contents (> 65% SiO_2) similar to those of Western Belt granite, other elements such as P_2O_5, Na_2O, Ba and Sr are very different. The Boundary Range granite can be classified as 'I' type granite as the granite has high Na_2O content, abundance of mafic microgranular enclave, contain sphene and hornblende and increasing ACNK values with SiO_2. Simple modeling of the granite using log-log Ba vs Sr plot suggest that plagioclase, K-feldspar and biotite are important crystallisation phases in the magmatic evolution.

INTRODUCTION

The granites of Peninsular Malaysia are distributed in three parallel belts which have been grouped into 2 granite provinces (Cobbing *et al.*, 1992); the Main Range province with a age range of 200 to 230 Ma and the Eastern province with a range of 200 to 264 Ma. The eastern granitoid province which consist of the Central belt and the Eastern Belt comprises of an extended compositional spectrum from gabbro to monzogranite form a small batholiths and small plutons which are generally smaller than those of the Main Range granites. The present study involved the granitic rocks from Boundary Range batholiths located in the northern part of Eastern Belt granite (Fig. 1). The batholith is the largest Eastern Belt granitic body of Terengganu-Kelantan sector. Cobbing *et al.* (1992) divided the batholith into two major components that is Machang batholith and which is 100 x 20 km and the smaller Kerai batholith situated on the western flank (Fig. 1). The former generally consist of more evolved rocks i.e. biotite granite and hornblende granite whereas the Kerai batholiths is made up of more wider spectrum of plutonic rocks ranging from pyroxinite to gabbro to granodiorite to granite.

The aim of this paper is to report some characteristic geochemical features shown by this batholith compared to other Eastern Belt granite batholiths. The data used in this study is taken from Cobbing *et al.* (1992).

GENERAL GEOLOGY

Detail subdivision of the Boundary Range batholith is given by Cobbing *et al.* (1992) (Fig. 1). The batholith has been divided into a smaller granitic bodies such as (from north to south) Panchor, Jawa, Bidang, Buloh, Terekak, Kapis, Manik, Bidang, Kerai, Peria, Lata Tunggil and Rek Red. The batholith has variable granite texture ranging from coarse to fine primary to secondary magmatic variants and microgranite. The granite is cut by several basaltic dykes possibly of Albian age (cf Haile *et al.*, 1983).

GEOCHEMICAL CHARACTERISTICS

A data set of 35 geochemical analyses of the Boundary Range granite has been collected from published and unpublished data (e.g. Liew, 1983; Cobbing *et al.*, 1992). The Boundary Range batholith is characterised by a wide range of rocks with SiO_2 ranging from 48.95 to 76.5%. Selected Harker diagrams for major element oxides is given in Figure 2. Al_2O_3, TiO_2, Fe_2O_3, FeO, MgO and CaO decrease with increasing SiO_2. Negative slope of Sr vs CaO support that plagioclase is being removed in the differentiation sequence. Precipitation of plagioclase is

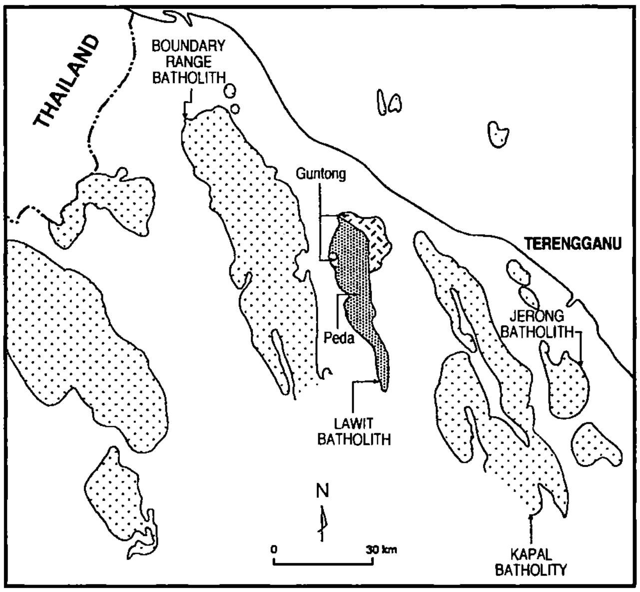

Figure 1. Map of the Peninsular Malaysia showing the location of Boundary Range batholith in relation to other granite batholiths.

also evidenced from Rb/Sr vs SiO_2 plot (Fig. 3b). The plot show a 'J' shaped trend which suggests the importance of fractional crystallisation process with plagioclase as the major precipitating felsic phase (Atherton, 1993).

The importance of K-feldspar, biotite and plagioclase in the differentiation is consistent with large ion lithophile (LIL) modelling. Inter element LIL variation diagram for pair Ba-Sr is shown in Figure 4. Also shown in each of the diagram is the vector diagram representing the net change in composition of the liquid after 30% Rayleigh fractionation by removing K-feldspar, hornblende, plagioclase or biotite. Two trends have been identified in the early crystallizing phases, the first trend is dominated by K-feldspar and biotite and the second trend controlled by crystallization of plagioclase and K-feldspar. Both trends converge into a single trend which dominated by plagioclase, K-feldspar and biotite. Thus the Ba vs Sr log-log plots suggest that crystal fractionation via crystallisation of plagioclase + K-feldspar and biotite play an important role in the magmatic evolution of the Boundary Range magmas

Na_2O vs SiO_2 (Fig. 3a) plot show that the Boundary Range and the Eastern Belt rocks (granitic rocks from Terengganu sector) cluster at SiO_2 below 65% and Na_2O between 3 to 4.6%. Both granites also share the same trend in the Rb/Sr vs SiO_2 plot which emphasizes the importance of plagioclase crystallization in the magmatic evolution of the magmas from both areas. However, compared to the Western Belt granite, the Boundary Range granite has lower SiO_2 content. This is evident from the P_2O_5 vs SiO_2 diagram (Fig. 5a) where both granites show different trends. The Boundary Range granite also has higher Na_2O content (Fig. 5b) compared to the Western Belt granite The Sr content is four times higher compared to the Western Belt granite at the same Ba content (± 500 ppm Ba). The concentration can reach up to 1,000 ppm which indicate the influence of mantle composition (Stephens & Halliday, 1984) (Fig. 6).

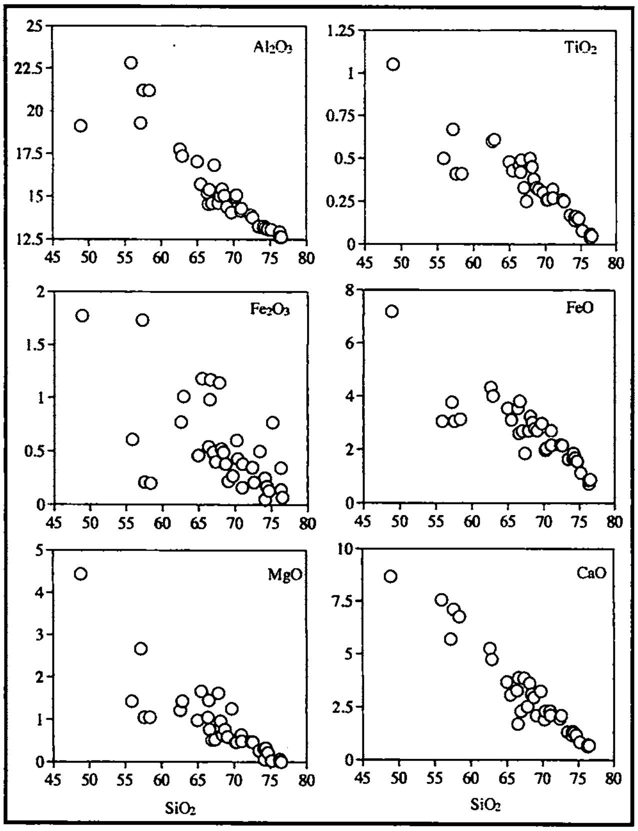

Figure 2. Major elements Harker diagram of the granitic rocks from the Boundary Range batholith.

ROCKS CLASSIFICATION

The main criteria for distinguishing 'I' and 'S' type granites can be summarised as follows (see Chappell & White, 1992, for a comprehensive review): 'S' types are always peraluminous (Alumina saturation index, ASI > 1)

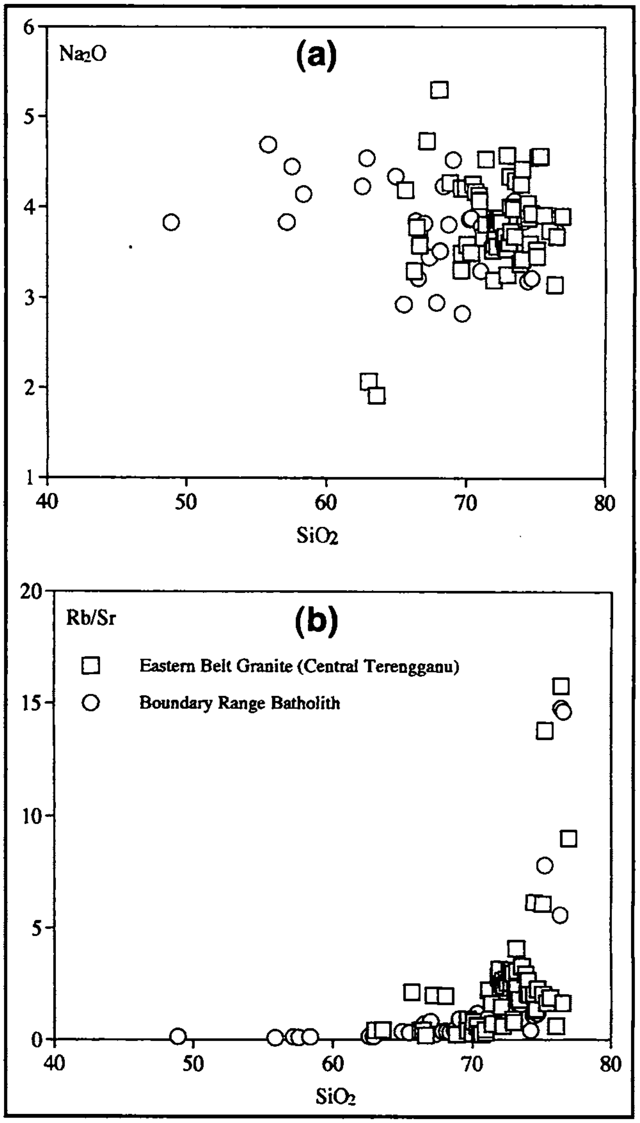

Figure 3. (a) Na_2O vs SiO_2 and (b) SiO_2 vs. Rb/Sr diagrams of the granitic rocks from the Boundary Range Batholith and the Eastern Belt granite (Terengganu Sector).

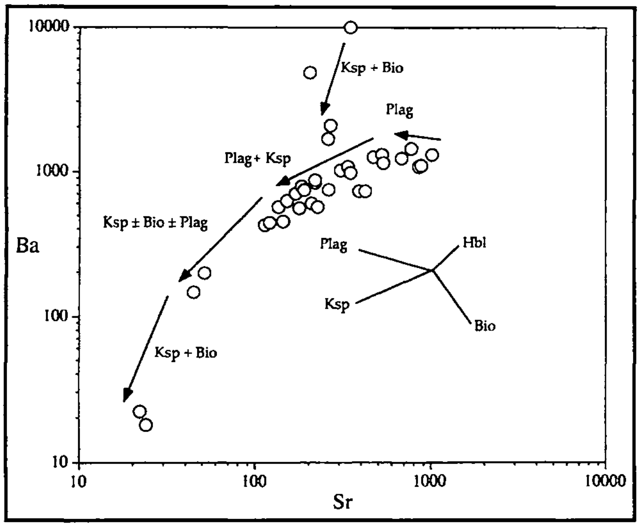

Figure 4. Log-log Ba vs Sr plot of the Boundary Range granite. Mineral vector indicate path evolved liquids for 20% of mineral precipitating.

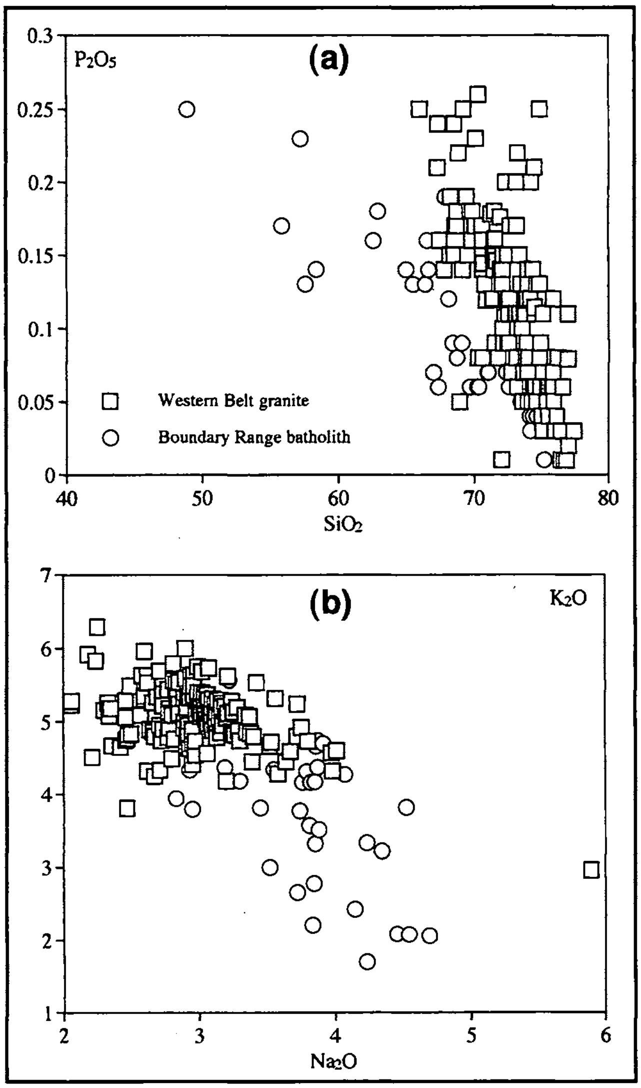

Figure 5. (a) P_2O_5 vs. SiO_2 and (b) Na_2O vs. SiO_2 diagrams of the granitic rocks from the Boundary Range Batholith and the Western Belt granite.

Table 1. Summary of the contrasting petrographic features of the Boundary Range batholith and the 'I' type granite from the Lachlan Fold Belt, Australia.

Boundary Range Granite	'I' Type Granites from Southeastern Australia
Primary sphene and amphibole.	Primary sphene and amphibole.
Mafic microgranular enclave.	Mafic microgranular enclave.
Increasing ACNK value with SiO_2. Peraluminous to metaluminous.	Increasing ACNK value with SiO_2. Peraluminous to metaluminous.
Higher CaO and Sr (ppm).	Higher CaO and Sr (ppm).
High Na_2O: more than 3.2% Na_2O for the rocks with ± 5% K_2O	High Na_2O: more than 3.2% Na_2O for the rocks with ± 5% K_2O

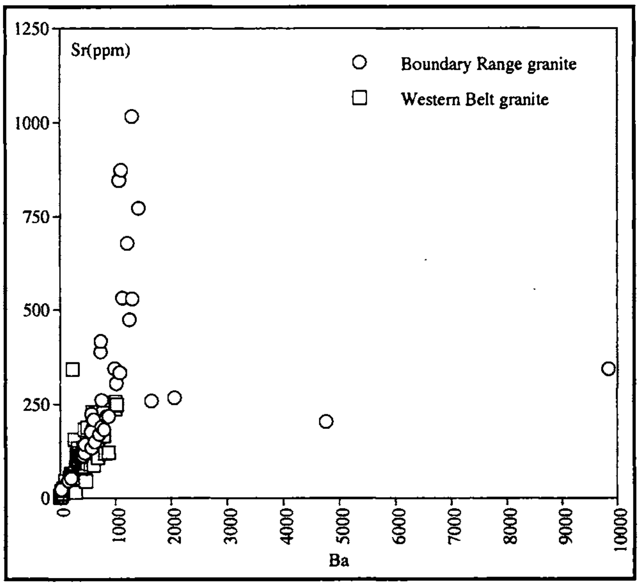

Figure 6. Ba vs Sr diagram of the granitic rocks from the Boundary Range Batholith and the Western Belt Granite.

and contain Al-rich minerals (e.g. Al rich biotite, cordierite, muscovite, garnet, sillimanite and andalusite). Chemically they are lower in Na, Ca, Sr and Fe^{3+}/Fe^{2+} and higher in Cr and Ni. 'I' types are metaluminous to weakly peraluminous (ASI < 1.1) and commonly contain biotite, hornblende and sphene. In terms of their isotopic composition, 'S' type granites have higher $S^{18}O$ values (> 10°/oo) and more evolved Sr and Nd isotopic composition. 'I' type granites range in $^{87}Sr/^{86}Sr$ from 0.704 to 0.712 and epsilon Nd from +3.5 to –8.9. For the 'S' type granites, the corresponding values are 0.708 to 0.720 and –5.8 to –9.2. The 'S' types granites contain a diverse assemblage of metasedimentary enclaves, whereas enclaves in 'I' types are commonly metaluminous and hornblende bearing. Comparison of the Boundary Range batholith rocks with the original 'I/S'

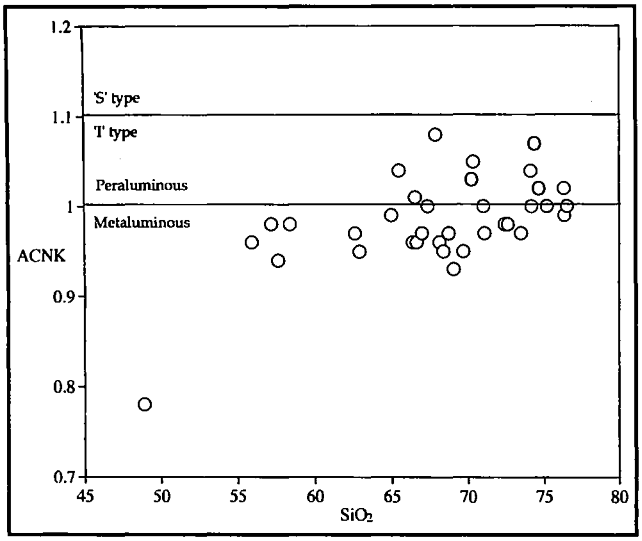

Figure 7. $Al_2O_3/CaO + Na_2O + K_2O$ vs. SiO_2 (ACNK) diagram for the Boundary Range granite. Line at ACNK = 1 divided between peraluminous and metaluminous and line at ACNK = 1.1 divided between 'I' and 'S' type granite.

type classification (Chappell & White, 1974) is shown in Table 1. In general, mineralogy of the batholith especially the occurrence of sphene and hornblende suggest that they are 'I' type. This is supported by ACNK values, all the samples analysed from the batholith plots well below ACNK =1.1 (Fig. 7) (Shand, 1943; Zen, 1988). The increasing of ACNK values with SiO2 also similar to the I type feature (Chappell & White, 1992; Chappell, 1999).

CONCLUDING REMARK AND FUTURE WORK

Geochemical characteristics show that the Boundary Range granite is similar to the Eastern Belt rather than the Western Belt Granite. Although the majority of the rocks from the Boundary Range granite have similar SiO_2 content (> 65% SiO_2) to the Western Belt granite, other elements such as P_2O_5, Na_2O, Ba and Sr are very different. The Boundary Range granite can be classified as 'I' type granite as the granite has high Na_2O content, abundance of mafic microgranular enclaves, contain sphene and hornblende and increasing ACNK values with SiO_2. Simple modeling of the granite using log-log Ba vs Sr plot suggest that plagioclase, K-feldspar and biotite are important crystallisation phases in the magmatic evolution. Two trends have been identified in the early crystallizing phases, the first trend is dominated by K-feldspar and biotite and the second trend controlled by crystallization of plagioclase and K-feldspar. This probably indicates mixing between two magmas. Both trends converge into a single trend which dominated by plagioclase, K-feldspar and biotite. A good correlation of the latter trend suggests that the connection exists between all the rocks from the Boundary Range Batholith at some stage of their magmatic evolution.

A detailed study of geochemistry and mineralogy of the individual plutons or granitic body with more careful, controlled sampling using a greater number of samples has to be done in order to understand more fully the petrochemistry of each of the plutons. Detailed study of radiogenic isotope especially Sr, Nd, Sm and Pb should be undertaken to determine the source region and other processes such as mixing and high level interaction. The various types of enclaves that occur in the Boundary Range granites should be studied in more detail because they may provide information on the mode of emplacement, the origin of the granitic magma and the dynamics of magma chambers including magma interaction.

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