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Geochemistry of Jawa and Panchor granite: the most northern granitic bodies of the Boundary Range Batholith

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Abstract: The Panchor and Jawa granites are two isolated granitic bodies located at the north of the Boundary Range Batholith. They consist of coarse, K-feldspar megacrystic, biotite hornblende granite with some incipient two-phase variation in the Jawa granite. Mineralogy of both Panchor and Jawa granites in decreasing abundance are K-feldspar, quartz, plagioclase, biotite, allanite, zircon, apatite and hornblende. Both granites show many I type feature such as (i) mafic minerals are invariably hornblende and biotite, (ii) muscovite, garnet and cordierite are absent, (iii) accessory minerals present include sphene, allanite and apatite (iv) monazite is not present, (v) sedimentary xenoliths are very rare and (vi) Na_2O is greater than 3.2% in rocks with approximately 5% K_2O. Both granites also show many geochemical differences, which suggests that they are made up of individual batches of melt. Both Panchor and Jawa granite magma seems to be controlled by different mineral proportion during magmatic fractionation, thus, the Panchor granite is controlled by K-feldspar and biotite whereas in the Jawa Granite, plagioclase and K-feldspar are important phases in magmatic evolution. However the continuous trend shown by the Jawa and Panchor granites and the other Boundary Range Granites in Rb/Sr vs SiO_2, Sr vs CaO and and P_2O_5 vs SiO_2 diagrams suggest that a connection exists between all the rocks at some stage of their magmatic evolution.

INTRODUCTION

The Peninsula Malaysia granites are distributed in three parallel belts which have been grouped into 2 granite provinces: the Main Range province with an age range of 200 to 230 Ma and the Eastern province with a range of 200 to 264 Ma. The eastern granitoid province, which consists of the Central belt and the Eastern Belt, comprises of an extended compositional spectrum from gabbro to monzogranite form small batholiths and plutons, which are generally smaller than those of the Main Range granites. Among the largest granitic batholith of the Eastern Belt Granite is the Boundary Range Batholith located in the north part of the granite belt **(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 pyroxenite to gabbro to granodiorite and granite. Cobbing et al (1992) have divided the Boundary Range Batholith into more than fifteen granitic units e.g. Bidang, Terekak, Lata Tunggil, Kerai, Jawa and Panchor. Among these units, Jawa and Panchor are separated from the proper Boundary Range Batholith. These two granitic bodies are two isolated hills located at the northeast of the batholith. The aim of this paper is to report the major and trace elements characteristic of the Jawa and Panchor granites.

PETROLOGY

Both Jawa and Panchor granite consists of primary textured granite (Cobbing et al 1992). They consist of coarse, K-feldspar magacrystic, biotite hornblende granite with some incipient two-phase variation in the Jawa granite. Mineralogy of both Panchor and Jawa granites in decreasing abundance are K-feldspar, quartz, plagioclase, biotite, hornblende, allanite, zircon and apatite.

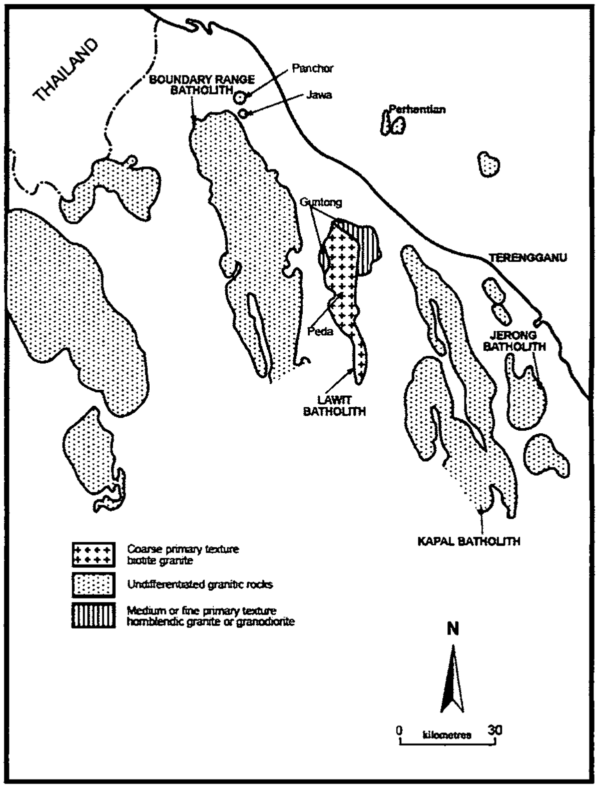

Figure 1: Map of the Peninsular Malaysia showing the location of Panchor and Jawa pluton in the Boundary Range batholith

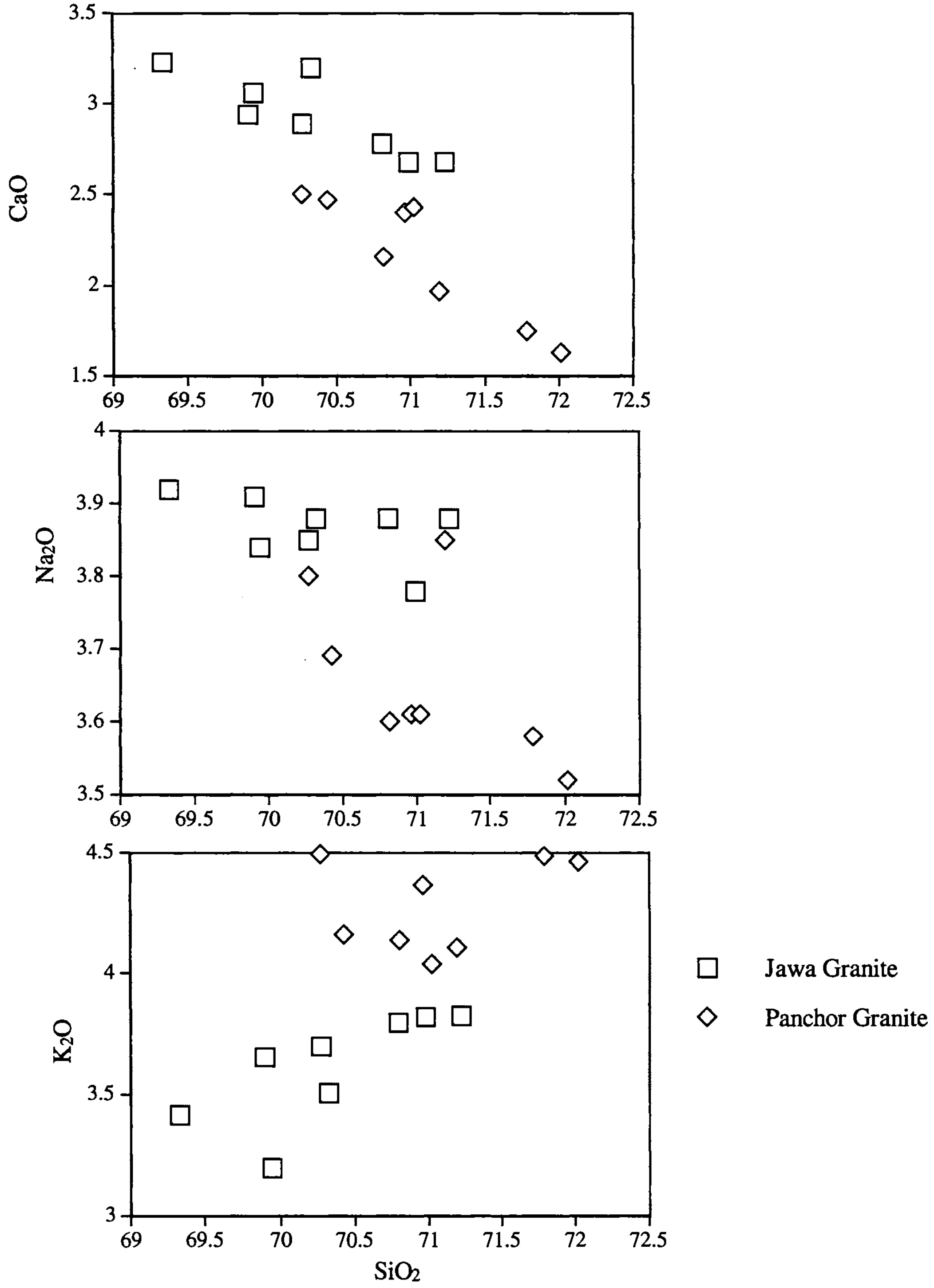

Figure 2: Selected major elements Harker diagram of the granitic rocks from Panchor and Jawa Granites.

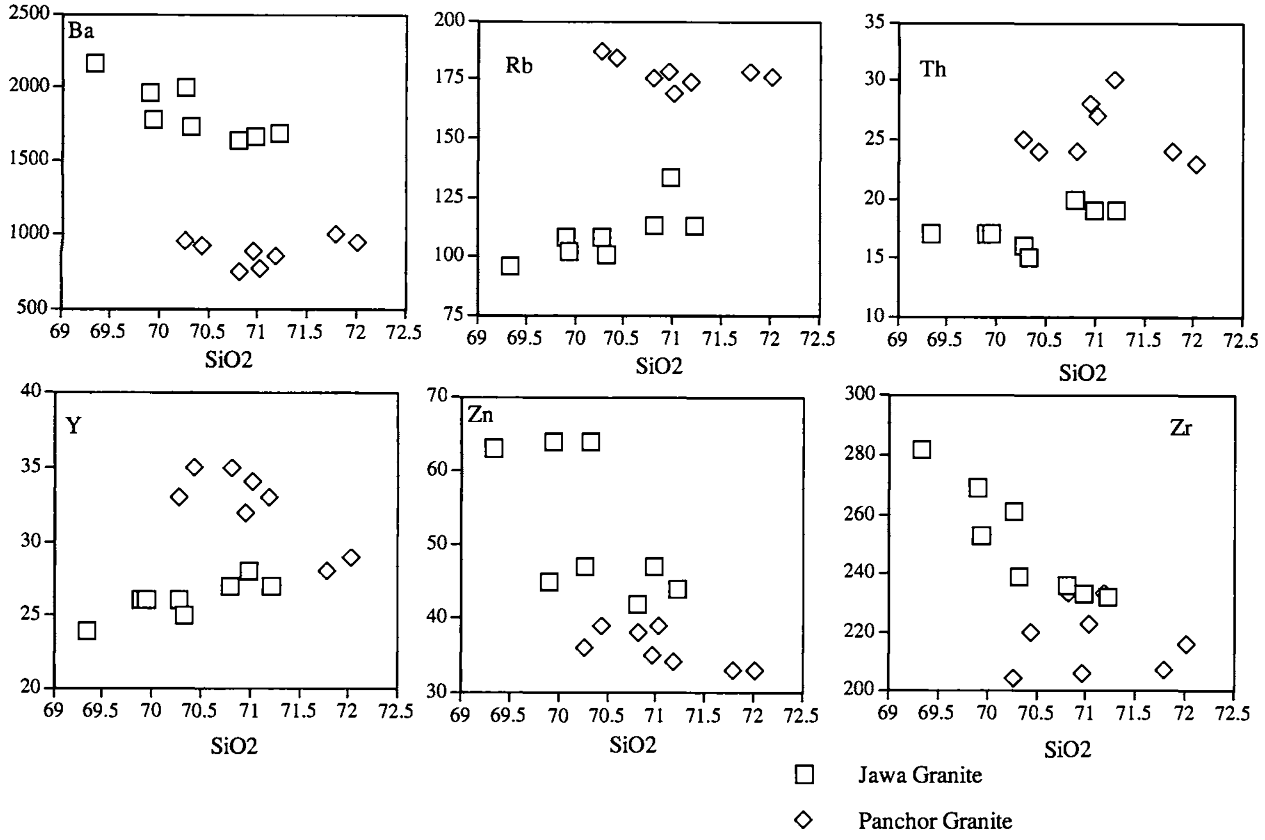

Figure 3: Trace elements Harker diagram of the granitic rocks from Panchor and Jawa Granites.

CHEMICAL CHARACTERISTICS

A data set of 16 samples of the Panchor and Jawa granites has been analysed. 4 additional analyses were obtained from Cobbing et al. (1992). (Sample: COB51, COB 78 (Panchor) and COB 101, COB 124 (Jawa)). Both Jawa and Panchor granites have a similar SiO2 content: 68.4 to 71.22 % SiO2 (Jawa) and 69.08 to 72.02 SiO2 % (Panchor). Thus, both Jawa and Panchor granites are among the felsic rocks of the Boundary Range Batholiths (SiO2 ranging from 48.95 to 76.5%). In general Al2O3, TiO2, Fe2O3, FeO, MgO, Na2O and CaO decrease with increasing SiO2. The differences between both Panchor and Jawa Granites are clearly shown in Figure 2 and 3, thus Al2O3, CaO, Ba, Zr and Na2O are higher and K2O, Rb, Th, Y and Zn are lower in Jawa compared to the Panchor granites. All rocks from both units generally have high alkali content (Na2O + K2O) ranging between 8.16 to 9.93 wt% for Panchor granite, 6.34-12.08 wt% for Jawa Granite.

Classification by alumina saturation index (ASI) of Zen (1988) indicates that the Panchor granite has higher ACNK values ranging from 1.03- 1.08 (mildly peraluminous), compared to the Jawa granites which ranges from 0.97 – 1.01 (metaluminous) (Fig 4). The samples from both plutons, however, plot in the I-type field of Chappell and White (1974). Furthermore, they show a different ACNK behaviour with SiO2, thus the ACNK trend of the Panchor rocks increase with increasing SiO2 whereas those from Jawa form a cluster with no clear trend with SiO2.

Both granites share the same trend as the main Boundary Range Batholith in the Rb/Sr vs SiO2 plot (Fig 5). This plot emphasizes the importance of plagioclase crystallization in the magmatic evolution of the magmas from the Boundary Range Batholith. The plot show a 'J' shaped trend which suggest the importance of fractional crystallisation process with plagioclase as the major precipitating felsic phase (Atherton 1993). The important 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 6. 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 is dominated by plagioclase, K-feldspar and biotite. Thus the Ba vs Sr log-log plots suggests that crystal fractionation via crystallisation of

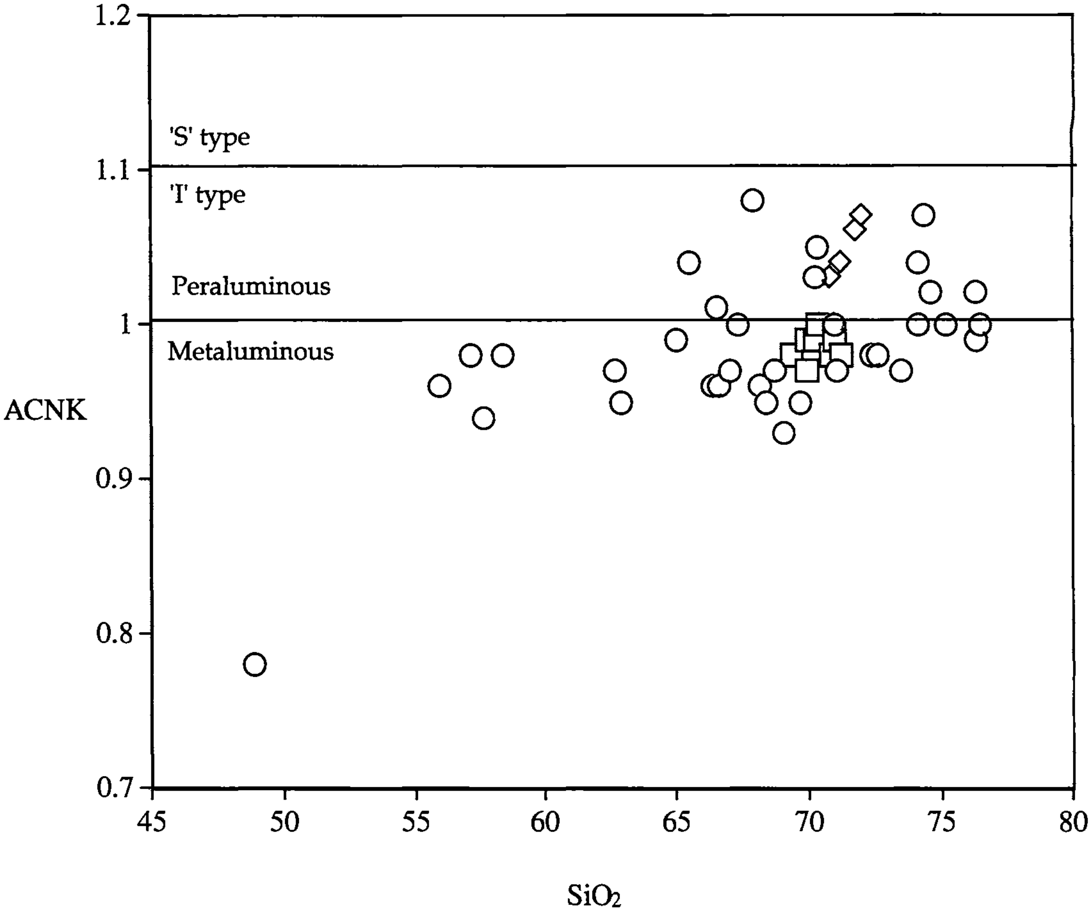

Figure 4: $Al_2O_3/CaO+Na_2O+K_2O$ vs SiO_2 (ACNK) diagram for the Panchor, Jawa and other Boundary Range granite. Line at ACNK =1 divided between peraluminous and metaluminous and line at ACNK = 1.1 divided between 'I' and 'S' type granite. Symbols as in Figure 5.

plagioclase + K-feldspar and biotite play an important role in the magmatic evolution of the Boundary Range magmas. Interestingly, both Panchor and Jawa granite show a different mineralogical trend, thus the Panchor granite plots in the first trend, controlled by K-feldspar and biotite whereas in the Jawa Granite plots in the second trend which is dominated by plagioclase and K-feldspar. This suggests that both Panchor and Jawa magmas may represent a different magmatic pulses.

A Ba vs. Sr plot for the rocks of both Panchor and Jawa granites together with all Boundary Range analyses is shown in Figure 7. Both Panchor and Jawa granites have about the same concentration of Sr (ppm) but the Ba (ppm) is higher in the later. Infact the Ba concentration in the Jawa pluton is among the highest compared to the other Boundary Range rocks (~ 2500 ppm). In general the Panchor analyses fall within the Boundary Range general trend. Majority of the Panchor granite rocks plot below the line Ba/Sr =1 and can be considered as low Ba-Sr granite according to Tarney and Jones (1994).

DISCUSSION

In general, mineralogy of both plutons especially the occurrence of hornblende and sphene suggest that they are 'I' type. This is supported by ACNK values, all the samples analysed from both plutons plots well below ACNK =1.1 (Fig 4) (Shand 1943; Zen 1988). The increase of ACNK values with SiO2 is also similar to the I type feature (Chappell & White 1992; Chappell 1999). However the trend shown by both plutons are different, thus the ACNK values of the Panchor granite increase with increasing SiO2 whereas those from the Jawa granite cluster just below the ACNK =1.1. The geochemistry also shows that both Jawa and Panchor granites are made up of individual batches of melt. This is evident from large ion lithophile modeling (Fig 7). Both magmas are controlled by different groups of minerals during crystallization, K-feldspar and biotite for the Jawa granite and plagioclase, K-feldspar and

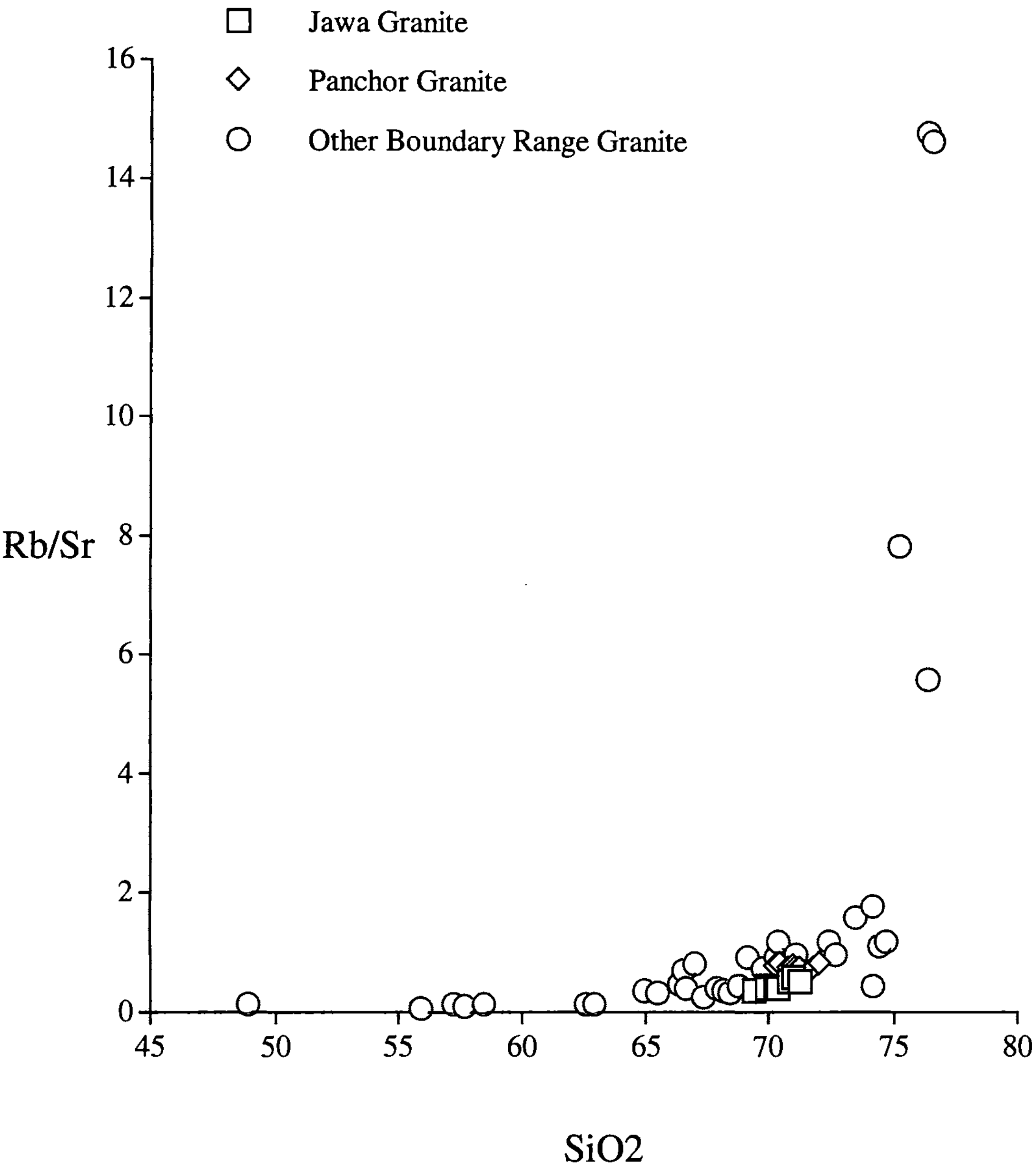

Figure 5: Rb/Sr vs SiO_2 plot for the Panchor, Jawa and other Boundary Range granite.

biotite for the Panchor granite. The Jawa granite has higher Ba content compared to the Panchor granite.

The Ba content in the Jawa Granite is among the highest of all Boundary Range Granite. The strong enrichment of these elements (Ba and Sr) is probably related to transfer of enriched (hydrous?) fluids from the mantle into the lower crust (and possibly initiated) melting to form the granites (Stephens and Halliday 1984). It is also possible for this to be linked with mantle plumes (e.g. Hill et al.1992). Not all deep mantle plumes are able to break through thick lithosphere, and may just underplate it, but at the same time provide energy for melting of the lower crust. Mantle derived liquids are enriched in Ba and Sr as a result of partial melting of (probably metasomatised) peridotite without plagioclase as a stable phase possibly followed by high pressure fractionation (Halliday and Stephen 1984). If such magma interacted with the lower crust, this only serves to maintain Ba and Sr at high levels and lower the Rb/Sr ratios (Rb/Sr : Jawa – 0.34 – 0.57 , Panchor (0.71 – 0.81). Other possibilities to create magma composition with high Ba and Sr with positive anomalies for Sr and P is simply by having garnet residual in the source to sequester the heavy REE and depress the multi-elements variation pattern (Tarney and

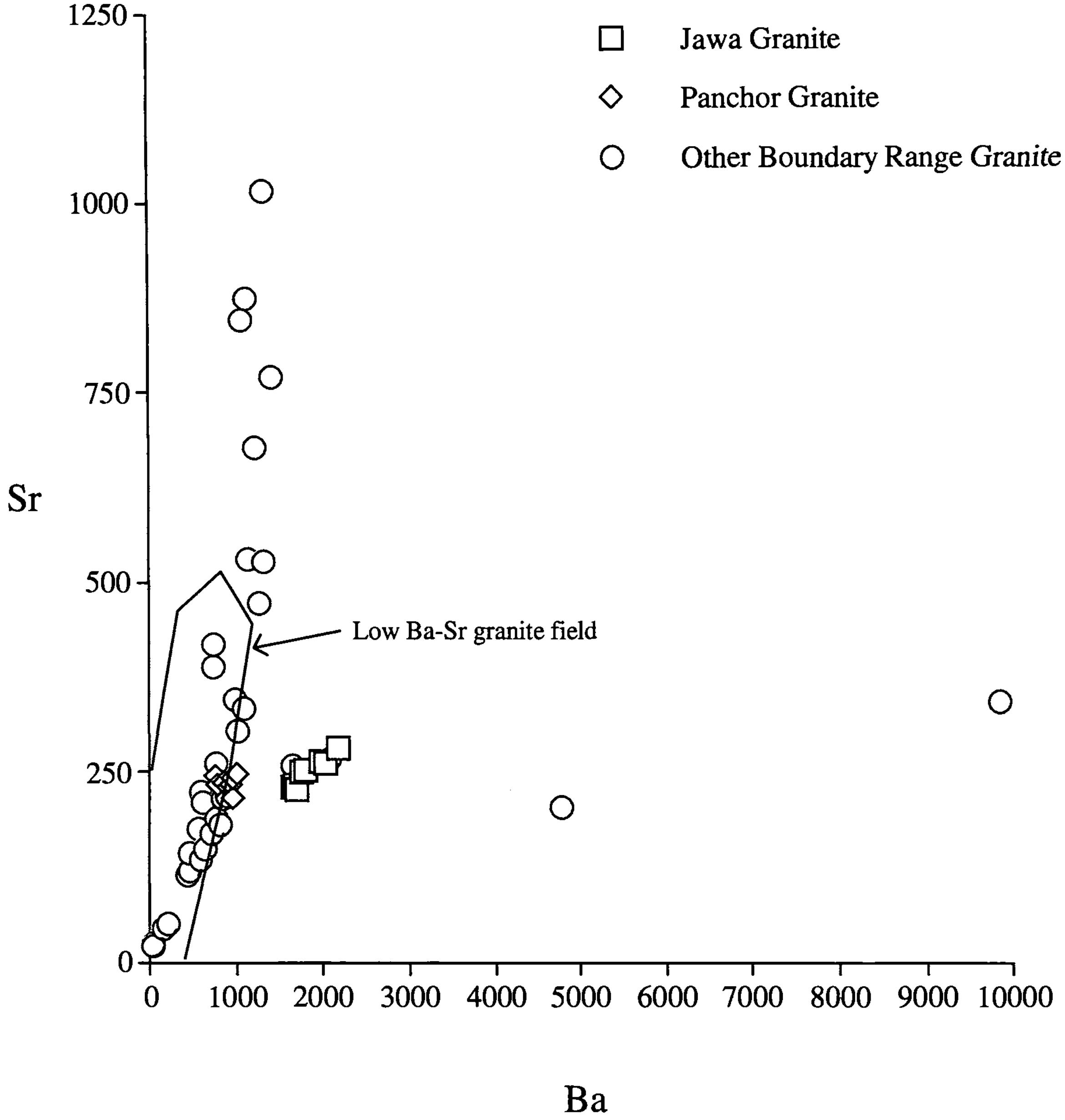

Figure 7: Ba vs Sr diagram of the granitic rocks from both Jawa and Panchor granite. Also plot in the diagram is the other Boundary Range granites

Jones 1994). Halliday and Stephen (1984) also suggested that the high Sr magmas in the British Caledonian granite are product of a particular province maintained by a particular process. Azman and Mustaffa (2002) considered that the high Ba and Sr values in the Raub area may result from the penetration of the lower lithosphere by a small volume of mantle material that is enriched in those elements. The Panchor granite has yielded an initial 87Sr/86Sr ratio of 0.70797 (Cobbing et al 1992), which points to an origin in highly enriched lithospheric mantle.

Typology of both Panchor and Jawa Granites are consistent with the 'I' type rock (Chappell and White, 1974, 1992). The I type characteristic of both granites are consistent with the Eastern Belt Granite. Notable 'I' type features are:

(a) mafic minerals are invariably hornblende and biotite,

(b) muscovite, garnet and cordierite are absent,

(c) accessory minerals present include sphene, allanite and apatite. Monazite is not present,

(d) sedimentary xenoliths are very rare

(e) Na2O is greater than 3.2% in rocks with approximately 5% K2O

Without isotopic data it is not clear what the source(s) of the both granites were, but the limited isotopic data available (Cobbing et al. 1992) suggest that the sources lie within the lower crust and upper mantle. The granites together with other Boundary Range granites probably were generated during each of the main deformation episodes when, in response to a slight increase in heat flow and followed by a progressive drop in pressure, a series of magma pulses of changing composition were formed. However the source of heat necessary to generate the individual melts during the deformation episodes is not clear. Some of the features e.g. high Ba-Sr in the Panchor granite can only be explained by melting in response to the heat supplies by underplated mafic magmas (Stephen and Halliday 1984; Yarr 1991; Tarney and Jones 1994). These separate melts were collected into discrete magmas which rose as a result of a buoyancy natural to their low density The continuous trend shown by the Jawa and Panchor granites and the other Boundary Range Granites in Rb/Sr vs SiO2, Sr vs CaO and and P2O5 vs SiO2 diagrams suggest that a connection exists between all the rocks at some stage of their magmatic evolution.

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