Geochemistry of tourmaline-bearing granite from Maras-Jong, Terengganu, Peninsular Malaysia

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Abstract: The Eastern Belt Granite of Peninsular Malaysia consists mainly of I-type granites with subordinate S-type granites. The monzo- to syenogranite Maras-Jong pluton in the Eastern Belt Granite show many S-type characteristics such as presence of tourmaline, garnet, similar texture (both granites are coarse grained primary textured sometimes dominated by K-feldspar phenocrysts) and high SiO₂ contents. However, using the previous granite classification, ACNK values below 1.1 and low Al biotite content, the Maras-Jong granite can be classified as I-type granite. It is suggested that the Maras-Jong granite is a felsic I-type granite.

INTRODUCTION

Granitoid batholiths in the East Coast Province are distributed as linear masses parallel to the medial suture in Peninsular Malaysia. The province extends for a distance of 600 km and has typical exposed width of 80 km. The western margin of the province is characterized by abrupt development of granitoid along a line approximately 100 km from the medial suture. A biotite ± hornblende granodiorite to granite of variable texture is the most common rock type but a single intrusive complex may result from partial melting of metasedimentary sequences (Cobbing et ai., 1992). Mafic plutons are usually the earliest in the sequence of intrusions and they occur as marginal bodies of the felsic plutons. Mafic dyke swarms mainly of doleritic composition are common.

Liew (1983) divided the Eastern Granite Province into three that is I-type granites, S-type granites and mafic rocks associated with the two granites. All the three types have different magma sources, the mafic association originate from high level fractionated components of mantle-derived primitive tholeitic magma, the S-type granite resulting from partial melting of metasedimentary sequences under amphibolite-granulite facies condition involving muscovite and/or biotite breakdown and the I-type granite resulted from hornblende fractionation of metalaminous magma. Among the characteristics of the S-type magma in the Eastern Granite Province are high SiO₂ content (69-77%), presence of high Al biotite, ilmenite and tourmaline. The granites occur as scattered stocks and as constituent plutons of large batholiths.

Maras-Jong pluton in the Eastern Belt Granite (Fig. 1) show many S-type characteristics such as presence of tourmaline, garnet and high SiO₂ content. The pluton is the most easterly granitic body of the Eastern Belt in the Peninsular Malaysia. The granites intruded the Sungai Perlis Beds which consists of slate, phyllite, metaquartzite and chiastolite slate. The Maras-Jong granite is divided into two units that is the granite proper and grey microgranite dyke intruded the granite. This paper will examined in detail the petrology, mineral chemistry and geochemistry of the pluton and in comparison with the Western Belt Granite.

PETROLOGY

The average modal data for Maras-Jong granite is quartz (35%), plagioclase (19%), K-feldspar (43%), biotite (4.5%) and can be classified as monzo-to syenogranite in the QAP diagram (Streckeisen 1976). Accessory minerals include apatite, garnet, tourmaline and zircon.

Large K-feldspar phenocrysts up to 3 cm long are common. In thin section most of the K-feldspar have perthitic texture. Chemical composition of the mineral shows that it contains up to 0.3% BaO and 12-16% K₂O. Plagioclases display a variety of habits (size between 0.5 mm to 2 mm). It may occur as discrete phenocrysts or as glomeroporphyritic aggregates showing resorbed outlines in the mafic members of the granites. The most common plagioclase type is oligoclase. Occasionally the crystals have corroded or cracked cores, which probably represents an early or pre-emplacement plagioclase, which was resorbed during the ascent of the magma (Mason, 1985). Thin late albic rim sometimes can be found surrounding the plagioclase crystal. Geochemical analyses of the
plagioclase show that the mineral contain 62 to 65% SiO₂, 22 to 24% Al₂O₃, 8 to 9% Na₂O and up to 0.2% BaO.

Quartz in the Maras-Jong granite is mostly anhedral and generally interstitial to all other minerals, especially plagioclase and to a lesser extent to the microcline. It also occurs as small round crystals at the margins of the plagioclase. Mymerkitic intergrowth of quartz and plagioclase is rather common. Biotite may occur as discrete plates, as ragged shreds in mafic clots and as small flakes associated with granoblastic aggregates of quartz and plagioclase. The pleochroism scheme is typically pale brown to dark brown. Available geochemical data indicate that the biotites from Maras-Jong granite (central part of the Western Belt) is different from the biotite that crystallized from peraluminous melt which is characterized by high Al₂O₃ content (17-21%). The biotite from the Maras-Jong granite typically has 12.56-13.6% Al₂O₃, 2.9-4.2% TiO₂, 3.9-4.2% MgO and 8.8-9.3% K₂O.

Zircon and apatite are ubiquitous accessory phases. Euhedral garnet is uncommon and only observed in rocks of leucogranitic composition. Tourmaline occurs as an interstitial mineral to plagioclase, quartz and K-feldspar. Euhedral allanite is present in several plutons and commonly show zonation. Secondary epidote, chlorite, and occasionally sphene often occur along biotite cleavages. Epidote occurs as secondary mineral associated with sericitised plagioclase and biotite.

**GEOCHEMISTRY**

**Analytical notes**

Fifteen samples of the Maras-Jong granite proper and the grey microgranite dykes were collected and analysed. The size of samples was dependent on grain size, the largest being 5 kg. Care was taken to ensure that the granites were unaltered, the state of decomposition of the feldspar being an important indicator. Major and trace element analyses were carried out on an automated Phillips PW1400 X-Ray fluorescence (XRF) spectrometer at the Victoria University of Wellington, New Zealand.

**Chemical variation**

Representative geochemical composition of the Maras-Jong granite is given in Table 1. Major and trace element data are plotted against SiO₂ on variation diagrams as this is the most common granite fractionation index. The Maras-Jong granite show a restricted aluminium saturation index (ASI) with molecular $\frac{Al_2O_3}{Na_2O+K_2O+CaO} = 0.86$ to 1.07, and therefore all the analysed samples are mildly metaluminous to peraluminous. The granites also have a variable major element chemistry ($SiO_2 = 65.57-74.64$ wt% and $Al_2O_3 = 12.96-14.65$ wt%). The grey microgranite has more basic composition compared to the Maras-Jong granite proper. Thus $Al_2O_3$, TiO₂, Fe (tot), MnO, MgO, Na₂O and P₂O₅ are higher in the former (Fig. 2). Infact most of the elements grey microgranite in the have different trends compared to the Maras-Jong granite. This is an evidence shows by the FeO (tot), MnO, CaO, Na₂O and K₂O. A gap occurs between the granite proper and the grey microgranite dykes from 68.1 to 71.2% SiO₂ and this may be a true gap and not related to under sampling. On the AFM plot the rocks from the Maras-Jong pluton plot at the evolved end of the calc alkaline trend. All analysed samples from the Maras-Jong granite proper have high alkali contents, with $Na_2O + K_2O$ ranges from 7.6-8.6%. The high alkali nature of the rocks is also shown on the $K_2O$ vs SiO₂ plot (Fig. 3), where all rocks plot in the high-K calc alkaline field. However, different behavior shown the grey microgranite samples. Trend of the plot is crossing a different field from calc alkali to high-k calc alkali.

Trace element variation diagrams (Fig. 4) of the Maras-Jong pluton show a gap occurs in some of the diagrams.
Table 1. Representative geochemical analyses of major and trace elements for the Maras-Jong granite.

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Granite: Maras-Jong granite proper  Grey: Grey microgranite dyke
granites have higher $\delta^{18}O$ values (>10%) 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. Mineralogy of the granite especially the presence of garnet and tourmaline suggest that the Maras-Jong granite fall in the S-type granite criteria of the Eastern Belt province. However Na$_2$O vs K$_2$O plot (Fig. 8) shows that the Maras-Jong granite plots in the I-type field. This diagram implies that the Maras-Jong granite has high Na$_2$O content. This is supported by ACNK values, the samples from Maras-Jong granite plot in well below ACNK =1.1 (Shand, 1943; Zen, 1988).

CONCLUDING REMARKS

The granite is homogeneous and has been intruded by dolerite and grey microgranite dyke magmas. The dolerite dykes are common throughout the Eastern Belt granite (Azman, 2001a, b; Azman et al., 1998, 2001, 2002) and are different in origin from the Maras-Jong granite proper. The grey microgranite dykes are restricted only to the Maras-Jong granite and closely associated with the granite. In K$_2$O vs SiO$_2$ plot (Fig. 3) the grey microgranites show a different trend from the Maras-Jong granite proper. The trend grades from calc alkali to high K calc alkali to high-k calc alkali which is clearly not a magmatic trend. Roberts and Clemens (1993) showed that a parent magma with a given K$_2$O and SiO$_2$ content will evolve within the particular field in a K$_2$O vs SiO$_2$ diagram and for magma to evolve into an adjacent field some process other than crystal-liquid separation must operate. This clearly indicates that the grey microgranites and the Maras-Jong granite are very different and have different sources. This is supported by the fact that the former shows a different trend of much of the trace elements compared to those from the Maras-Jong granite proper.

The granitic rocks of the Maras-Jong granite are texturally similar to the Main range granites. Other characteristics of the Maras-Jong granite that are similar to the Western Belt Granite are presence of tourmaline, garnet and high SiO$_2$ content (69-77%). Both granites are coarse grained primary textured sometimes dominated by K-feldspar phenocrysts. In some felsic members of the Maras-Jong granite, garnet is found as an accessory phase. Figure 3 show the K$_2$O vs SiO$_2$ plot for the Maras-Jong and associated grey microgranite dykes, as well as Eastern and Western belt granites. The Eastern belt samples are more scattered compared to the Western and Maras-Jong granites, thus the latter two have similar K$_2$O content. The Maras-Jong granite also has higher Rb/Sr ratio (Fig. 9) compared to the Eastern belt granite of similar SiO$_2$ content. This may lead to conclusions that the Maras-Jong granites is S-type rather than I-type. However the Na$_2$O vs K$_2$O plot clearly shows that the granite has high Na$_2$O and plot in the I-type field of Chappell and White (1992). The fact that Maras-Jong is I-type granite is support by the ACNK values of the rocks i.e all analysed samples have ACNK < 1.1. Geochemical analyses of the biotite from the Maras-Jong granite also give low Al$_2$O$_3$ which is in contrast to the biotite of sedimentary origin which has high Al$_2$O$_3$. Furthermore, REE plot show that the Maras-Jong granite

![Figure 2](image2.png)

Figure 2. Major elements Harker diagram of the granitic rocks from the Maras-Jong granite.

![Figure 3](image3.png)

Figure 3. K$_2$O vs SiO$_2$ diagram for the Maras-Jong granite and its microgranite dykes. Also plot in the diagram is the samples from both Western and Eastern belt granite.
Figure 4. Trace elements Harker diagram of the granitic rocks from the Maras-Jong granite.

Figure 5. Log-log Ba vs Sr and Ba vs Rb plots of the granitic rocks from the Maras-Jong pluton. 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.

Figure 6. TiO₂ vs Zr log-log plot for the Maras-Jong granite. Mineral vectors indicate path evolved liquids for 15% of a mineral precipitating: Pl: plagioclase; Kf: K-feldspar; Qz: quartz; Mt: magnetite; Sp: sphene; Hbl: hornblende; Bi: biotite; Zi: zircon.

Figure 7. The REE profiles for the granitic rocks from Maras-Jong pluton, Terengganu.

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produce a different profile compared to the highly evolved
S-type granite from the Western Belt granite (Fig. 10)
Azamie & Azman, 2003). Thus although the Maras-Jong
granite have many similarities to the S' type granite, the
granite is more likely a felsic I-type granite.

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