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Contrasting chemical characteristics of granite and syenite from Perhentian islands, Peninsular Malaysia

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Abstract: The Perhentian intrusion is a reversely zoned complex exposed over several islands off the coast of Peninsular Malaysia. The intrusion is made up of Perhentian Kecil syenite rimmed by more evolved Perhentian granite. The former consists of a variety of igneous rocks ranging in composition from syenitic to monzonitic and even gabbroic rocks whereas syenogranite dominated the latter pluton. Field relationships of the rocks suggest that the Perhentian granite is younger than Perhentian Kecil syenite. Both plutons show different trends in the Q-A-P classification. The essential minerals in the Perhentian Kecil syenite are K-feldspar, plagioclase, hornblende, augite, quartz, biotite, sphene, epidote, apatite, zircon and magnetite whereas K-feldspar, plagioclase, quartz, biotite, hornblende, allanite, zircon, epidote and opaque phase make up the Perhentian granite. As in the field and petrographic characteristics, geochemistry of both plutons also show a different behaviour. The differences are:

1. On a TAS diagram, the Perhentian Kecil syenite trend evolved towards the nepheline normative whereas the Perhentian granite rocks seems to evolved towards the quartz normative.
2. Both pluton show a different ACNK trend with SiO_2, thus the ACNK trend of the syenitic rocks increase whereas those from the granitic rock decrease with increasing SiO_2.
3. Plots of CaO and (Na_2O vs K_2O) vs SiO_2 emphasise the alkali calcic character of the syenitic rocks with alkali-lime index of 54.5, as well as very different character, in alkali term, of the Perhentian granite pluton in which the CaO and (Na_2O + K_2O) curves do not intersect. This is due to the lower CaO and higher (Na_2O + K_2O) contents of the granitic rocks which are constant over the SiO_2 ranges (71–75%).
4. Rocks from Perhentian Kecil syenite have high Sr, Ba and Sr/Y ratio compared to the Perhentian granite. All the Perhentian granite rocks plot below the line Ba/Sr = 1 and can be considered as low Ba-Sr granite.
5. The Perhentian granite has low total REE (106–382) compared to the Perhentian Kecil syenite (224–450). The granite also has more restricted La_N/Lu_N ratios (0.96–58.8) compared to the syenitic rock which has wider La_N/Lu_N ratios (30.7–218.5).

Field, petrology and geochemical studies of the Perhentian rocks indicate that both Perhentian granite and Perhentian Kecil syenite are made up of individual batches of melt.

INTRODUCTION

The Perhentian intrusion is a reversely zoned complex exposed over several islands off the coast of Peninsular Malaysia. The islands, known as the Perhentian group, consists of six main islands: Perhentian Besar and Kecil, Rawa, Serenggeh and Susu Dara Besar and Kecil (Fig. 1). The intrusion is made up of Perhentian Kecil syenite rimmed by a more evolved Perhentian granite. The former consists of a variety of igneous rocks ranging in composition from syenitic to monzonitic and even gabbroic rocks whereas syenogranite dominated the latter pluton. Field relationships of the rocks suggest that the Perhentian granite is younger than the Perhentian Kecil syenite. Evidences which support the younger age of the Perhentian granite are listed below (Azman and Khoo, 1998):

1. Occurrence of syenitic blocks in the granitic rock (Loc: Tanjung Batu Nisan).
2. Cross cutting relation of the contact between the rocks (Loc: Tanjung Batu Nisan, Pasir Patani, Pasir Karang and along Tanjung Batu Peti to Tanjung Batu Sireh).
3. Offshoot of microgranite vein from granite into syenite (Loc: Tanjung Batu Nisan and Pasir Patani).
4. Occurrence of microgranite and porphyritic rocks in the Perhentian granite at the contact, which suggests that the granitic magma quickly chilled against cooled syenitic rocks.

This paper will outline some of the geochemical as well as petrography and mineralogical differences between the syenitic and granitic rocks in the Perhentian islands.

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PETROGRAPHY

Plot of modal composition for the Perhentian Kecil syenite and Perhentian granite on a Q-A-P diagram is shown in Figure 2 (Streckeisen, 1967, 1976). All Perhentian granite samples plot in the syenogranite field whereas the Perhentian Kecil syenite samples grade from monzonite to syenite (Azman and Khoo, 1998). Both plutons show different trends, the Perhentian Kecil syenite samples show a similar trend to the rocks from alkaline province (e.g. Bowden and Turner, 1974) whereas the Perhentian granite samples plot in the field of granitoid formed by crustal fusion (e.g. Lameyre, 1966; Ashworth, 1976). The essential mineral in Perhentian Kecil syenite are K-feldspar, plagioclase, hornblende, pyroxene, quartz, biotite, sphene, epidote, apatite, zircon and magnetite whereas K-feldspar, plagioclase, quartz, biotite, hornblende, allanite, zircon, epidote and opaque phase made up the Perhentian granite.

GEOCHEMICAL DIFFERENCES BETWEEN THE SYENITE AND GRANITE

Selected Harker diagrams for the major elements of both plutons are shown in Figure 3. The range of SiO_2 for each of the Perhentian Kecil syenite and Perhentian granite are 46.8 to 65.9% and 70.96 to 75.35% respectively. The gap at SiO_2 of 65.9 to 70.96% probably represent a true compositional differences between the two plutons and not because of undersampling. This gap show that both rocks are different and not genetically related.

In rocks from the Perhentian Kecil syenite, Ba, Ce, La, Rb, Th increase and Sc, V, Sr, Pb, Y, Zn and possibly Zr decrease with increasing SiO_2 (Fig. 4). Trace elements in the Perhentian granite show some odd trends, thus Ce, Co, La, Nd, Pb, Th, Rb and Y neither increase nor decrease but produced a steeply vertical trends which is difficult to explain by simple fractional crystallization.

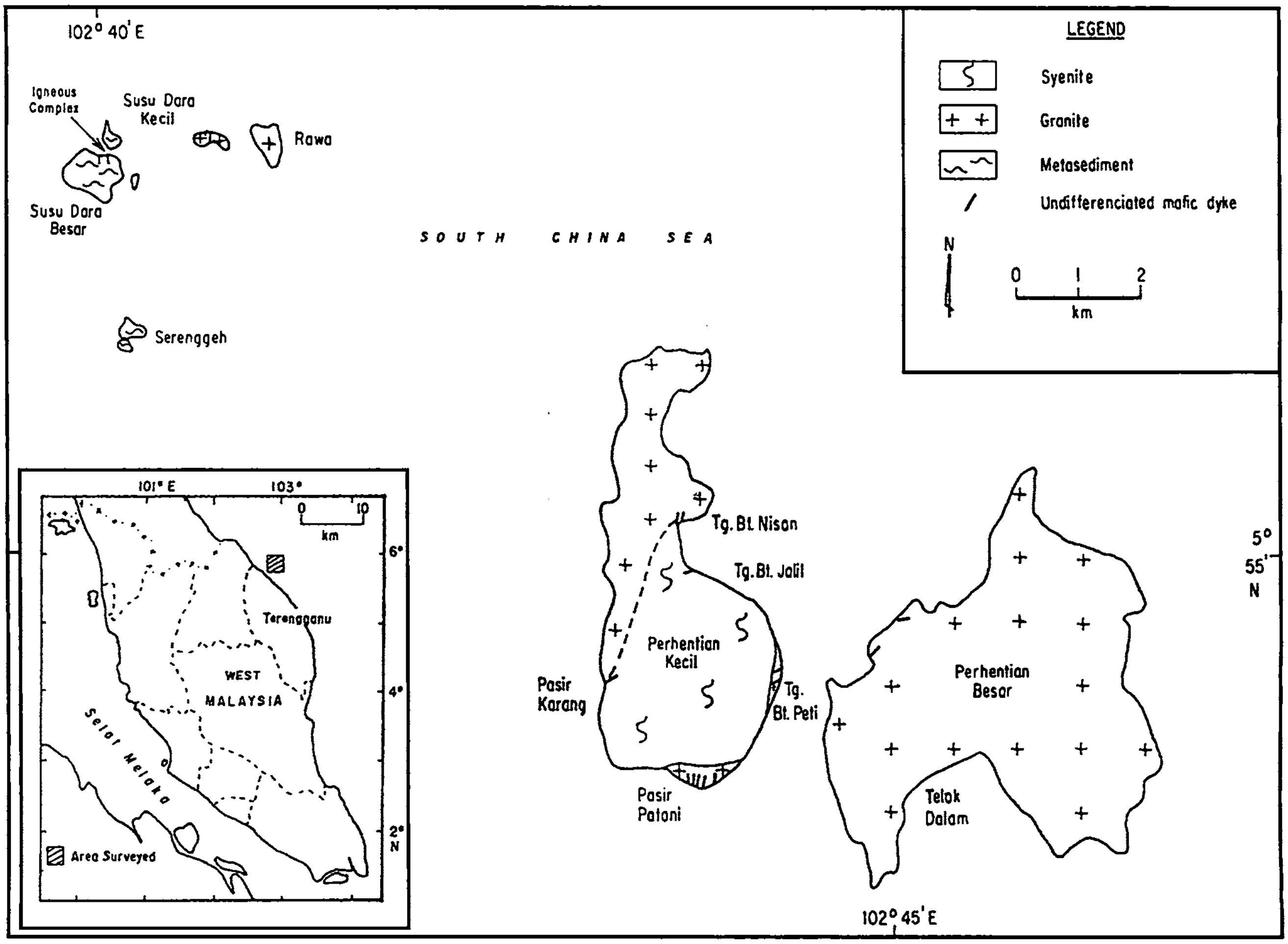

Figure 1. Geological map of the Perhentian islands and its surrounding area.

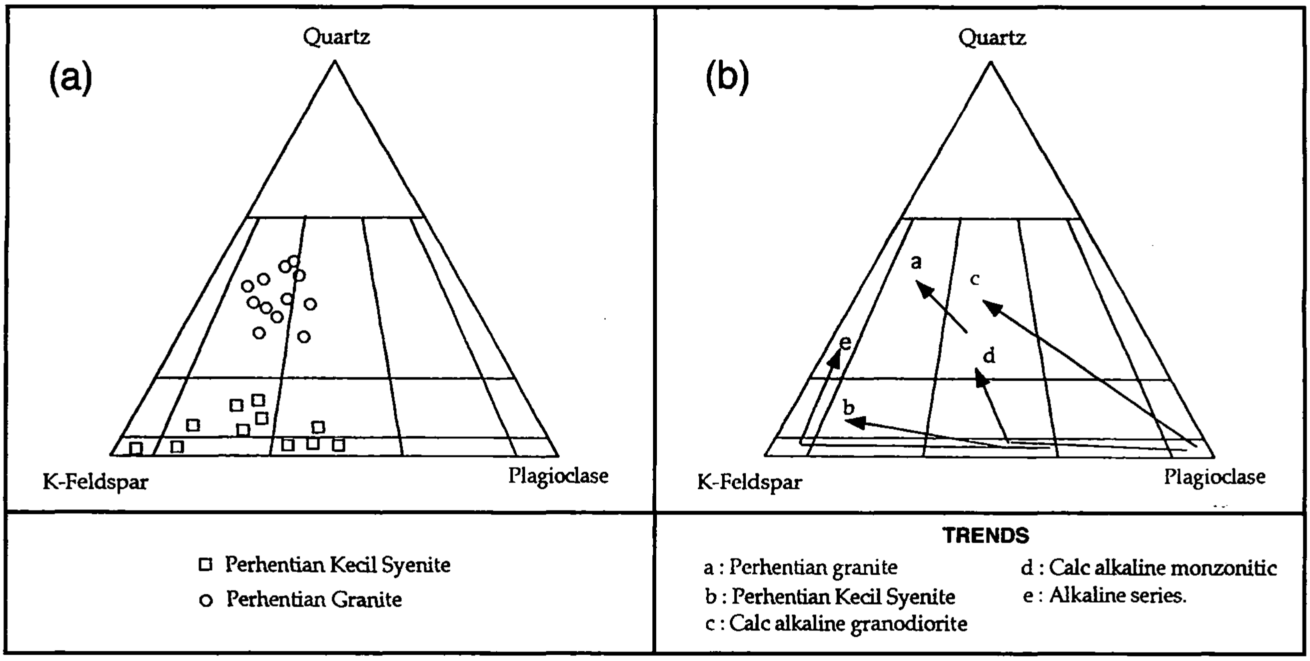

Figure 2. (a) Q-A-P classification of the Perhentian granite and Perhentian Kecil syenite. (b) General trend of both syenite and granite and comparison with other rock series elsewhere.

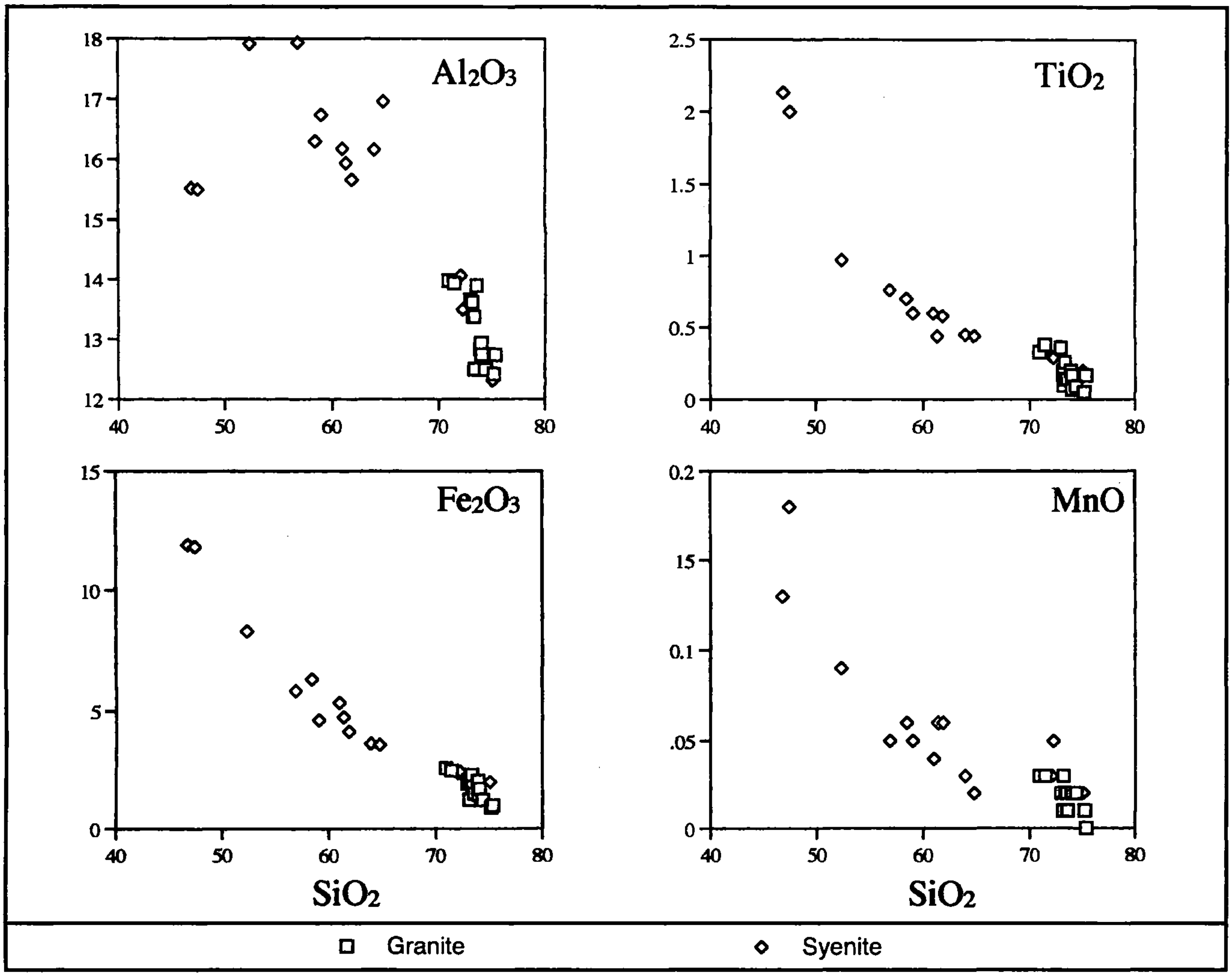

Figure 3. Selected major elements Harker diagram of the syenitic and granitic rocks.

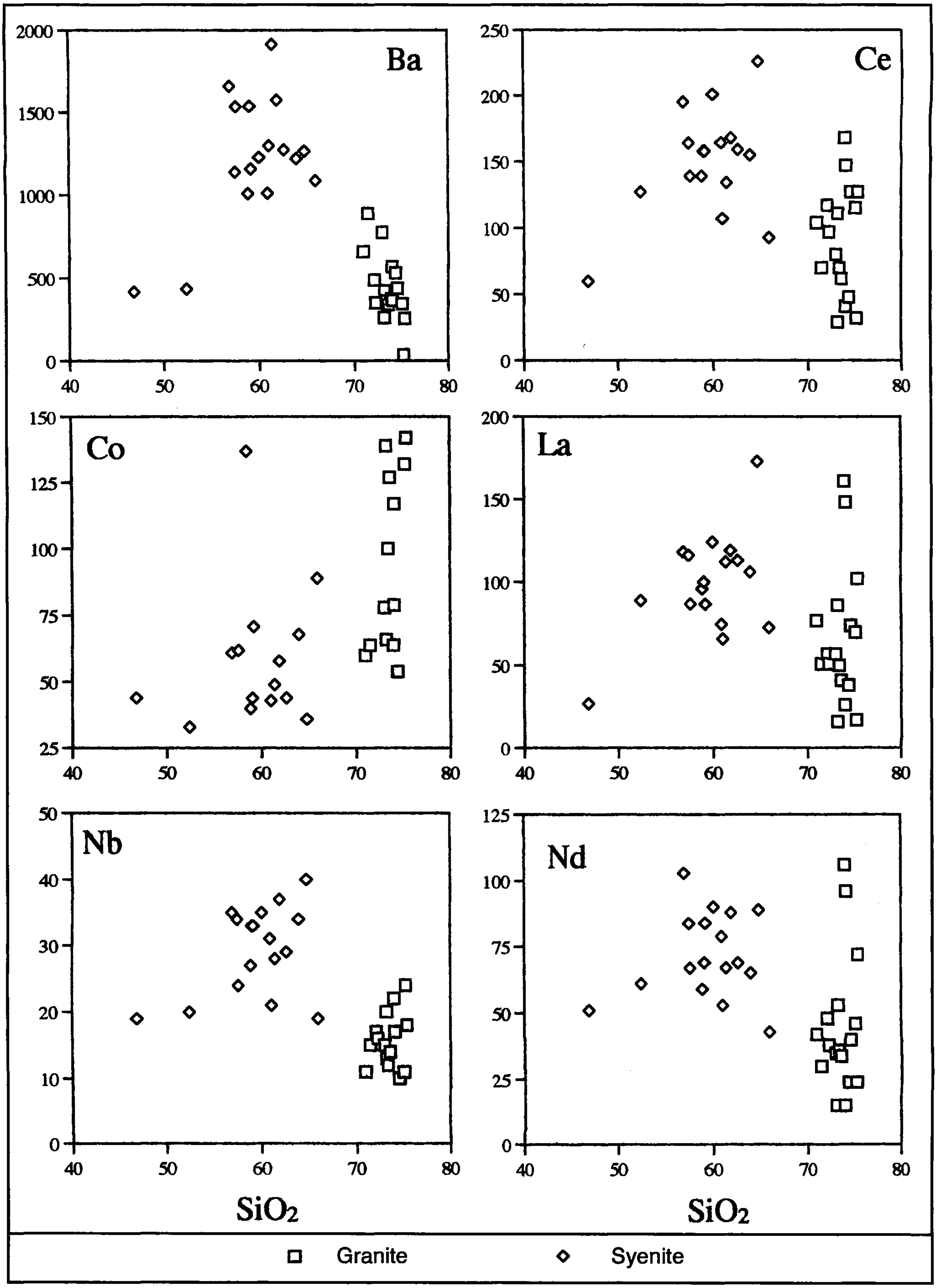

Figure 4. Selected trace elements Harker diagram of the syenitic and granitic rocks.

Both pluton show a different ACNK trend with SiO_2 (Fig. 5), thus the ACNK trend for the syenitic rocks increase whereas those from the granitic rock are decrease with increasing SiO_2. On a total alkali (Na_2O + K_2O) vs SiO_2 diagram (Fig. 6) (Lameyre and Bonin, 1991) both plutons show a different trend, with the Perhentian Kecil syenite trend evolved towards the nepheline normative and the data plot in the alkalic field. On the other hand, the Perhentian granite rocks seem to evolve towards the quartz normative and plot in the monzogranite field.

Plots of CaO and (Na_2O vs K_2O) vs SiO_2 (Fig. 7) emphasize the alkali calcic character of the syenitic rocks that is alkali-lime index of 54.5, as well as very different character, in alkali term, of the Perhentian granite pluton in which the CaO and (Na_2O + K_2O) curves do not intersect. This is due to the lower CaO and higher (Na_2O + K_2O) contents of the granitic rocks which are constant over the SiO_2 ranges (71–75%). Rocks from Perhentian Kecil syenite have high Sr and Ba compared to the Perhentian granite. Average content of both elements in the syenitic rock are Ba: 1,222 ppm and Sr: 1,929 ppm compared to the 439 ppm Ba and 142 ppm Sr in the granitic rock. All the Perhentian granite samples plot below the Ba/Sr = 1 and can be considered as low Ba-Sr granite (Tarney and Jones, 1994) (Fig. 8).

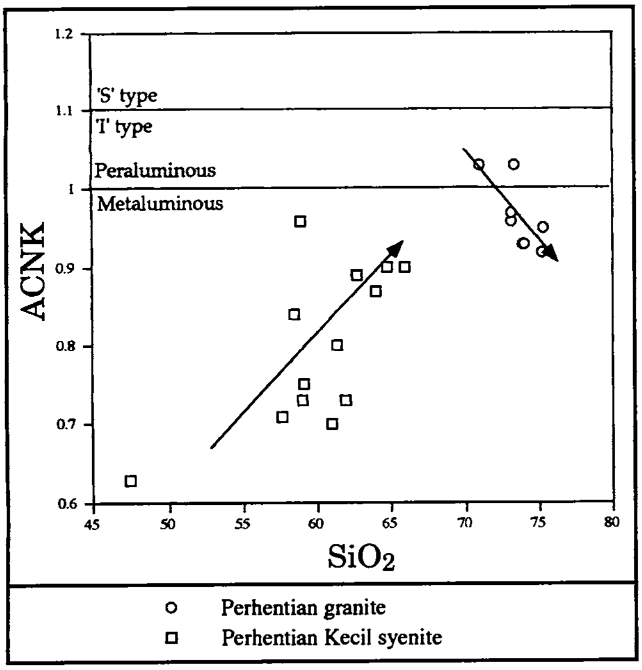

Figure 5. ACNK vs SiO_2 plot of the syenitic and granitic rocks. Line at ACNK = 1 divides peraluminous and metaluminous field and line at ACNK = 1.1 divides 'I' and 'S' type granite field.

The Perhentian granite has low total REE (106–382) compared to the Perhentian Kecil syenite (224–450). The granite also has more restricted La_N/Lu_N ratios (0.96–58.8) compared to the syenitic rock which has much wider La_N/Lu_N ratios (30.7–218.5). Steep REE patterns of the syenitic rocks, with large La_N/Lu_N, suggests the presence of residual garnet during the partial melting event. Furthermore, some of the Perhentian Kecil syenite samples show a slight concave upward REE pattern which may be the result of minerals such as garnet, clinopyroxene and amphibole having remained residual in their source (Williamson *et al.*, 1992)

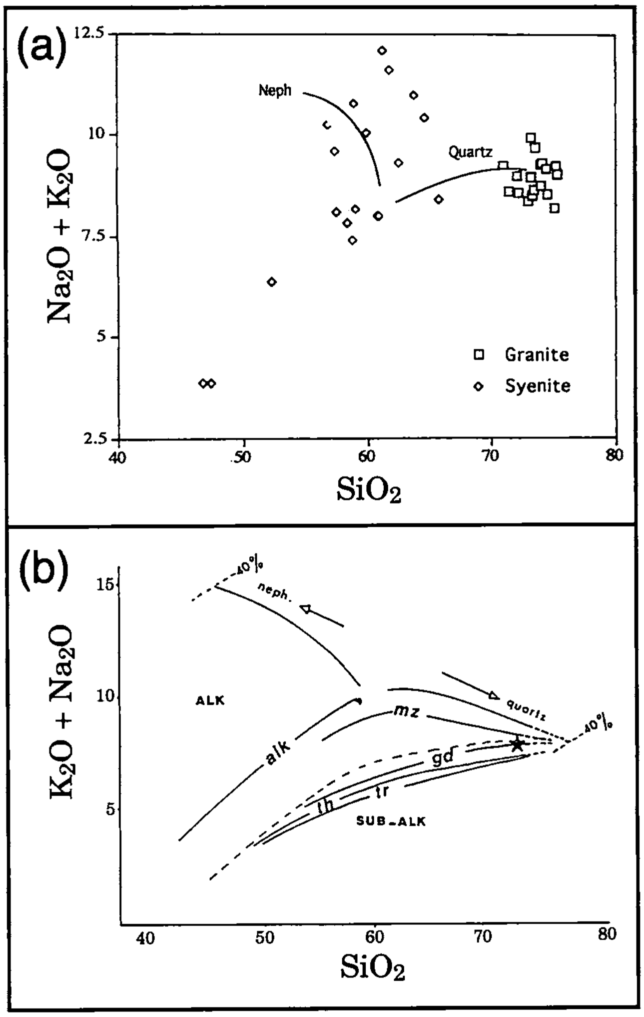

Figure 6. (a) Total alkali (Na_2O + K_2O) vs SiO_2 for the syenitic and granitic rocks. Normative quartz and nephline contents of 40% are delineated. (b) Main trends of some plutonic series in the same diagram for comparison. It show that the Perhentian Kecil syenite trend similar to the alkaline rock series. Alk = alkaline series, mz = monzonitic series, gd = granodioritic series, th = tholeiitic and transitional series, tr = tonalitic-trondhjemitic series. The broken line separates alkaline (ALK) from subalkaline (SUB-ALK) series. After Lameyre and Bonin (1991).

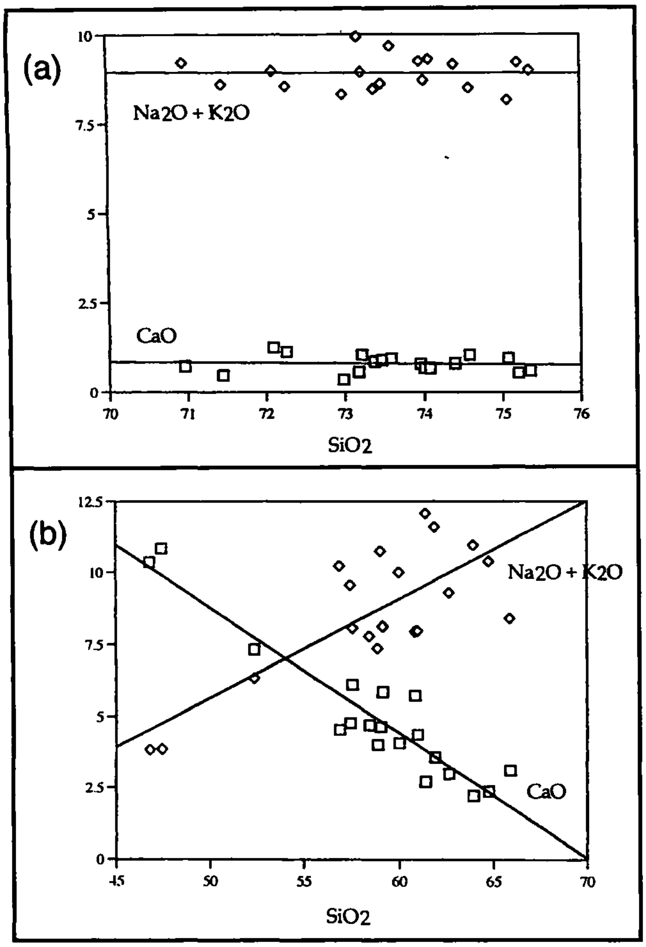

Figure 7. Combined plot $Na_2O + K_2O$ and CaO vs SiO_2 for the (a) Perhentian granite and (b) Perhentian Kecil syenite.

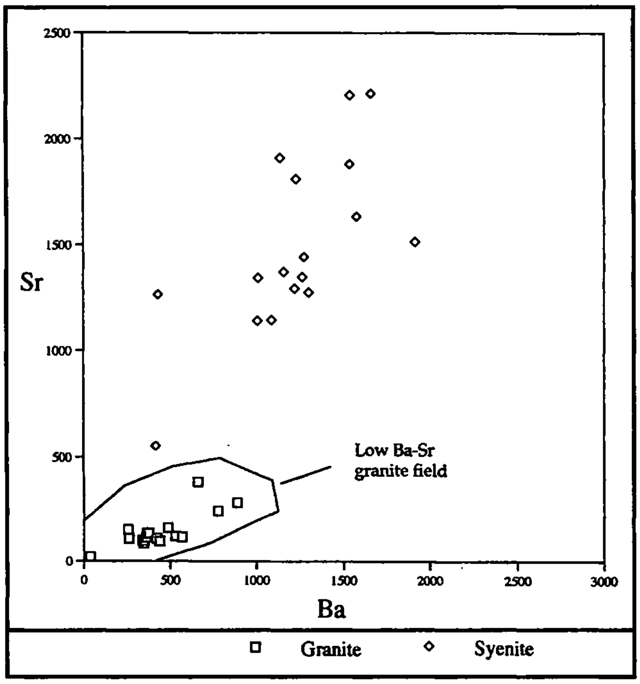

Figure 8. Sr vs Ba plot of the syenitic and granitic rocks from Perhentian area. Low Ba-Sr granite field is after Tarney and Jones (1994).

(Fig. 9). The chondrite normalised pattern of the syenitic rocks is also characterized by absence of Eu anomalies. The absence of prominent Eu anomaly in the syenitic rocks, indicates the plagioclase fractionation is not a necessary requirement in the development of this syenite intrusion (e.g. Liggett, 1990). The REE pattern of Perhentian granite (Fig. 9) has pronounce Eu anomaly, indicating plagioclase fractionation. One of the granite sample (sample TKG) show a typical 'seagull' shape profile with large Eu anomaly which is similar to REE profiles of other highly evolved granites and pegmatites elsewhere (e.g. Ludington, 1981; Whalen, 1983; Thorpe *et al.*, 1990). The sample generally has flat chondrite normalised pattern from LREE to HREE (except Eu anomaly). The spider diagrams of the trace elements (+K, P and Ti) for the rocks from Perhentian Kecil syenite and Perhentian granite are shown in Figure 10. The syenitic profiles is enriched in Pb, Rb, La, Ce, Sr, Nd, P, and Ti compared to the granite profile. The profiles suggesting no connection exist between the syenite and granite.

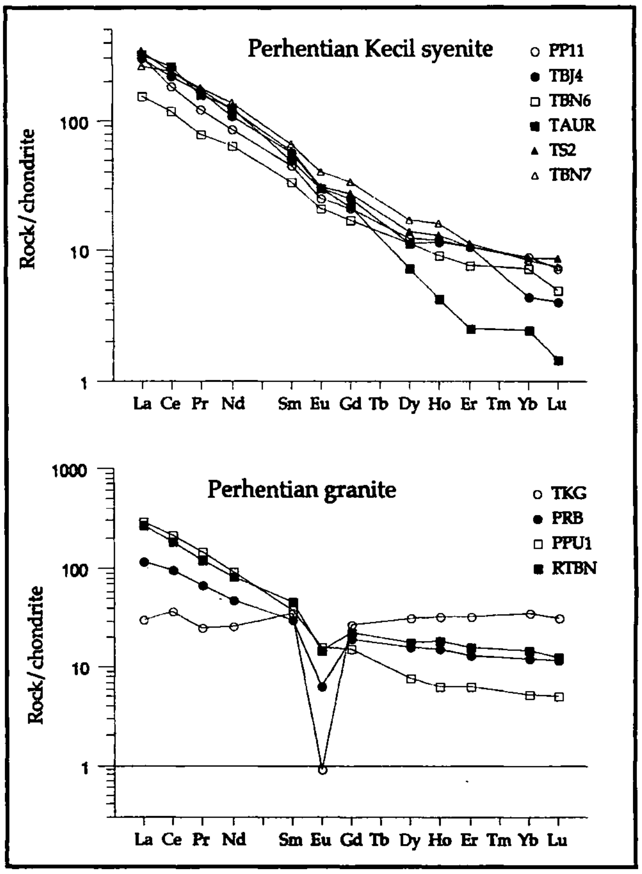

Figure 9. REE profiles for the syenitic and granitic rocks from Perhentian area.

CONCLUDING REMARKS

The Perhentian intrusion is a reversely zoned complex exposed over several islands off the coast Peninsular Malaysia. The intrusion is made up of Perhentian Kecil syenite rimmed by more evolved Perhentian granite. The former consists of a variety of igneous rocks ranging in composition from syenitic to monzonitic and even gabbroic rocks. The main body of Perhentian granite consists of medium to coarse grained granite as well as microgranite and granite porphyry occurring mainly at the contact with the Perhentian Kecil syenite. The interesting features shown by the rock association in the Perhentian area is that they are similar to the rocks in the alkaline province (e.g. Lameyre and Bowden, 1982). In this area, the high alkali Perhentian granite ($Na_2O + K_2O$: 8.16 to 9.93%) associates with the alkali feldspar syenites, monzonites and gabbros, the latter three formed the Perhentian Kecil syenite. The rock sequence is similar to alkali feldspar granite-alkali feldspar syenite-syenite-monzonite-gabbro of the alkaline granitoid series (see Lameyre and Bowden, 1982; p. 175). They have showed that these series and associated rocks are found in the areas of continental rifting (e.g. Oslo, Barth, 1944, in Streckeisen, 1967), anorogenic mid-plate magmatism which is either continental (e.g. Nigeria and Sudan, Jacobson *et al.*, 1958; Bowden and Turner, 1974) or oceanic (e.g. Kerguelen, Giret and Lameyre, 1980). The fact is further support by the Q-A-P plot. In this diagram, the syenitic rock show a trend similar to the rock from the other alkaline area (Lameyre and Bowden, 1982). The study showed that the Perhentian rocks indicate that both Perhentian granite and Perhentian Kecil syenite are made up of individual batches of melt.

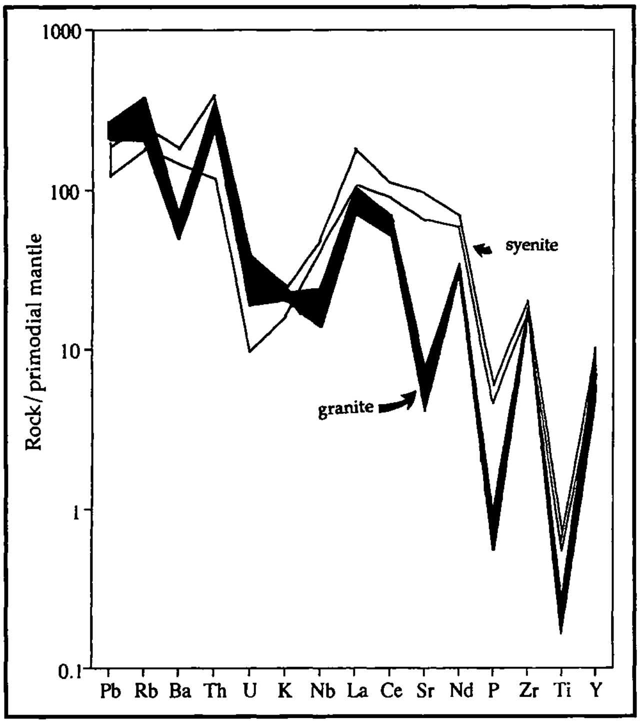

Figure 10. Multi-element variation diagram illustrating geochemical characteristics of average Perhentian granites and Perhentian Kecil syenite. Elements are arranged with increasing incompatibility, right to left, for spinel-lherzolite mantle assemblage. Normalizing values after Sun and Mc Donough (1989). Note that the granite profile is more evolved compared to the syenitic profile.

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