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Paired host-enclave geochemistry of mafic microgranular enclaves in the Eastern Belt granite, Peninsular Malaysia

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Abstract: This paper describes some of the important petrographic characteristics of the mafic microgranular enclaves and their host rock as well as their chemical relationship to selected granitic rocks from the Eastern Belt granite of Peninsular Malaysia. The enclaves are invariably darker coloured and finer grained than the enclosing granitic rocks. They usually have sharp contact with the granitic host. Occurrence of acicular apatite and quartz-hornblende ocellar textures in the enclave indicates that quenching and hybridism are among the main processes during cooling of the magmas. The variable geochemical trends in the enclave and their host rocks probably related to the variable degrees of diffusive exchange between the enclave and their host rock magmas during slow cooling.

INTRODUCTION

It is recognized that mafic (mantle derived) magmas have an important role to play in the generation of granitic melts, through, for example providing heat energy for crustal anatexis. Petrologists have also recognized that the wide range of rocks types observed in many calc alkaline intrusions can be produced through mixing and mingling of mafic and felsic magmas (e.g Reid *et al.*, 1983). The term enclave was proposed by Lacroix (1890) to describe fragments of rocks enclosed in homogeneous igneous rocks. Among the common enclaves in igneous rock are xenolith (piece of country rocks introduced into magmas), schlieren (elongated or lenticular enclave with gradual margins), surmicaceous enclave (melting residues) and mafic microgranular enclave (blob of coeval magma that have sharp contact with their host). Although in most cases, enclaves are scattered in the granitoid plutons, they may be locally associated in swarms. The polygenic swarms contain various types of enclave in contrast to monogenic swarms that group only one type of enclave.

In Peninsular Malaysia, mafic microgranular enclaves (MME) are found abundantly in the Eastern Belt granite. The granite is compositionally expanded calc-alkaline series mainly metaluminous I-type characterised by hornblende and sphene. The batholiths are mainly small and composite ranging from gabbro to granodiorite and monzogranite. The present paper describes the general characteristics of mafic microgranular enclaves in the Eastern Belt, with emphasis on the paired host enclave geochemistry. The Eastern granitoid province which consists of the Central Belt and the Eastern Belt (Cobbing *et al.*, 1992) comprises an extended compositional spectrum from gabbro to monzogranite. The whole province consists of several batholith such as the Boundary Range, Kapal and Stong complexes to the north and the Blumut Muntahak granite to the south (Johore). The batholiths are surrounded by narrow contact metamorphic aureoles superimposed on low grade metamorphic country rocks (Hutchison, 1977). A biotite ± hornblende monzogranite – granodiorite of variable texture is the most common rock type. Mafic dykes of continental tholeiite, and similar to the magma formed in a within plate tectonic settings are common (Azman, 2000).

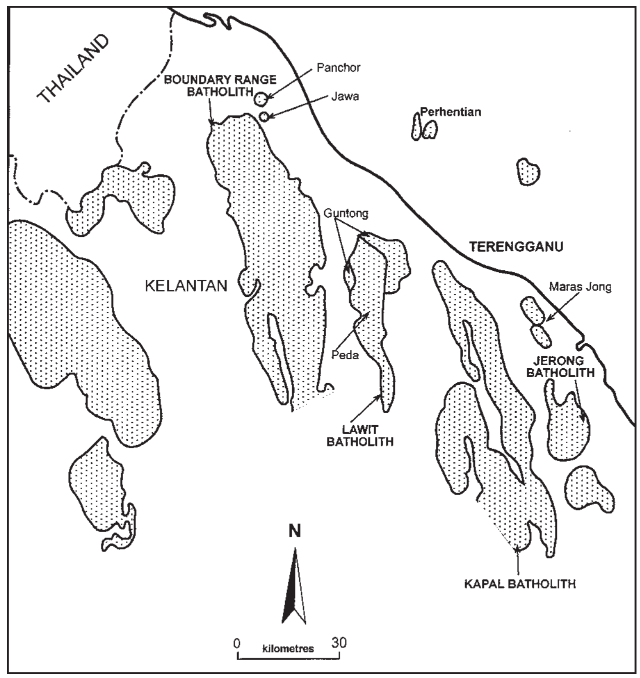

Figure 1: Map showing the granitic batholith of the northern part of the Eastern Belt of Peninsular Malaysia. The undifferentiated Jerong and Maras Jong batholiths are located at the eastern part of the Kapal batholith.

In this paper the samples for enclave study are taken from the Jerong and Maras Jong granite (Figure 1) located at the central part of the Eastern Belt Granite. The Jerong batholith is a small but complex body having a compositional range from gabbro to granite. Cobbing *et al.* (1992) has identified five granitic bodies in the Jerong batholith: the Tanggol, Wakaf, Temiang, Kenanga and Ajil granites. The gabbroic body known as the Mempelas Gabbro is ilmenite bearing and contains both olivine and hornblende gabbro. The gabbroic body is located at the center of the batholith. The enclave samples for geochemical study are taken mainly from Temiang granite. The Maras Jong granite is located to the north of the Jerong granite and is divided into two units, the granite proper and grey microgranite dykes that intruded the granite. Texturally the Maras Jong Granite proper shows little variation, being medium to coarse grained, partly porphyritic and holocrystalline. The main rock type is a coarse to very coarse grained megacrystic biotite granite.

FIELD OCCURRENCE AND PETROGRAPHY OF THE MME IN THE EASTERN BELT GRANITE

The mafic microgranular enclaves found in the Eastern Belt granite range from 1 cm to 50 cm in size. The enclaves are finer grained and darker coloured than their host and usually have a well defined, sharp contact with the surrounding host granite. Sometimes they show porphyritic texture. Their distribution, however is not restricted to any particular part of the granite as observed. Microscopically the enclaves are holocrystalline and consist of K-feldspar, quartz, plagioclase, biotite, hornblende, clinopyroxene, apatite, zircon, magnetite, chlorite and epidote. The mafic minerals constitute about 30 to 70% of the enclaves and are mainly biotite, hornblende and clinopyroxene. Hornblende sometimes rimmed a quartz crystal, forming a quartz-hornblende occeli texture. Biotite occurs as euhedral to subhedral crystals with the colour ranging from reddish brown to green. Plagioclase crystal is usually zoned and the composition ranges from An_{27} to An_{32}. Apatite crystals of accicular and equant shape are found as accessory minerals.

PAIR HOST-ENCLAVE GEOCHEMISTRY

Major and trace elements of the enclave and their host rocks are given in Table 1. The enclave – host paired samples were collected from several different plutons. The range of SiO_2 for the enclave and the host rock are 50.47 to 66.04% and 68.88 to 72.59% respectively. In general, the plots show clear trends of decreasing Al_2O_3, TiO_2, Fe_{tot}, MgO, CaO and P_2O_5 with increasing SiO_2. The Harker diagrams also show that there is a gap between the enclave and their host rock at SiO_2 of 66.04 to 68.9%. The enclave samples have higher Al_2O_3 (except for one sample containing 14% Al_2O_3) TiO_2, Fe_{tot}, MgO, CaO, Na_2O and P_2O_5 but lower K_2O contents compared to the granitic host. In some of the major elements plot (e.g. MgO and Fe_{tot}) both the enclave and their host rock form a good decreasing trend, similar to the trend produce by two co-magmatic magmas. The relationship between paired enclave-host is shown in Figure 3. In this diagram SiO_2 is plotted against paired enclave – host samples. A line was drawn between the enclave and the host rock where the enclave was found. In all samples analysed, the host rock has higher SiO_2 content compared to their enclave. The highest difference is the E2–H2 pair, with a gap of about 22% SiO_2 and the lowest is about 5% (sample E3-H3).

Harker diagrams of trace elements are shown in Figure

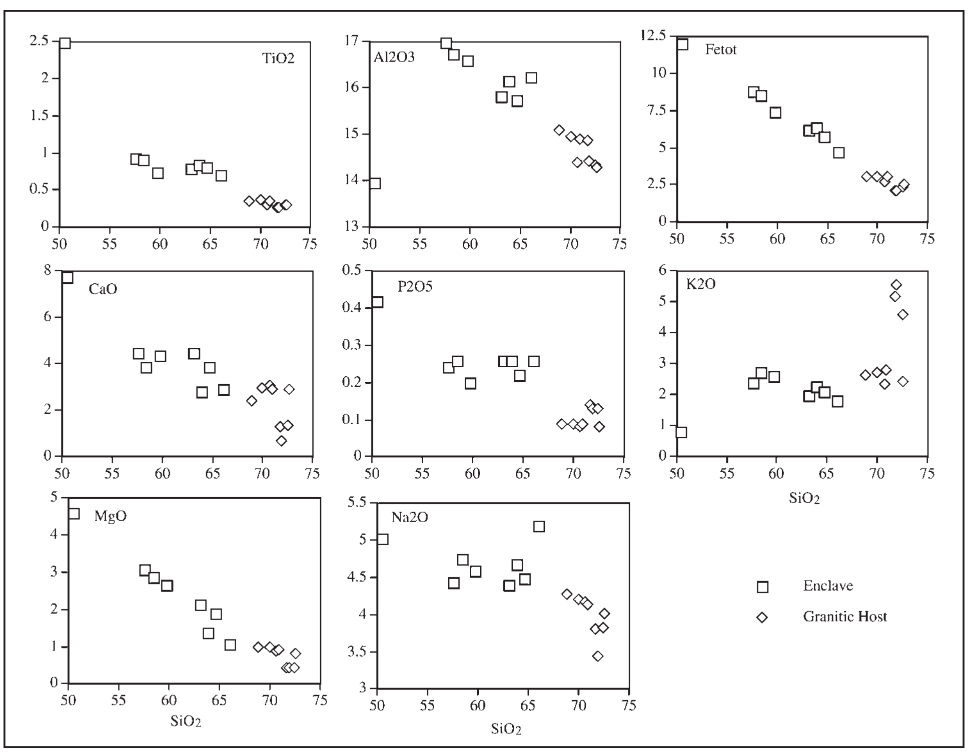

Figure 2: Major elements Harker diagrams of the enclave and the host granite from the study area . Values in wt%.

Table 1: Representative major and trace elements of the enclaves from the study area.

Sample No	ENC1E Enclave	ENC1R Host Granite	ENC2E Enclave	ENC2R Host Granite	ENC3E Enclave	ENC3R Host Granite
Major element in wt%						
SiO_2	63.11	72.59	50.47	71.90	66.04	71.74
TiO_2	0.79	0.29	2.48	0.27	0.7	0.27
Al_2O_3	15.82	14.28	13.94	14.43	16.23	14.86
Fe(tot)	6.21	2.52	12.03	2.08	4.69	2.14
MnO	0.11	0.03	0.21	0.04	0.08	0.05
CaO	4.47	2.89	7.73	0.69	2.91	1.32
K_2O	1.96	2.43	0.80	5.56	1.81	5.18
P_2O_5	0.26	0.08	0.42	0.13	0.26	0.14
MgO	2.14	0.81	4.59	0.43	1.06	0.44
Na_2O	4.40	4.02	5.02	3.45	5.20	3.80
LOI	0.72	0.39	1.35	0.86	0.66	0.48
Total	99.99	100.33	99.04	99.84	99.64	100.42
Trace element in ppm						
Ba	423	389	112	275	81	244
Ni	10	6	11	12	8	13
Pb	5	5	19	32	21	33
Rb	117	79	179	303	265	304
Sr	307	277	155	136	158	129
Th	11	12	21	20	16	18
V	82	25	53	20	48	19
Zr	194	126	263	152	280	153
Zn	73	34	81	35	100	49
Cu	6	8	9	8	6	7
U	2	1	9	7	8	7
Nb	15	9	28	21	29	21

4. In all elements both of the enclave and the host rock samples show a scattered plot and no distinct trend. Many of the elements overlap, particularly Ba, Ni, Rb,Th, Zr and U.

CONCLUDING REMARKS

The relative fine grained size of the enclaves is consistent with a high nucleation rate and low growth rate, which apply when the degree of undercooling of magma is relatively large. This can occur when a globule of relatively mafic magma comes into contact with the granitic magma. This implies that magma of the globule is much more undercooled than the granitic magma with respect to its liquidus (Vernon, 1983). The occurrence of large K-feldspar crystals in the enclave has been interpreted in various ways, this include as phenocryst/megacrysts (Furman and Spera, 1985; Vernon, 1986; Frost and Mahood, 1987), porphyroblast (Pitcher and Berger, 1972; Augustithis, 1973 ; Le Bas, 1982) and foreign crystals (Cantagrel *et al*., 1984). The occurrence of igneous microstructures such as inclusions of biotite in the large K-feldspar crystals (Stone and Austin, 1961) and glomeroporphyritic texture formed by the large crystals suggest that they are phenocrysts or megacrysts. Vernon (1986) suggests that the large size of the megacrysts is evidently due to nucleation difficulties for K-feldspar in granitic melts.

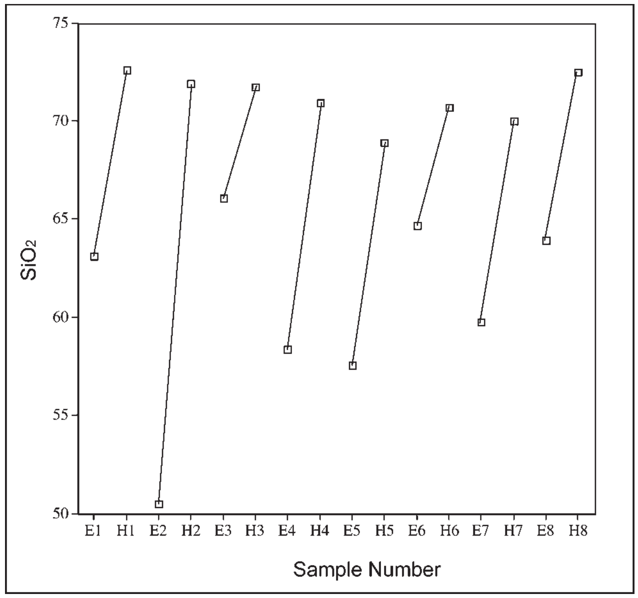

Figure 3: SiO_2 content (wt%) between paired enclave-host granite from the study area.

Occurrence of the acicular apatite indicates that the crystals were quenched, when globules of relatively mafic magma came into contact with cooler granitic magma (Wyllie *et al*., 1962). Gardner (1972) reported similar quenched apatites from the super-cooled roof zone of a basic magma chamber. The presence of quenched apatite in the mafic microgranular enclave is significant since apatite is judged to be an early crystallising phase. This implies that the basic magma must have been virtually crystal free when it was injected into the felsic granitic magmas. The presence of quartz-hornblende ocellae suggests that some mixing between the two magma took place. The texture probably formed in response to the instability of quartz in the mafic magma (Vernon, 1991).

The variable geochemical trends in the enclave and their host rocks especially in the trace elements, probably related to the variable degrees of diffusive exchange between the enclave and their host rock magmas during slow cooling (Waight *et al*., 2001).

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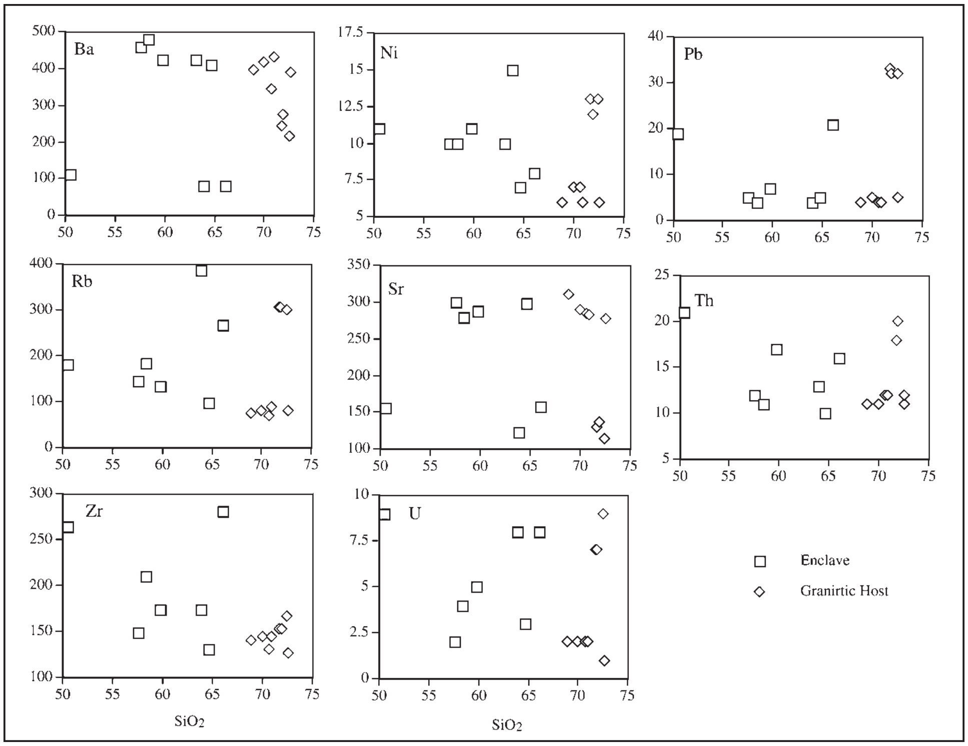

Figure 4: Harker diagrams trace elements of the enclave and the host granite from the study area. SiO_2 in wt% and trace elements in ppm.

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