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Chemical variation of muscovite from the Kuala Lumpur granite, Peninsular Malaysia

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Abstract: This work presents new muscovite analyses from the Kuala Lumpur granite. The muscovites have been analysed from three different samples namely equigranular normal biotite-muscovite granite (normal facies — NBMG), deformed muscovite granite (deformed facies — DBMG) and porphyritic biotite-muscovite granite (contact facies — PBMG). On textural ground the muscovite can be divided into primary and secondary. The primary muscovite is characterised by subhedral to euhedral shape, large grain size and occurs as muscovite clot. Those of secondary origin occurs mainly as replacement of feldspar. The primary muscovite is characterised by high Ti, Al, Mg/Mg + Fe and Ba and low Na and P. The major difference of the muscovites from the three samples are the TiO_2 contents. Thus, muscovites from the PBMG have the lowest TiO_2 content (mean: 0.04%) and those from the NBMG have the highest TiO_2 content (mean: 0.53%). All muscovites sample from the DBMG and PBMG plot in the secondary muscovite field of Miller *et al.* (1981) those from the NBMG plot in the primary muscovite field. Muscovites from the NBMG have high BaO and low P_2O_5 contents compared to those from the other two samples. The decreasing Na content in muscovite from the DBMG may be related to the decrease of formation temperature and the variation of Fe, Mg and Al with Si can be related to solid solution between the end members muscovite and caledonite.

INTRODUCTION

The occurrence of primary muscovite in granitic rocks has been used both as an indicator that the magma source rock was peraluminous (Miller *et al.*, 1981), and an estimate of the conditions under which it crystallized (Zen, 1988). Among the textural criteria for primary muscovite in granitic rocks are, (1) large grain size, (2) subhedral to euhedral shape, (3) occurs in a host rock with clean, unaltered igneous texture and (4) is not enclosed by, or raggedly encloses a mineral (Miller *et al.*, 1981). Miller *et al.* (1981) found that most texturally defined primary muscovite are considerably higher in Ti, Al and Na and lower Mg and Si than secondary muscovite. High Ti in primary muscovite has been noted by Anderson and Rowley (1981) who pointed out the analogy with high grade muscovite which are enriched in Ti compared to low grade muscovite.

This study presents new major elements (+ Ba) analyses of muscovite from the Kuala Lumpur (KL) granite. The muscovites were analysed from three different samples which represent different facies of the KL granite i.e. normal, deformed and porphyritic facies. There are:

1. Equigranular biotite-muscovite granite (normal facies) (NBMG).
2. Deformed muscovite granite collected within the KL fault zone. Muscovite from the deformed part of the KL granite (Ng, 1994) (deformed facies) (DBMG).
3. Porphyritic biotite-muscovite granite (PBMG). Muscovite from the 'contact' facies. The granite sample was collected in the marginal zone of the granite, (~10 meters from the contact with the country rocks) (contact facies). The sample from this study is taken from Batu Dam and detail geology of the area is given by Yusari Basiran (1993).

The aims of this paper are to provide the chemistry of the muscovite from the KL granite and to determine texturally and chemically whether the origin of the muscovites (whether primary or secondary).

GENERAL GEOLOGY

The KL granite is located on the western side of the Main Range batholith. Peninsular Malaysia (Cobbing *et al.*, 1992) (Fig. 1). It was emplaced into metasedimentary rocks (schists and phyllites) and limestones of the Silurian and Devonian age. In general the granite consists of two lobes, that is a smaller lobe to the west of Kuala Lumpur city and the main body to the east of the city. The rocks mainly are biotite to muscovite granite with local areas of fine grained tourmaline rich leucogranite. Two phase hydrothermally modified granites are also common. Pitfield *et al.* (1990) suggested that the large textural variation may reflects the

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constantly changing proportion of primary texture to late magmatic variants. The granite has been cut by several fault zones, for example the KL (Tjia, 1972) and the Bukit Tinggi Fault zones (Shu, 1969, 1989). The rock type of the deformed part of KL granite includes fault breccia, cataclasites and mylonites Ng (1994).

PETROGRAPHY

This section will emphasize the relation between muscovite and other minerals. All facies have a similar mineral content, that is alkali feldspar, plagioclase, biotite, muscovite, quartz, Fe-Ti oxide and tourmaline. Summary of petrographic features of the three samples is shown in Table 1. The main difference of the three samples is that the porphyritic texture shown by the PBMG and the biotite has pleochroism X = black brown and Y = foxy red brown compared to the other two samples, X = olive and Y = dark brown.

Based on the textural criteria, muscovites in all three samples can be divided into secondary and primary. Secondary muscovite occurs as small or

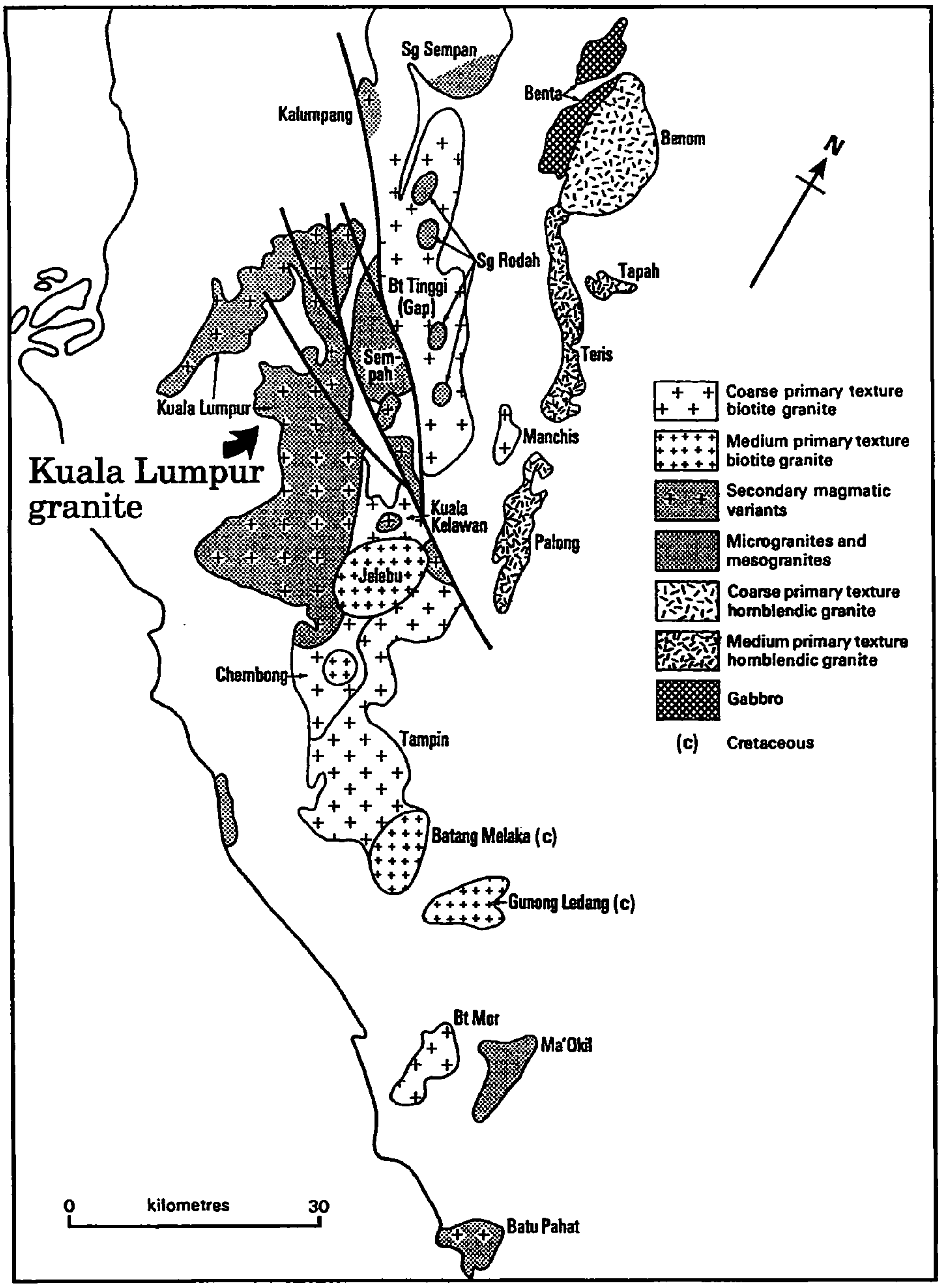

Figure 1. Map showing location of the Kuala Lumpur granite (Cobbing *et al.*, 1992).

Table 1. Summary of petrographic features of the three facies of the Kuala Lumpur granite.

PETROGRAPHIC FEATURES	CONTACT FACIES	NORMAL FACIES	DEFORMED FACIES
Mineralogy	Kf, Plag, Qtz, Bio, Musc, Tour, Zir, Opaque, Apa.	Kf, Plag, Qtz, Bio, Musc, Tour, Zir, Opaque, Apa.	Kf, Plag, Qtz, Bio, Musc, Tour, Zir, Opaque, Apa.
General Texture	Porphyritic.	Equigranular.	Equigranular, deformed.
Biotite	X = black brown, Y = foxy red brown. Small crystal (< 1.5 mm). Chloritised, pleochroic haloes.	X = olive, Y = dark brown, 0.5 to 2 mm in size. Chloritised.	X = olive, Y = dark brown, 0.5 to 3 mm in size. Highly chloritised (pale green).
Plagioclase	2 phases, small euhedral as inclusion in Kf (< 0.5 mm) and large euhedral to subhedral (up to 6 mm). Zoning — well developed.	Subhedral to anhedral (up to 4 mm).	Small subhedral to anhedral (< 2 mm).
K-Feldspar	Microline — microperthite.	Microcline-microperthite	Microcline-microperthite.
Accessory Mineral	Opaque, Zir (inc in Bio), Apa.	Opaque, Zir (inc in Bio), Tour (euhedral-anhedral).	Opaque, Zir (inc in Bio), Tour (anhedral).
Muscovite	Skeletal grains in Plag/Kf. Small inc. in Plag is less common (secondary)	Subhedral to anhedral shape, large (0.5–3 mm), clot up to 5 grains (primary). Small Musc grains (0.1 mm) in plagioclase or as an alteration product along grain boundary (secondary).	Secondary skeletal, replace Plag and main component of the foliation.

Kf: K-Feldspar Plag: Plagioclase Qtz: Quartz Bio: Biotite Musc: Muscovite
Zir: Zircon Apa: Apatite Tour: Tourmaline Opaque: Opaque phases

skeletal crystals as a result of alteration of plagioclase and K-feldspar. This type of muscovite is small (less than 0.5 mm) and occurs in heavily sericitised parts of plagioclase (Fig. 2a). Sometimes the tiny muscovite flakes are well oriented at the centre of plagioclase suggesting that they developed along cracks. None of the muscovite of this type extends outside of the plagioclase crystal. These textural relationships suggest that the muscovite is not primary but altered from the plagioclase. This type of secondary muscovites are found in all three facies. The skeletal muscovite occurs mainly in the PBMG (Fig. 2b). Textural relationship also strongly suggests that the muscovite (0.5 to 1 mm across) is replaced an early plagioclase and K-feldspar.

Primary muscovite occurs as large subhedral to anhedral crystals adjoining all other rock forming minerals. Sometimes they form a clot of 5 to 6 muscovite crystals and usually associated with biotite. Single crystal can be up to 3 mm in size. This type of muscovite is only found in the NBMG and makes up less than 2% of the total modes.

CHEMISTRY OF MUSCOVITE

Compositions of the muscovite have been determined by using electron microprobe analysis located at the University of Manchester. A total of 28 muscovite analyses were obtained from the three different facies. Representative muscovite analyses for the three facies are given in Table 2. Structural formulae was calculated on the basis of 22 oxygens.

Muscovite from individual samples show inconsistent pattern of elements from core to rim. Muscovite from the PBMG show an increase of MgO from core to rim whereas those from DBMG show a decrease of FeO in the same direction. Muscovite from NBMG show a decrease of Al_2O_3, TiO_2 and perhaps Na_2O from core to rim.

Bivariate plots of the major elements versus Mg/Mg + Fe values for these muscovites are shown in Figure 3. Muscovite from the DBMG has high Si, Fe, Mn and K compared to muscovite from the other facies. Muscovites from the NBMG have high Al, BaO and Mg/Mg + Fe ratio and those from the PBMG are slightly higher in Na compared to the other facies. The major difference of the muscovites in the three facies is the TiO_2 contents. Thus, muscovites from the PBMG have the lowest TiO_2 content (0 to 0.028%; mean: 0.04%) and those from the NBMG have the highest TiO_2 content (0.29 to 0.65%; mean: 0.53%). The DBMG muscovites have intermediate TiO_2 content (0.02–0.67%; mean: 0.46). The low TiO_2 content of the muscovites from the PBMG is shown in the TiO_2 vs MgO vs Na_2O diagram (Fig. 4). All the samples from this facies plot in the secondary muscovite field of Miller *et al.* (1981). All the NBMG samples plot in the primary muscovite field.

The variation diagrams of Si with respect to Al, Fe, Mg and Na (Konings *et al.*, 1988) (Fig. 5) show remarkable differences between the chemical composition of muscovite from the different facies. Muscovite from the DBMG has the widest range of Si(pfu) content compared to the other facies. Good

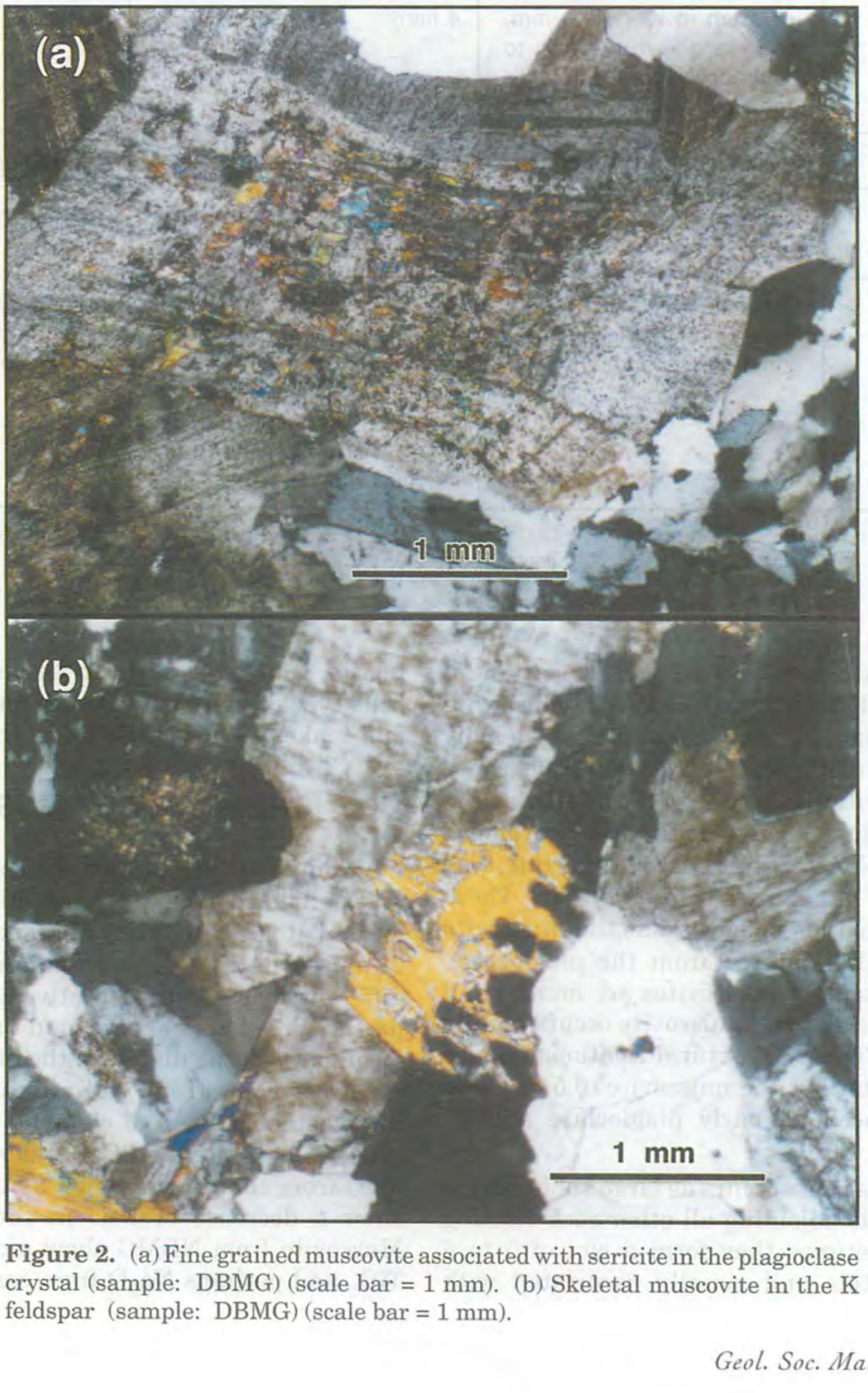

Figure 2. (a) Fine grained muscovite associated with sericite in the plagioclase crystal (sample: DBMG) (scale bar = 1 mm). (b) Skeletal muscovite in the K feldspar (sample: DBMG) (scale bar = 1 mm).

Table 2. Representative muscovite analyses of the Kuala Lumpur granite.

Sample	PBMG	PBMG	PBMG	PBMG	DBMG	DBMG	DBMG	DBMG	NBMG	NBMG	NBMG	NBMG
Facies	Contact	Contact	Contact	Contact	Deform	Deform	Deform	Deform	Normal	Normal	Normal	Normal
Location	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim
wt %												
SiO_2	45.99	45.54	46.07	46.07	45.82	46.92	47.23	46.05	45.75	45.57	45.36	45.54
TiO_2	0.03	0.00	0.00	0.00	0.57	0.63	0.67	0.48	0.65	0.53	0.54	0.45
Cr_2O_3	0.02	0.00	0.00	0.10	0.01	0.05	0.04	0.00	0.02	0.02	0.03	0.03
Al_2O_3	34.53	33.99	34.40	33.79	30.41	29.87	29.47	28.76	33.22	33.14	33.50	33.40
FeO	1.40	1.19	1.46	1.18	4.09	3.63	4.14	5.44	1.83	2.45	1.64	1.41
MnO	0.00	0.03	0.00	0.00	0.15	0.02	0.25	0.29	0.10	0.00	0.00	0.00
MgO	0.72	0.73	0.80	0.84	1.32	1.46	1.49	1.70	0.78	1.02	0.91	0.56
Na_2O	0.56	0.59	0.60	0.47	0.30	0.40	0.42	0.32	0.84	0.83	0.98	0.91
K_2O	10.30	10.28	10.39	10.57	10.56	10.62	10.03	10.61	10.03	10.19	10.09	9.94
CaO	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P_2O_5	0.21	0.01	0.11	0.08	0.07	0.00	0.04	0.05	0.07	0.14	0.11	0.11
BaO	0.00	0.15	0.00	0.00	0.06	0.00	0.00	0.00	0.07	0.13	0.06	0.40
Total	93.75	92.52	93.83	93.12	93.37	93.60	93.77	93.69	93.35	93.99	93.20	92.75
Structural formulae on the basis of 22 oxygens												
Si	6.22	6.24	6.24	6.27	6.34	6.45	6.48	6.41	6.24	6.20	6.20	6.25
Ti	0.00	0.00	0.00	0.00	0.06	0.07	0.07	0.05	0.07	0.05	0.06	0.05
Cr	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Al	5.50	5.49	5.49	5.42	4.96	4.84	4.77	4.72	5.34	5.32	5.40	5.40
Fe	0.16	0.14	0.17	0.14	0.47	0.42	0.48	0.63	0.21	0.28	0.19	0.16
Mn	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.01	0.00	0.00	0.00
Mg	0.15	0.15	0.16	0.17	0.27	0.30	0.31	0.35	0.16	0.21	0.18	0.12
Na	0.15	0.16	0.16	0.13	0.08	0.11	0.11	0.09	0.56	0.22	0.26	0.24
K	1.78	1.80	1.79	1.84	1.87	1.86	1.76	1.88	1.75	1.77	1.76	1.74
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	0.02	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.01
Ba	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
Total	13.95	13.99	14.01	13.99	14.08	14.06	14.01	14.17	14.01	14.07	14.04	13.99

correlation trend is only shown by the muscovite from the DBMG. Thus Al and Na decrease and Mg and Fe increase with increasing Si. Konings *et al.* (1988) suggested that the decreasing Na content in muscovite from Abas granite, Portugal, may be related to the decrease of formation temperature and the variation of Fe, Mg and Al with Si can be related to solid solution between the end members muscovite and caledonite.

DISCUSSION

Ti content of white mica has been used, along with other criteria, to distinguish magmatic from subsolidus muscovite (Miller *et al.*, 1981; Speer, 1984; Villa *et al.*, 1997). Although Zen (1988) has suggested that muscovite containing more than 0.6% TiO_2 is a candidate for primary muscovite, the Ti content of the normal facies of Kuala Lumpur granite (0.29 to 0.65%; mean: 0.53%) is somewhat comparable to white micas interpreted as of magmatic origin (e.g. Villa *et al.*, 1997). This is supported by the textural evidence such as large grain size, subhedral to euhedral shape and occurrence as glomerocryst. Based on the textural ground, secondary muscovite occurs in the all three samples. Occurrence of secondary and primary muscovite in a single sample or even in a single crystal is not uncommon. Dempster *et al.* (1994) showed that both types of muscovite can occur together in a single crystal. They have examined muscovites from the Oughterard granite using backscattered electron image and found an overgrowth of postmagmatic layer of muscovite on magmatic grains. The secondary muscovite occurs mainly as replacement products of plagioclase during the subsolidus stage. In this stage, plagioclase will served as nucleation site to the secondary muscovite.

Occurrence of inferred primary muscovite in the Kuala Lumpur granite suggests that the granite formed from magma under relatively high water pressure. Hall (1966, 1993) in explaining the primary muscovite from the Rosses granite,

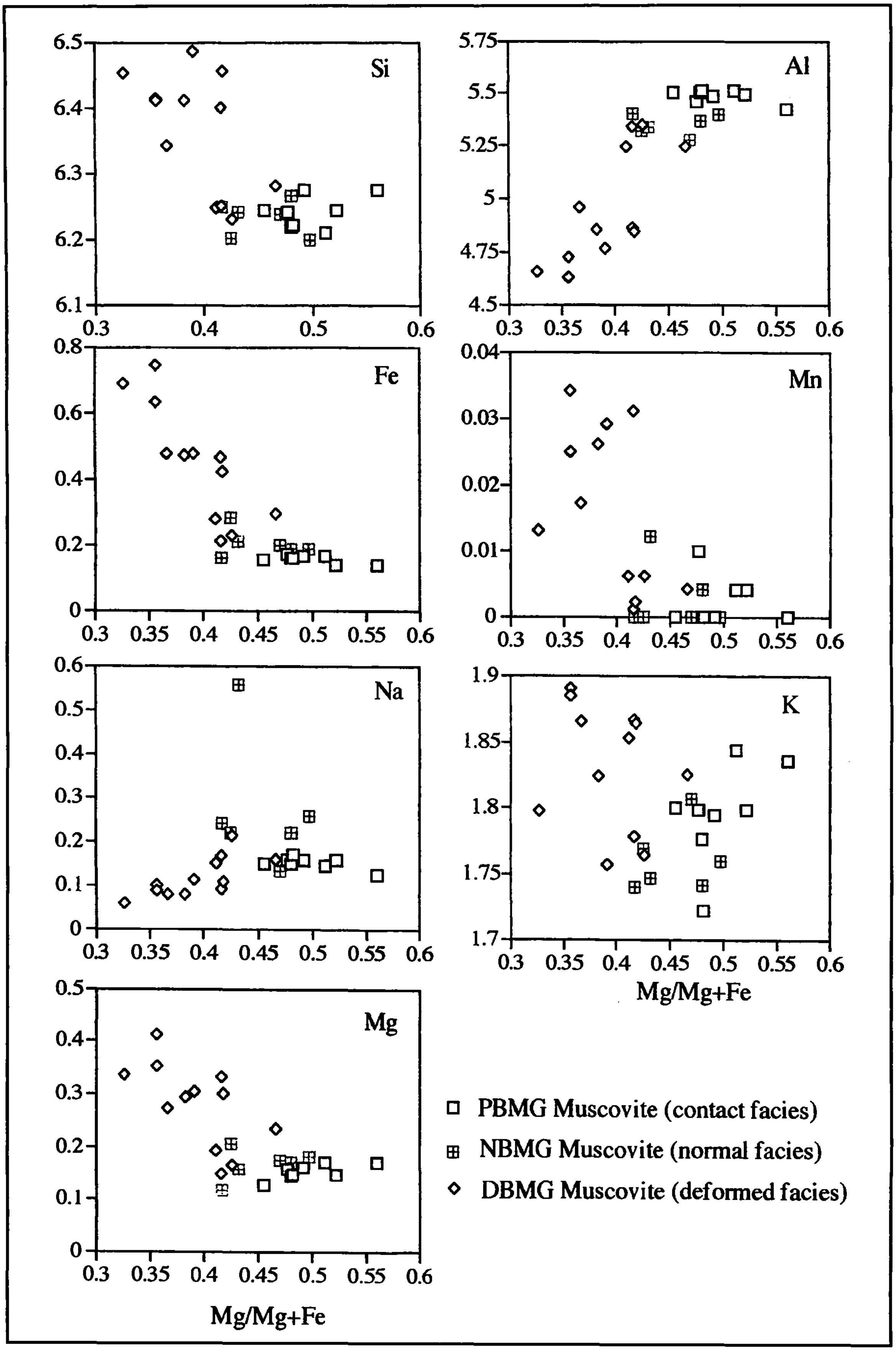

Figure 3. Bivariate plot of major elements vs Mg/Mg + Fe of the muscovites from the Kuala Lumpur granite.

Donegal, suggested that the water pressure can increase in granitic magma during the crystallisation of feldspar and quartz. The crystallisation of these minerals, which are all anhydrous minerals, can cause the water pressure to rise as the proportion of liquid to crystals decrease. Thus, the muscovite will crystallise after the pressure was sufficiently high in the magma chamber.

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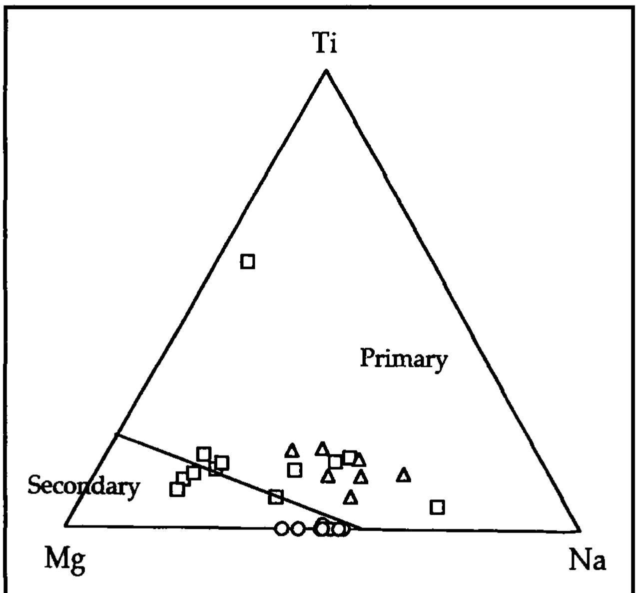

Figure 4. Ti vs Mg vs Na diagram for muscovite from the Kuala Lumpur granites. Primary and secondary muscovite field after Miller *et al.* (1981).

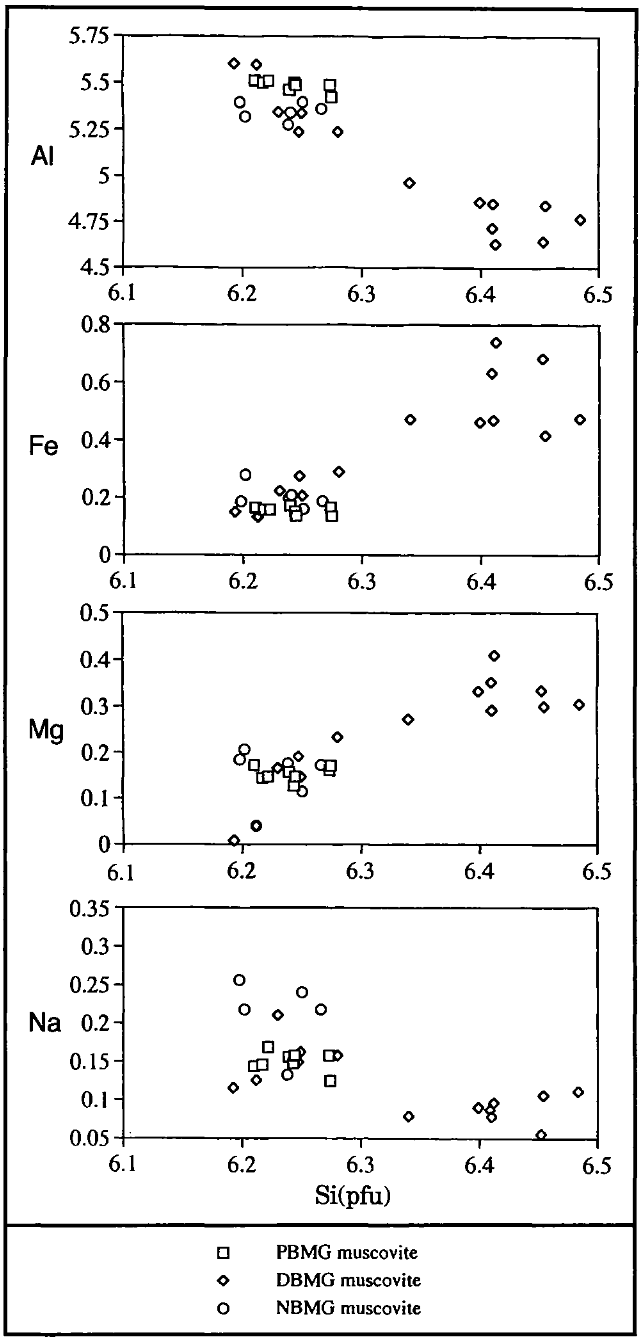

Figure 5. Variation diagram of Al(pfu), Fe(pfu), Mg(pfu) and Na(pfu) vs Si(pfu) of the muscovites from Kuala Lumpur granite. PBMG: porphyritic biotite muscovite granite (contact facies); DBMG: deformed muscovite granite (deformed facies); NBMG: Normal biotite muscovite granite (normal facies).

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