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Geochemistry of the Granitic Rocks from North of the Lawit Batholith, Besut, Terengganu

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Abstract

The Lawit batholith consist of a very coarse, inequigranular, biotite granite as a central core known as the Peda granite, bordered to the east and west by the earlier hornblende bearing Guntong granodiorite. This paper describes in detail the petrological and geochemical differences of the northern part of the Lawit batholith. The main petrological differences between these two rocks are that the granodiorite contains hornblende and biotite whereas the granite contains only biotite as the main mafic phase. The petrological, field and chemical data indicate that the Guntong granodiorite and Peda granite are made up from separate individual melts. The different behaviour of most of the trace elements in the Peda granite and Guntong granodiorite suggests that each unit of the Lawit batholith may not be related by a simple magma fractionation from the margin to the centre of the pluton.

Geokimia Batuan Granit dari Utara Batolith Lawit, Besut Terengganu

Abstrak

Batolit Lawit yang dikenali sebagai granit Peda merupakan granit biotit yang sangat kasar dan inequigranular pada bahagian pusatnya dan di sempadani di timur dan barat oleh hornblend yang lebih muda mengarah ke granodiorit Guntong. Kertas ini akan membincangkan dengan lebih lanjut tentang perbezaan petrografi dan geokimia bagi batolit Lawit bahagian utara. Perbezaan petrografi yang utama di antara kedua batuan ini ialah granodiorit mengandungi hornblend dan biotit manakala granit hanya mengandungi biotit sebagai fasa mafik utama. Data petrologi, lapangan dan kimia menunjukkan bahawa granit Guntong dan granit Peda adalah dibentuk oleh pencairan dari magma individu yang berasingan. Perbezaan sifat kebanyakan unsur surih yang terdapat dalam granit Peda dan granidoirit Guntong mencadangkan bahawa setiap unit batolit Lawit berkemungkinan berkait rapat bukan hanya melalui pemecahan ringkas magma dari pinggir ketengah pluton.

INTRODUCTION

While much has been written on the petrography and regional geochemistry of the Eastern Belt granites (e.g. Cobbing *et al.*, 1992) there has been relatively little systematic study of their intra-pluton geochemistry. This study is concerned with the detailed magmatic and geochemical processes that operate on a smaller scale. To date, with the information from published (e.g. Cobbing *et al.*, 1992; Azman and Khoo, 1998) and unpublished work (Mohd. Rashid Salukhi, 1995; Mohd. Fairuz Isa, 1995; Mohd Shah, 1995; Azlan Mohamad, 1999), we were able to distinguish the different components in the granitic bodies. In this study, the northern part of Lawit batholith, north Terengganu were re-mapped. This area consists of a central core of very coarse, inequigranular, biotite granite knows as the Peda granite, bordered to the east and west by the earlier hornblende bearing Guntong granodiorite (Cobbing *et al.*, 1992). This paper will describe in detail the petrological and geochemical differences between the Peda granite and Guntong granodiorite.

REGIONAL SETTING AND FIELD RELATIONS

The Lawit batholith is bordered by the two Eastern Belt main batholiths, the Boundary Range batholith in the west and Kapal batholith in the east. The batholith is distributed as linear masses parallel to the two batholiths (Fig. 1). The granite (s.l) intruded the metasedimentary and metatuff of (?)Upper Paleozoic age. In the study area both the Guntong and Peda plutons are separated by older (?Permian) metatuff. The Guntong granodiorite occurs in the Jabi area as a small stock of about 1.5 km across whereas the Peda granite occupies mostly the central and southeastern part of the study area. It forms the highest peak in the area, that is Gunung Tebu. Outcrops are exposed mainly on the river banks and at rapids such as Sungai Belatan and Lata Belatan.

PETROLOGY

Modal analyses for the Guntong and Peda samples are plotted on a QAP diagram (Streckeisen, 1967) (Fig 2). All

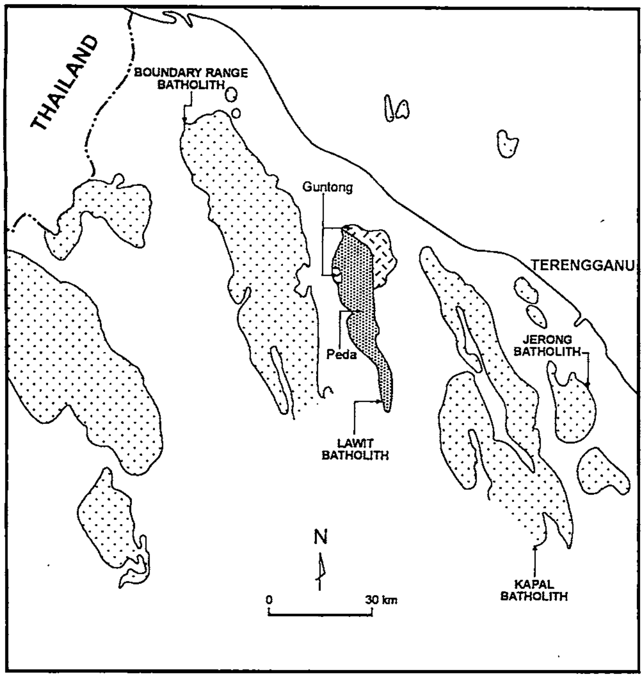

Figure 1: Map showing the location of the Lawit batholith in relation to the other granitic batholiths of the Eastern Belt (After Cobbing *et al.*, 1992).

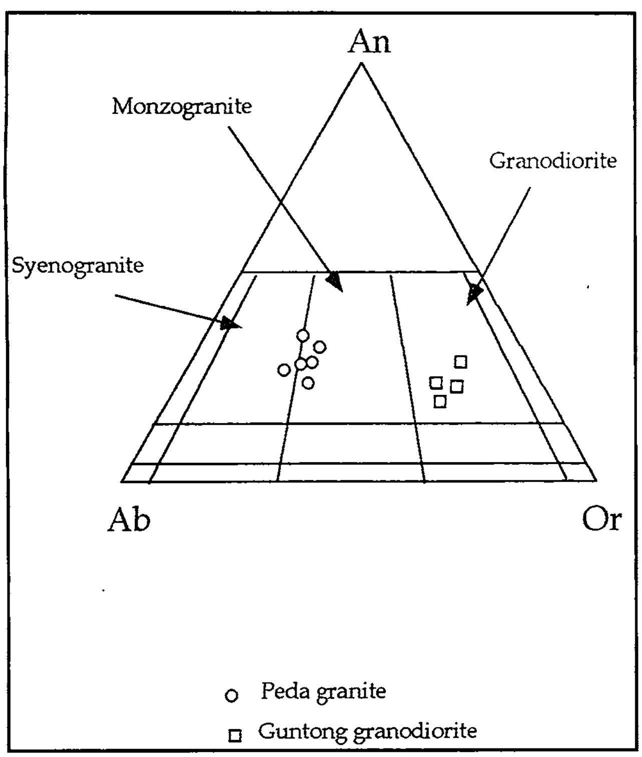

Figure 2: Modal quartz, plagioclase and K-feldspar contents of the Guntong and Peda rocks plotted on a QAP diagram.

Peda samples straddle the monzogranite and syenogranite fields, whereas those from Guntong plot in the granodiorite field. The main petrological differences between these two rocks are that the granodiorite contains hornblende and biotite whereas the granite only contains biotite as the main mafic phase. The grain sizes of the latter are also coarser (crystal size can be up to 6 cm across) compared to the former (less than 1 cm). Detailed petrographic descriptions for both rocks are given in separate sections below.

Peda Granite

The Peda granite consists of K-feldspar, quartz, plagioclase, biotite, apatite, zircon and secondary muscovite. The grain size ranges from 5 mm to 3 cm. Plagioclase is subhedral to anhedral and occurs as isolated clots compared to the K-feldspar which usually occurs as interconnected networks (Bryon *et al.*, 1994, 1995). The latter is subhedral to anhedral with sizes ranging from about 2 cm to 6 cm. Most of the K-feldspar contains inclusions of euhedral to subhedral plagioclase. The crystals usually show coarse perthitic texture. The perthite can be up to 0.2 mm thick and 3 to 4 mm long. Alterations to sericite and secondary muscovite are common. Plagioclase appears to be the first mineral to crystallize compared to alkali feldspar and quartz; the latter two are anhedral and usually occur interstitial to plagioclase. Plagioclase is characterised by euhedral shape, with normal and oscillatory zoning. It usually shows albite and Carsbad-albite twinning. Occasionally the plagioclase shows corroded and cracked cores. Mason (1985), in explaining the same plagioclase texture from granitic rocks of the Coastal batholith, Peru, suggested that it probably represents an early or pre-emplacement plagioclase, which was resorbed during the ascent of the magma. Quartz occurs as large anhedral crystals of about the same size as feldspars displaying shadowy extinction indicating strain.

Biotite is subhedral and occurs as aggregates or as individual crystals and can occur up to 5 % in a single thin section. Common pleochroism is X= dark brown and Y= pale yellow. The crystals are sometime severely chloritised. Zircon and apatite occur as accessory minerals. Apatite is euhedral and occurs as inclusions in biotite, K-feldspar and plagioclase.

Guntong Granodiorite

The main components of the Guntong granodiorite are quartz, plagioclase, K-feldspar, biotite, hornblende, zircon, apatite, opaque phase and secondary chlorite and sericite. K-feldspar in the Guntong granodiorite is anhedral with grain size between 1 to 3 mm and sometime contains inclusions of euhedral plagioclase. Perthite texture is uncommon. Two types of plagioclase crystals can be distinguished; (i) small (less than 0.5 mm) subhedral, unoriented, sericitized plagioclase enclosed in anhedral quartz, K-feldspar and biotite, (ii) large (up to 3 mm) anhedral to subhedral crystals usually occurring in clusters. Quartz in the Guntong granodiorite is mostly anhedral. It is

Table 1: Representative major and trace elements analysis of the Lawit batholith.

Sample	A1a	A3a	A3b	A4	LB1	LB2	SB3	SB4	BB1	BB3	C3	C4
Rock type	Gdr	Gdr	Gdr	Gdr	Sgr	Sgr	Sgr	Sgr	Sgr	Sgr	Sgr	Sgr
SiO_2	65.33	65.00	65.48	65.15	74	74.5	73.2	74.15	73.18	73.87	70	71.2
Al_2O_3	15.48	16.31	15.97	15.81	13.45	12.94	13.11	13.1	14.1	12.78	15.47	14.79
Fe_2O_3	4.18	4.07	4.24	4.01	1.58	1.8	1.69	1.8	1.58	1.69	1.59	1.7
MnO	0.09	0.09	0.09	0.09	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.05
MgO	2.7	2.58	2.63	2.53	0.19	0.11	0.19	0.19	0.14	0.2	0.31	0.28
CaO	4.45	4.09	4.35	4.42	1.46	1.27	1.27	1.34	1.12	1.01	2.46	1.98
Na_2O	3.91	3.82	3.58	4.26	3.95	3.89	4.31	3.76	3.78	4.04	3.95	3.86
K_2O	3.15	3.2	3.05	3.27	5.3	5.18	5.41	5.4	5.52	5.52	5.97	5.9
Total	99.29	99.16	99.39	99.54	99.97	99.73	99.22	99.78	99.46	99.15	99.81	99.76
Zn	54	50	57	60	35	31	45	49	46	42	55	60
Ni	3	2	4	3	9	5	13	10	18	7	20	15
Co	24	25	22	18	6.4	3.1	8	7	10	5	15	11
Cr	306	261	320	251	345	312	380	358	339	330	393	370
Ba	753	770	777	772	273	267	361	290	328	290	802	482
Nb	9	3	9	8	13	10	10	9	6	10	3	4
Zr	171	170	190	171	109	108	121	117	126	132	148	133
sr	424	420	426	410	108	108	127	119	141	136	178	154
Rb	130	118	127	112	386	391	381	397	423	410	338	348

generally interstitial to all other minerals, especially plagioclase, biotite, hornblende and to a lesser extent to the K-feldspar.

The main mafic phase is biotite. It is euhedral to subhedral with a grain size usually 0.1 mm to 3 mm across. The pleochroic scheme is X = dark brown and Y = straw yellow. Alteration of biotite to chlorite is not uncommon and developed mainly along the biotite cleavage. Inclusions of small euhedral plagioclase, of 0.5 mm across, and hornblende are occasionally found in the biotite. Hornblende is euhedral to subhedral with a grain size usually 0.4 mm to 2.5 mm across. The most common pleochroic scheme is X = light yellowish green, Y = Z = dark green. The mineral usually forms multi-granular aggregates associated with the biotite and magnetite resulting in a clotted appearance. Alteration of hornblende to secondary biotite is very common and developed as patches in the hornblende crystals. Apatite and zircon occur as inclusions in hornblende, biotite, plagioclase and quartz.

GEOCHEMISTRY

Twelve samples were analysed for major and trace elements. They are divided into Peda granite (8 samples) and Guntong granodiorite (4 samples). The results are shown in Table 1. Major and trace elements Harker diagrams are shown in Figures 3 and 5 respectively. In general the Guntong granodiorite is more basic compared to the Peda granites, SiO_2 ranging from 65 - 65.48% and 70 - 74.5% respectively. They are separated by a gap of about 5% SiO_2. In general, Harker diagrams for the major elements show that the Al_2O_3, Fe(tot), MnO, MgO and CaO decrease in concentration from the granodiorite to the granite with increasing SiO_2. Na_2O does not show any specific trend. The samples from the Guntong granodiorite tends to form a cluster except Na_2O that shows a vertical pattern with SiO_2. They contain exceptionally high MnO (average : 0.09 %), Fe (total) (4.2%), CaO (4.2%) and MgO (2.7%) compared to the granite (0.04%, 1.7%, 1.5% and 0.2%

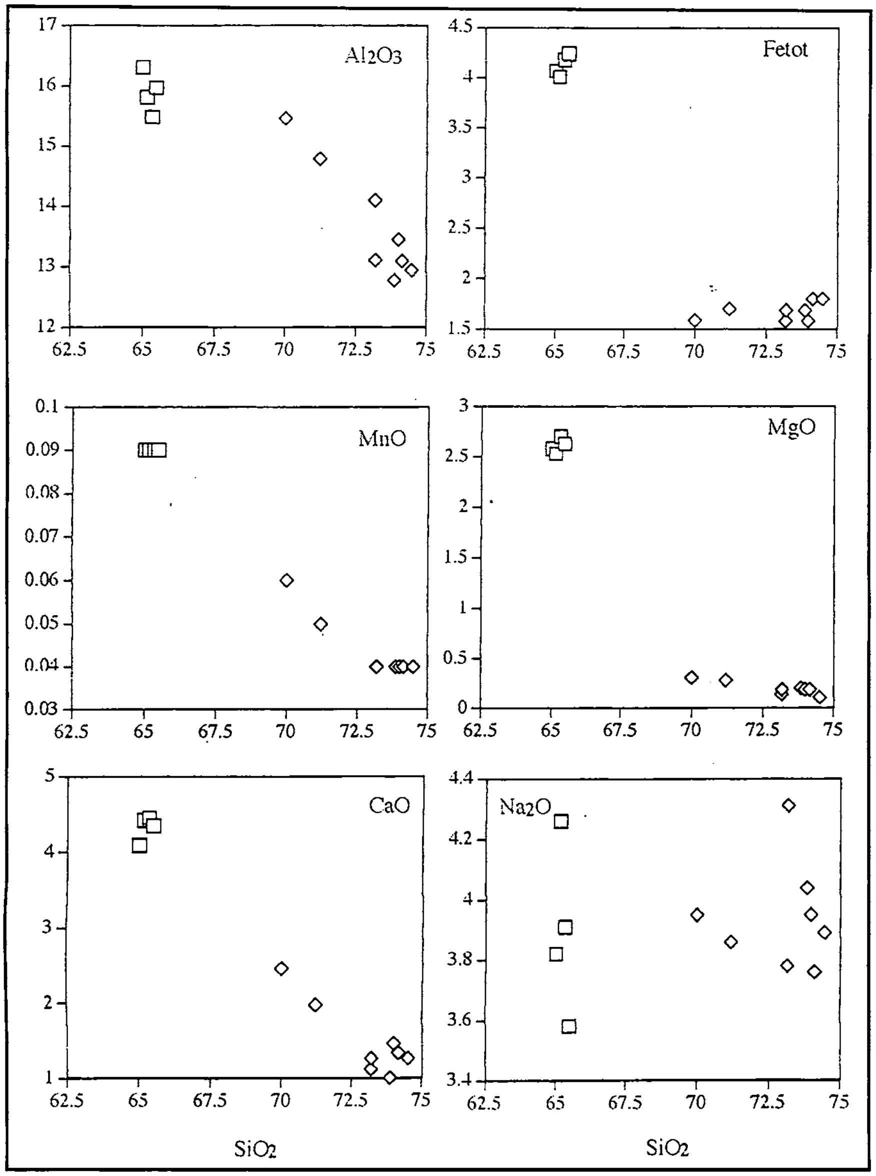

Figure 3: Harker plots of major element oxides for the Lawit batholith. Key: squares: Guntong granodiorite; diamonds: Peda granite.

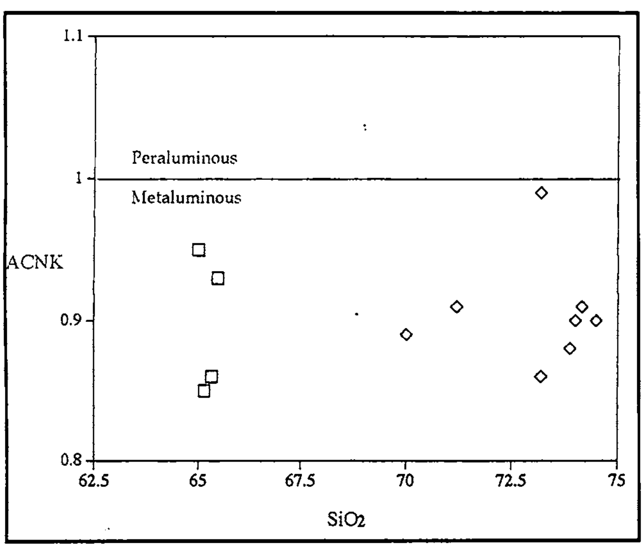

Figure 4: Al_2O_3/ $CaO + Na_2O + K_2O$ vs SiO_2 diagram for the Lawit batholith. Line at ACNK = 1 divides peraluminous from metaluminous (Shand 1943).

respectively). Al_2O_3, MnO, MgO, CaO and Na_2O for the Peda granite decrease whereas Fe(total) increases with increasing SiO_2. All the four samples of the Guntong granodiorite contain Hy (3.56 to 5.57) and are lacking in normative Wo. On the other hand, all except one of the granite sample contain Wo normative (0.95 to 1.89). The differentiation index (D.I.) of both plutons is also different; the granodiorite has a low D.I., ranging from 68.69 to 71.6 whereas the granite shows a much higher D.I. (88.29 to 94.54).

All samples from both granodiorite and granite are metaluminous (ACNK value below 1) (Fig 4) with the range of ACNK values for the Guntong and Peda rocks 0.85 - 0.95 and 0.86 - 0.99 respectively. All the samples plot in the I type field of the Chappell and White (1974) classification. The Guntong samples do not show any significant trend compared to those of the Peda granite, which form two similar trends, increasing ACNK with increasing SiO_2.

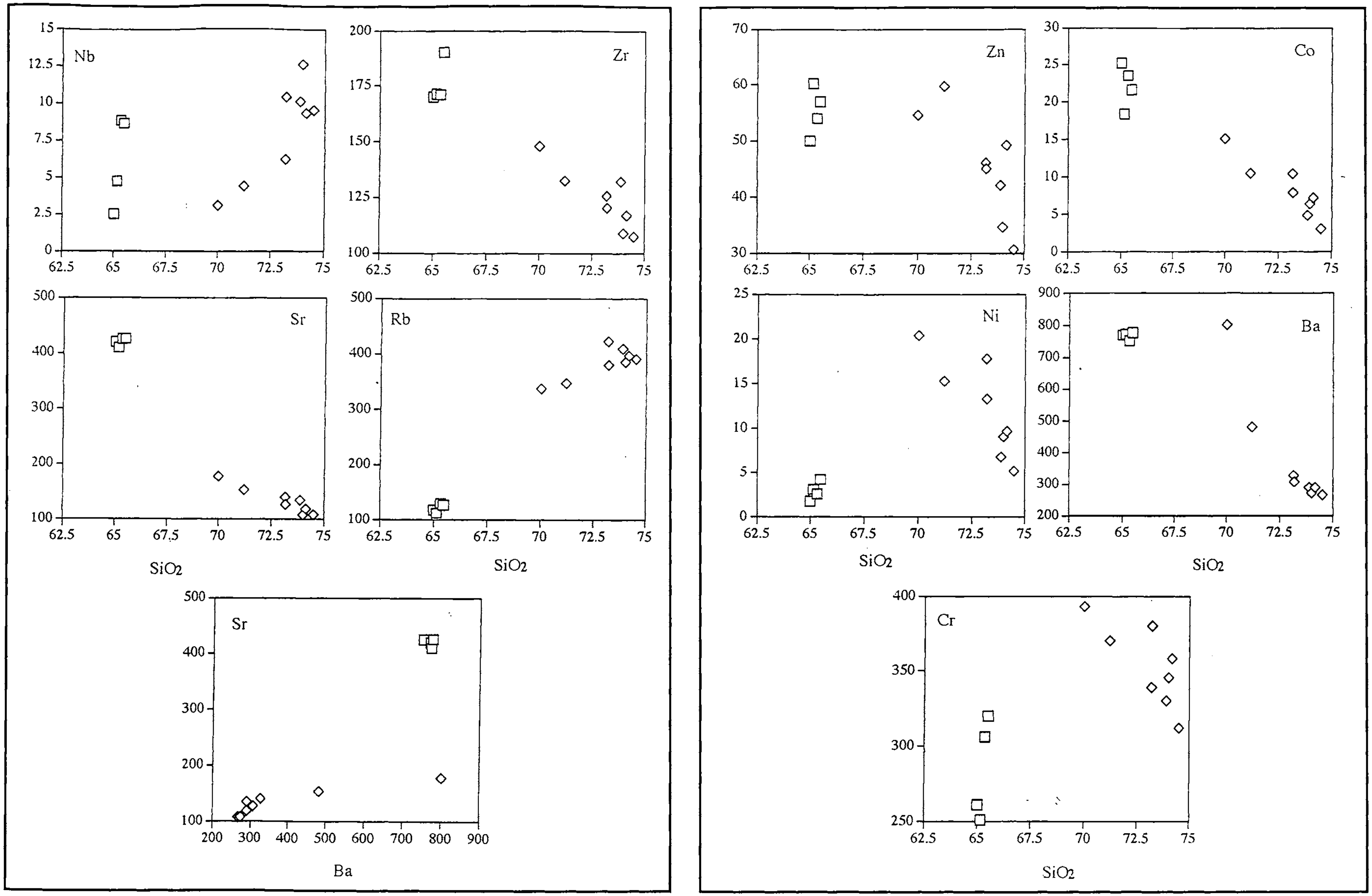

Figure 5: Harker plots of trace elements for the Lawit batholith. Key: squares: Guntong granodiorite; diamonds: Peda granite.

Trace element Harker diagrams are shown in Figure 5. In nearly all plots, both Guntong and Peda samples show a different trend. Two elements which show the largest gap between the granites (s.l) are Sr and Rb. Average Sr in the Guntong granodiorite is 400 ppm compared to the Peda granite with less than 200 ppm (Fig 6). On the other hand Rb in the former is less than 50 ppm compared to the latter with more than 350 ppm. This is evident from the Rb vs Ba diagram (Fig 6). Co, Zn, Cr and Zr in the Guntong granodiorite showing similar trends. All elements show vertical trends with increasing SiO_2. Zn, Co, Ba, Ni, Cr, Zr and Sr in the Peda granite decrease with increasing SiO_2.

ROCKS CLASSIFICATION

The main criteria for distinguishing I and S type granites can be summarised as follows (see Chappell and White, 1992, for a comprehensive review): S types are always peraluminous (Alumina saturation index, (ASI > 1)) and contain Al-rich minerals (e.g. Al rich biotite, cordierite, muscovite, garnet, sillimanite and andalusite). Chemically they are lower in Na, Ca, Sr and Fe^{3+}/Fe^{2+} and higher in Cr and Ni. I types are metaluminous to weakly peraluminous (ASI < 1.1) and commonly contain biotite, hornblende and sphene. In term of their isotopic composition, S type granites have higher $S^{18}O$ values (> 10°/oo) 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 type granites contain a diverse assemblage of metasedimentary enclaves, whereas enclaves in I type is commonly metaluminous and hornblende bearing. Mineralogy of the Lawit batholith, especially the Guntong granodiorite, suggests that they are I type. This is supported by ACNK values, the samples from both plutons plot well below ACNK =1.1 (Shand, 1943; Zen, 1988).

DISCUSSION AND CONCLUSION

The petrological, field and chemical data indicate that the Guntong granodiorite and Peda granite are derived from separate individual melts. All the geochemical plots presented earlier strongly suggest that there no connection exists between the magmas. Among the main differences between the granodiorite and granitic rocks of the Lawit batholith are listed below :

1) Guntong granodiorite contains hornblende and biotite as main mafic phases whereas the Peda contains only biotite. The latter is coarse grained (crystal size can be up to 6 cm across) compared to the former (less than 1 cm).
2) In Harker diagrams, a gap occurs at SiO_2 65.5 to 70.0 %, separating the granodiorite from the granitic rocks.
3) The granitic rock are significantly low in MgO, Fe(total) and Rb compared to the granodiorite.

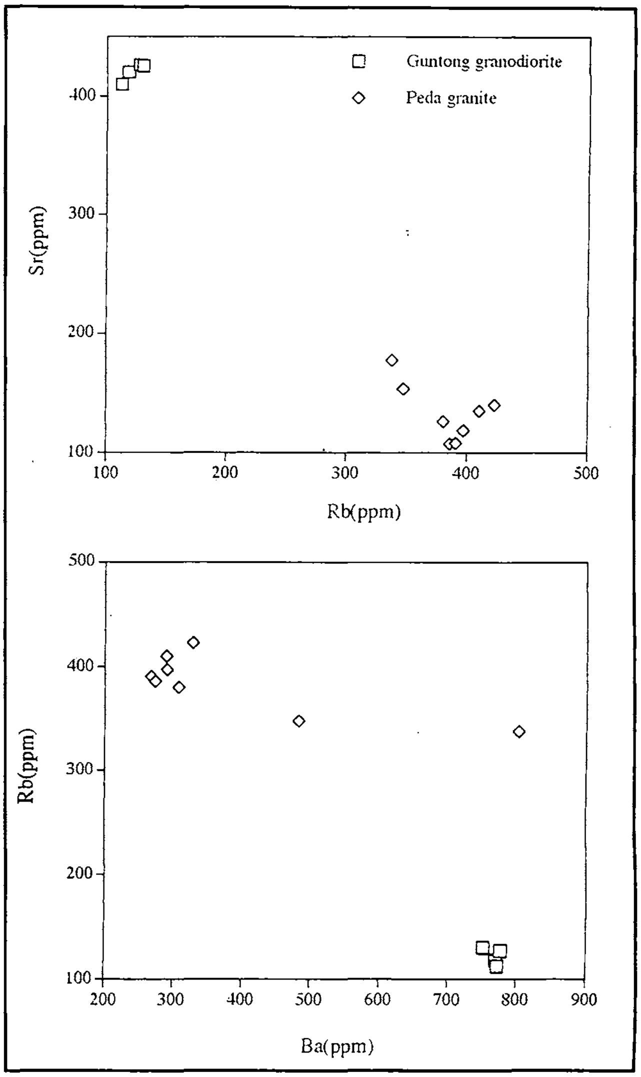

Figure 6: Sr vs Rb and Rb vs Ba for the Lawit batholith.

4) Different behaviour shown by Na_2O, Nb, Cr and Ni is difficult to explain by simple fractional crystallization between the two rocks.

The different behaviour of most of the trace elements in the Peda granite and Guntong granodiorite suggests that each units of the Lawit batholith may not be related by a simple magma evolution from the margin to the centre of the pluton. Although no contacts were found in the present study, the map from Cobbing *et al.* (1992) shows that the contacts between Peda and Guntong are not gradational. This further supports the conclusion that the magma is not related by simple fractional crystallisation.

The Peda granite may consist of several magmatic pulses. This is evident from the Sr vs Rb plot (Fig 8), where the granite samples produced two different trends. In the first trend Sr decrease with increasing Rb compared to the other trend where Sr increases with increasing Rb. The latter trend is similar to the trend produced by the granodiorite, which could result from K-feldspar fractionation.

The rocks from the Lawit batholith can be classified as I according to the Chappell and White classification (1974, 1992). The rocks contains hornblende, which is a characteristic of I, type granite. Furthermore, all analysed samples have low ACNK values (ACNK<1). The I type nature of the rock is similar to most of the Eastern Belt granites (Cobbing *et al.*, 1992).

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