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Contrasting Two Facies of Muncung Granite in Lingga Regency Using Major, Trace, and Rare Earth Element Geochemistry

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Abstract - Lingga Regency is located in the main range of the famous Southeast Asia granitic belt related to tin resources. There are two granitic units in this region: the S-type Muncung Granite and I-type Tanjungbuku Granite. XRF and ICP-MS were used to measure the major, trace, and rare earth elements of nine Muncung Granite samples. Two different patterns were identified from major data plotting on Harker variation diagram. Granitic rocks from Lingga and Selayar Islands are classified as A facies while others from Singkep Island is B facies. This paper used graphs and variation diagrams to reveal the differences of those two facies. Thus, REE correlation to SiO_2, trace element spider diagram, and REE spider diagram show more contrasts correlation. However, both facies are syn-collisional and High-K calc-alkaline granites. Some identical characters with other granitic units in Peninsular Malaysia were also detected in this work.

Keywords: Harker diagram, Muncung Granite, peraluminous, syn-collision, Spider diagram, two facies

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Introduction

Background

Tin was produced massively in Lingga Regency for more than four decades and was one of the three main resource locations in Indonesia besides Bangka and Belitung. This resource is related to granitic rock of the area. There are two granitic units in Lingga region such as Muncung and Tanjungbuku. Cobbing *et al*. (1992) classified the Muncung Granite as stanniferous S-type while Tanjungbuku Granite as I-type. The Centre for Geological Survey of Indonesia conducted a research regarding rock types and chemical composition of Lingga granite. The research area (Lingga) is part of the main range of granite province in Indonesian Tin Islands (Barber *et al*., 2005). Formerly, only low level of connection could be observed about geochemistry data from plutonic samples. Better correlations obtained after splitting the samples into two facies although they just come from one unit of rock, The Muncung Granite.

The aim of this research is to identify characteristic of two facies of the S-type Muncung Granite based on major, trace, and rare earth element data. Various geochemistry diagrams about plutonic rock classification, correlation, and tectonic setting are used to portray the divergence.

Geological Setting

Lingga is a regency in Kepulauan Riau Province, located to the east of Sumatra and northwest of Bangka Island (Figure 1). The survey of island toponymy in Lingga Regency has been

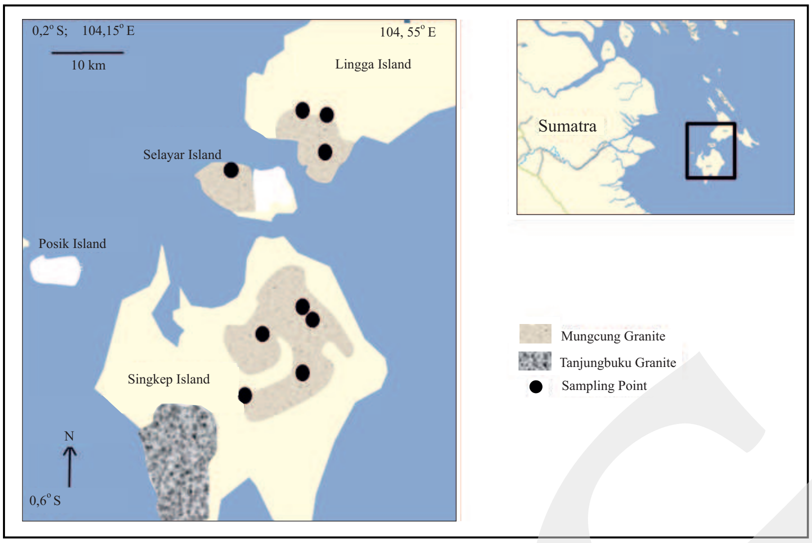

Figure1. Simplified geological map shows two granite units and the sampling points in Lingga Regency (modified from Sutisna *et al*., 1994 using Garmin BaseCamp).

identified a total of 455 islands (Yulius, 2009). Lingga, Singkep, and Selayar are the three main islands in the regency. The general geology of this region consists of five sequences (Sutisna *et al*., 1994): (1) Permian Persing Complex and Duabelas Bukit Quarzite; (2) Triassic granite and granodiorite of Muncung Granite; (3) Jurassic Tanjungbuku Granite (comprises granite and granodiorite), and Tanjungdatuk Formation (low grade methamorphic rock composed of slate and quartz veinlets); (4) Tengkis Formation, Pancur Formation, and Semarung Formation formed in Cretaceous age; and (5) Tertiary Alluvium and Swamp Deposits. The Muncung Granite spreads in the southwestern area of Lingga Island, west part of Selayar Island, and in the central region of Singkep Island. The Tanjungbuku Granite is located in the southwestern part of Singkep Island.

Analytical Method

Four granitoid samples were collected from both Singkep and Lingga Islands and only one from Selayar Island. The chemical composition of the nine samples were measured using X-ray fluorescence analyzer (XRF) and inductively coupled plasma mass spectrometry (ICP-MS). The chemical data were then compared to petrography analysis of the samples. Both the preparation and instrumental analysis were conducted at Geological Laboratory of The Centre for Geological Survey of Indonesia in Bandung.

After being dried at the room temperature, the samples were crushed by a jaw crusher to 200 mesh and were ground by a mill. Major and trace elements were analyzed with Advant XP XRF while REE were measured using The X Series Thermo ICP-MS. Before ICP-MS measurement, rock samples were first dissolved with three acids leach using nitric acid (ultrapure grade), formic acid (ultrapure grade), and perchloric acid (pro analysis grade). AGV-2 and GBW 07110 andesites were also measured as calibration materials for ICP-MS method, while GBW 7103 for XRF. Sample preparation, ICP-MS set up procedure, and certified reference evaluation are based on study of Irzon and Permanadewi (2010).

Result and Discussion

Petrology

Nine granitic rock samples in this study representing the Triassic Muncung Granite comprise granite and diorite (Sutisna *et al*., 2004). Samples are generally holocrystalline, medium-grained, phaneritic, and composed of quartz, K-feldspar, and plagioclase. Granitoids from Singkep Island are lighter in colour than others which is confirmed with quartz composition from petrographic data (Tabel 1). Plagioclase and biotite may partly

Table 1. Petrographic Data of Granitoid Samples (RGL, RGS, and RGI) taken from Lingga, Selayar, and Singkep Islands

	RGL 10	RGL 12	RGL 17	RGS 33	RGI 46	RGI 48	RGI 55	RGI 60	RGI 63
Phenocryst									
Quartz	37	33	29	31	40	35	41	37	35
K-Feldspar	50	43	29	36	32	30	28	34	33
Plagioclase	7	12	22	18	18	17	12	12	16
Hornblende	1	1	3	-	-	1.5	-	-	-
Muscovite	1	1	2	2		-	-	-	3
Biotite	-	-	1	1.5	2	7	7	6	1
Ore mineral	0.5		2	2	0.5	1	0.5	1	0.5
Alteration Mineral									
Sericite	2	7	9	8	6	5	6	6	8
Chlorite	0.5	1	2	0.5	0.5	0.5	0.5	0.5	1
Secondary quartz	0.5	1	-	-	-	0.5	4	1	-
Porosity	0.5	1	1	1	1	0.5	1	0.5	0.5
Xenolith						2		2	2

be sericitized and chloritized, respectively by alteration in most samples. Note that no hornblende was found in samples from Singkep except in RGI 48. No granitoids from Lingga and Selayar Islands contain xenolith, but three of five samples from Singkep have a small amount of xenolith (2%).

Geochemistry

Geochemistry data of the nine granitoid samples are described in Tabel 2. A number of schemes based on chemical composition have been applied for the classification and nomenclature of igneous rocks. Granitic rocks from Lingga Regency are classified based on Middlemost (1985) using total alkali and silica data. All granitoids from Singkep Island belong to granite suites, only one from Lingga Island is granodiorite (Figure 2). This result confirms the previous study of Muncung Granite that consists of granite and granodiorite (Sutisna *et al*., 1994). The diagram indicates that all plutons are acid igneous rocks.

Major Elements Variations

Molecular A/CNK (Al_2O_3/CaO+Na_2O+K_2O) ratios of the samples are more than 1.10. In the A/CNK *versus* A/NK (Al_2O_3/Na_2O+K_2O) diagram (Shand, 1943; Figure. 3) these rocks were plotted into the peraluminous domain, hence the rocks are S-type in the sense of Chappell and White (1974). The presence of two subgroups within Muncung Granite is apparent on this ratio. Samples from Singkep Island are more peraluminous than others because of the higher degree of A/CNK ratio. The peraluminous nature of the granitic rocks is evident from major cation parameters of Debon and Le Fort (1983), which essentially consist of muscovite and biotite (Figure 3b) and is confirmed with petrographic data (Tabel 1).

The main compositional trends of the intrusive rocks are tried to be correlated using Harker variation diagrams. After splitting the data into two facies, correlation coefficients of SiO_2 *versus* major oxides (Table 3) are close to 1, pointing to strong degree of relationship (Taylor, 1990). Granitoid samples from Lingga and Selayar Islands are included in A facies while from Singkep Island in B facies.

The range of SiO_2 of all nine Muncung Granite samples is 70.95-76.16%, four samples are identified as A facies with 71.34 - 76.16% SiO_2, while the other five samples falling within B facies are 70.95 - 72.71% SiO_2 based on their major and trace element signatures. An identical character with granitoid from Endau Rompin (Ghani *et al*., 2013) and Machang plus Kerai batholith (Ahmad *et al*., 2002) in Peninsular Malaysia is detected in B facies where TiO_2, Al_2O_3, Fe_2O_3, CaO, and

Table 2. Major, Trace and Rare Earth Element Data of Granitoid Samples (RGL, RGS, and RGI) taken from Lingga, Selayar, and Singkep Islands

		RGL 10	RGL 12	RGL 17	RGS 33	RGI 46	RGI 48	RGI 55	RGI 60	RGI 63
SiO_2	%	76.16	72.28	71.34	75.20	72.71	71.66	70.95	71.25	71.51
TiO_2	%	0.10	0.33	0.40	0.12	0.07	0.12	0.16	0.17	0.11
Al_2O_3	%	12.93	12.53	12.46	12.77	16.30	16.33	16.85	16.39	16.90
Fe_2O_3	%	0.68	4.33	6.19	1.27	1.09	1.39	1.46	1.62	0.98
FeO	%	0.61	3.71	5.57	1.14	0.98	1.25	1.31	1.46	0.88
MnO	%	0.01	0.07	0.08	0.01	0.03	0.04	0.03	0.02	0.02
CaO	%	0.35	1.19	0.68	0.44	0.18	0.76	0.66	0.67	0.25
MgO	%	0.19	0.46	0.44	0.14	0.11	0.44	0.33	0.24	0.14
Na_2O	%	3.17	3.30	3.58	3.73	2.83	4.03	3.43	4.04	3.89
K_2O	%	5.09	4.44	3.53	5.02	4.97	4.33	4.75	4.90	4.81
P_2O_5	%	0.01	0.12	0.17	0.02	0.01	0.06	0.04	0.05	0.01
LOI	%	1.09	0.93	1.23	0.84	1.61	1.00	1.20	0.62	1.13
Cs	ppm	2.73	6.21	3.14	7.59	26.50	14.49	36.01	15.54	30.67
Rb	ppm	150.05	176.51	120.65	253.89	346.71	187.43	303.16	230.78	334.07
Ba	ppm	298.70	698.30	547.26	217.50	54.28	119.30	337.20	117.10	40.51
Th	ppm	38.13	21.74	14.62	35.76	29.10	17.53	28.35	39.96	34.56
U	ppm	9.75	5.63	2.92	11.09	12.87	12.90	9.36	7.78	13.81
Nb	ppm	8.68	10.56	11.56	9.69	15.16	7.95	13.01	17.44	4.90
Pb	ppm	7.55	49.09	10.44	22.93	48.35	26.30	50.59	29.42	46.29
Sr	ppm	54.82	110.46	64.50	18.66	15.95	18.85	52.34	23.90	17.59
Tl	ppm	0.62	0.86	0.55	1.06	2.27	1.46	1.80	1.07	3.36
V	ppm	12.74	22.55	15.96	10.82	10.25	33.15	9.77	9.99	7.63
Sc	ppm	2.57	11.41	19.01	2.81	3.28	2.54	2.97	2.89	2.94
Y	ppm	144.69	51.38	39.56	99.60	53.82	28.17	13.13	40.76	49.03
Bi	ppm	3.27	1.17	0.95	1.57	2.68	1.75	0.08	0.66	0.03
La	ppm	735.79	50.34	51.64	131.78	24.95	19.96	27.08	51.70	27.68
Ce	ppm	133.98	103.35	101.26	246.90	37.99	39.41	61.28	111.52	60.37
Pr	ppm	143.22	12.34	11.81	27.52	2.89	7.74	5.44	15.07	6.77
Nd	ppm	529.00	49.14	47.19	99.43	25.93	19.06	18.37	51.96	25.27
ΣLREE	**ppm**	***1541.99***	***215.17***	***211.90***	***505.63***	***91.76***	***86.18***	***112.18***	***230.25***	***120.09***
Sm	ppm	103.27	10.89	11.23	19.65	6.55	4.90	4.18	11.76	7.26
Eu	ppm	4.01	1.70	2.04	0.56	0.18	0.14	0.33	0.25	0.16
Gd	ppm	89.33	10.99	10.11	19.64	7.26	4.80	3.06	8.88	6.56
ΣMREE	**ppm**	***196.61***	***23.58***	***23.38***	***39.85***	***13.99***	***9.85***	***7.57***	***20.88***	***13.98***
Tb	ppm	9.21	1.66	1.45	2.75	1.39	0.67	0.52	1.50	1.40
Dy	ppm	40.07	10.53	8.42	16.05	9.77	5.94	2.74	8.10	8.75
Ho	ppm	6.36	2.12	1.59	3.05	2.03	1.27	0.56	1.67	1.95
Er	ppm	14.86	6.06	4.12	8.52	6.11	4.47	1.46	4.08	5.24
Tm	ppm	1.80	0.91	0.65	1.24	0.94	0.63	0.22	0.63	0.91
Yb	ppm	10.46	5.76	4.06	8.36	6.33	4.97	1.39	3.79	5.74
Lu	ppm	1.51	0.82	0.59	1.20	0.90	0.79	0.21	0.56	0.88
ΣHREE	**ppm**	***96.24***	***34.44***	***25.54***	***50.72***	***34.71***	***24.49***	***8.69***	***24.69***	***31.49***
ΣREE	**ppm**	**1834.83**	**273.18**	**260.81**	**596.20**	**140.46**	**120.51**	**128.44**	**275.83**	**165.56**

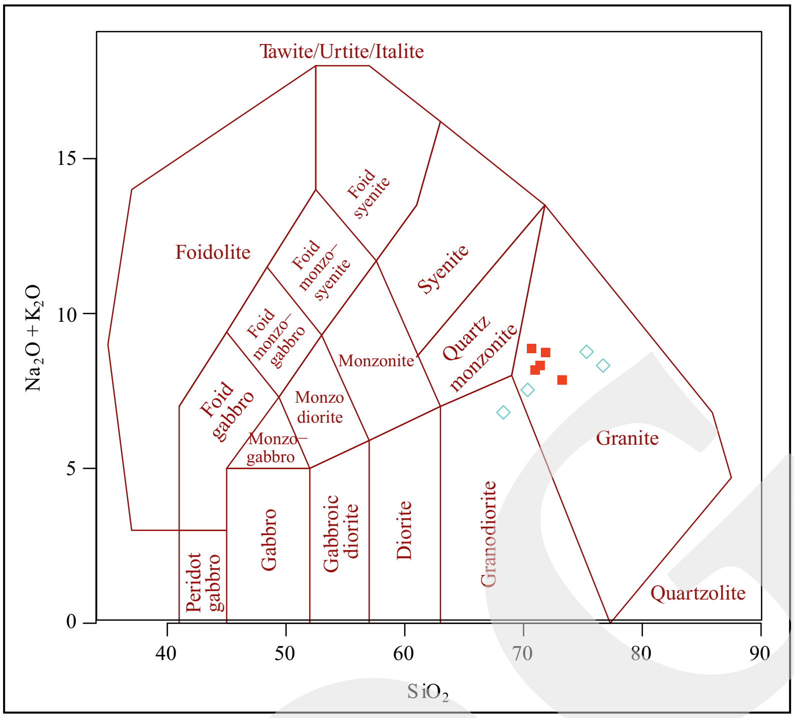

Figure 2. Plot of rock samples from Lingga Regency in the classification diagram of Middlemost (1985). All variables are in wt%*(open diamond=A facies, solid rectangle=B facies*).

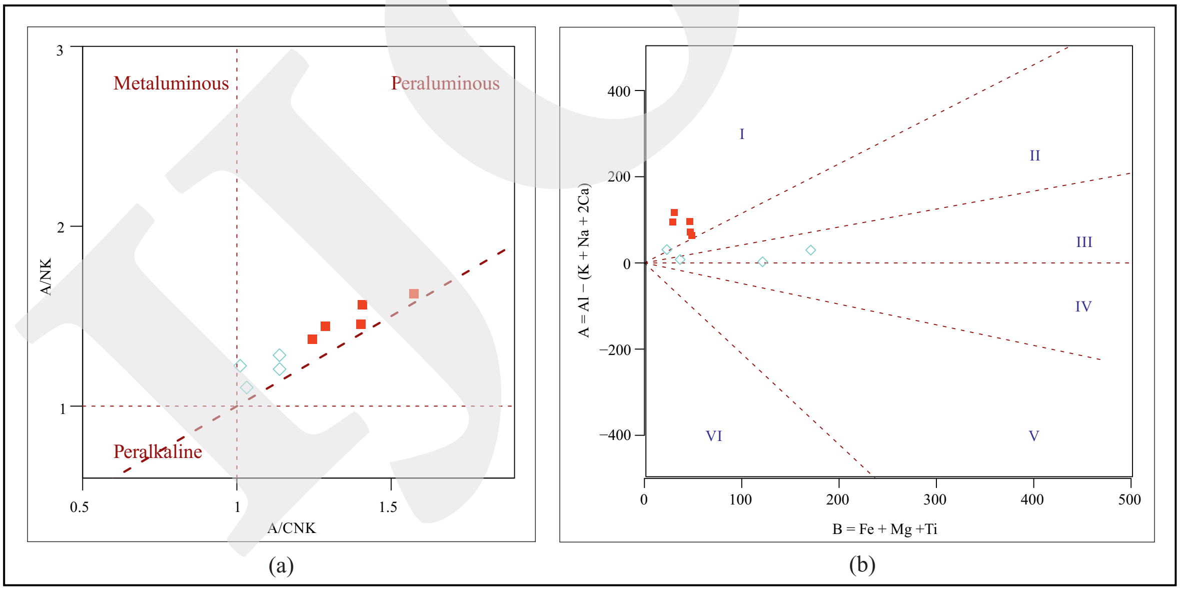

Figure 3. (a) Aluminium Saturation Index (ASI) of Shand (1943). (b) A-B diagram (Debon and LeFort, 1983) plotted for granitoid. I, II and III are peraluminous sectors, where I: muscovite>biotite (by volume); II: biotite>muscovite; III: biotite alone; IV, V, and VI are metaluminous sectors, where IV: biotite+ amphibole±pyroxene;V:clinopyroxene ± amphibole ± biotite; VI: unusual rocks*(open diamond=A facies, solid rectangle=B facies).*

MgO decrease with increasing SiO_2. The difference of A and B facies is clearly shown from Al_2O_3 and SiO_2 correlation. The A facies has a positive correlation, while B facies is negative (Figure 4). A little iron depletion in A facies during fractionation suggests their calc alkaline nature (Zaw *et al.*, 2011) which is confirmed by SiO_2-K_2O diagram (Figure 5).

Table 3. Correlation Coefficients of SiO_2 *versus* Major Oxides. Minus in Correlation Coefficient Denote A Negative Correlation, as Values for x Increase, The Values for y Decrease

Correlation	Before divided	After Divided	
		A Facies	B Facies
SiO_2 *vs.* TiO_2	-0.3615	-0.9911	-0.9196
SiO_2 *vs.* Al_2O_3	-0.5649	0.9905	-0.5844
SiO_2 *vs.* Fe_2O_3	-0.3455	-0.9889	-0.5866
SiO_2 *vs.* CaO	-0.3455	-0.7284	-0.6745
SiO_2 *vs.* MgO	-0.4633	-0.9307	-0.5014
SiO_2 *vs.* K_2O	-0.4307	0.9243	0.2403
SiO_2 *vs.* Sc+Y	0.9420	0.9522	0.7108
SiO_2 *vs.* Bi	0.7441	0.8507	0.8813
SiO_2 *vs.* ΣHFSE	0.9370	0.9826	0.5297
SiO_2 *vs.* Rb/Sr	0.0517	0.6841	0.8159

*Note the difference of this value after the samples are divided into two facies

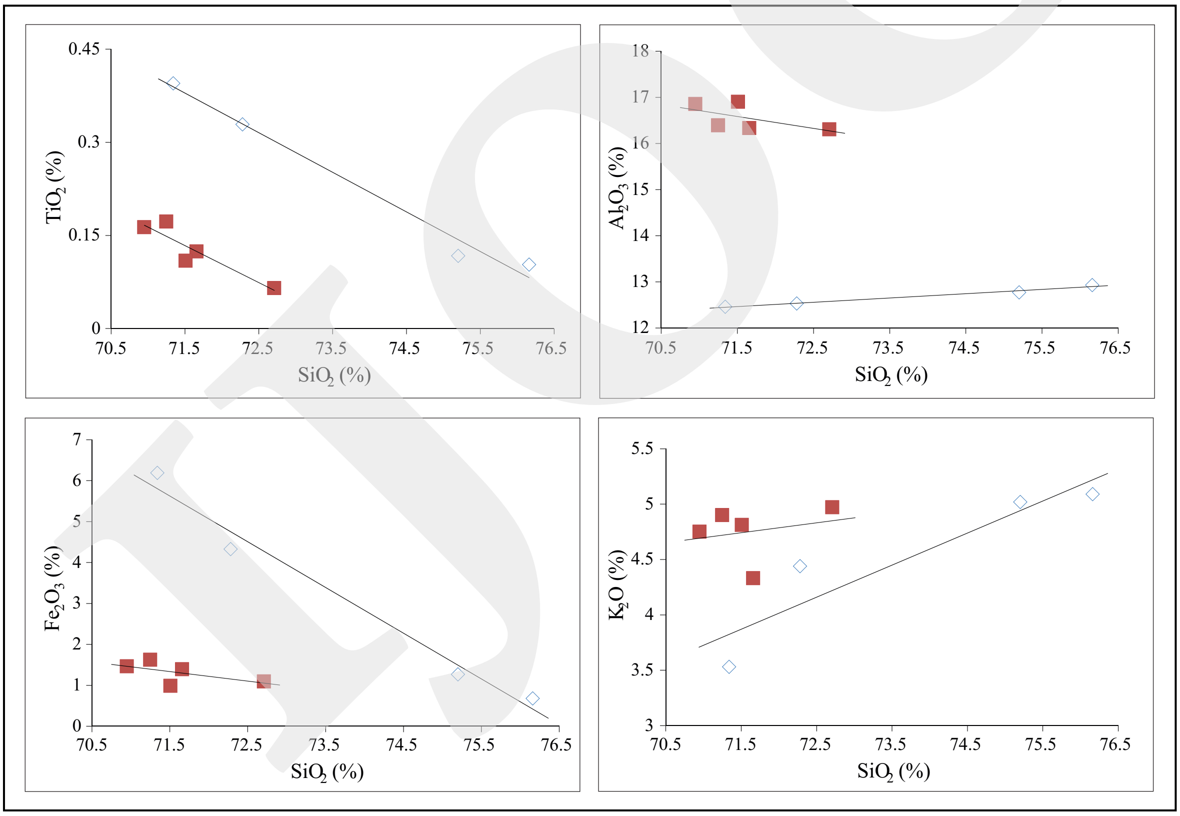

Figure 4. Major oxides trend from two facies of Muncung Granite *(open diamond=A facies, solid rectangle=B facies).*

Trace and Rare Earth Elements Variations

A sample with full set of trace and rare earth elements is of greater help in determining the nature of the source material, and in constructing the tectonic setting of origin. HFSE (High Field Strength Elements) in both groups show a positive correlation to SiO_2 without significant difference on HFSE enrichment (Figure 6a). Relative enrichment of HFSE suggests that the granitic rocks are primarily derived from a felsic source (Ray *et al.*, 2011). All granitoid samples from Lingga Regency show a negative anomaly of Ba, Nb, P, and Tl in

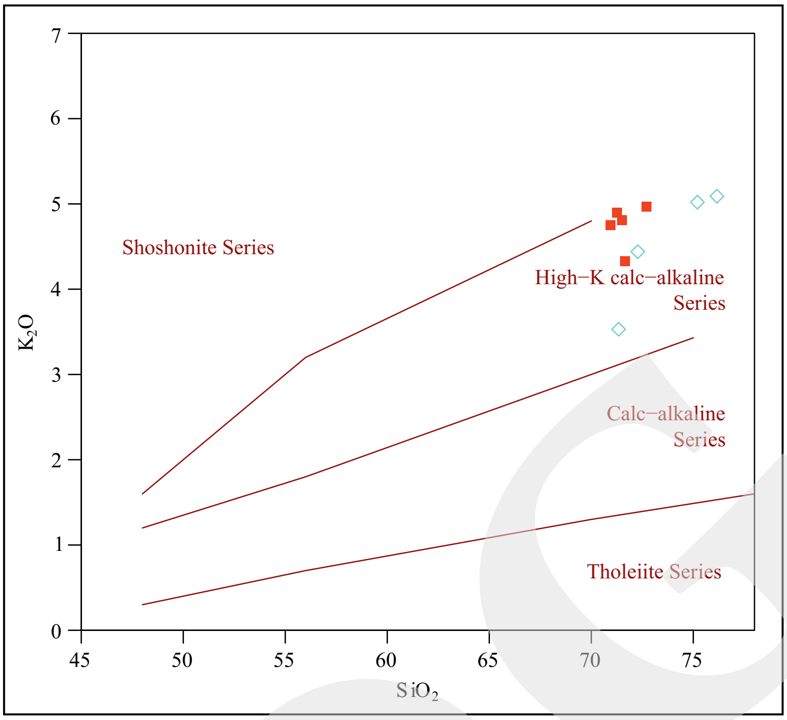

Figure 5. All nine granitoid samples from Lingga Regency are plotted in High-K calc-alkaline Series in Peccerillo and Taylor (1976) diagram *(open diamond=A facies, solid rectangle= B facies).*

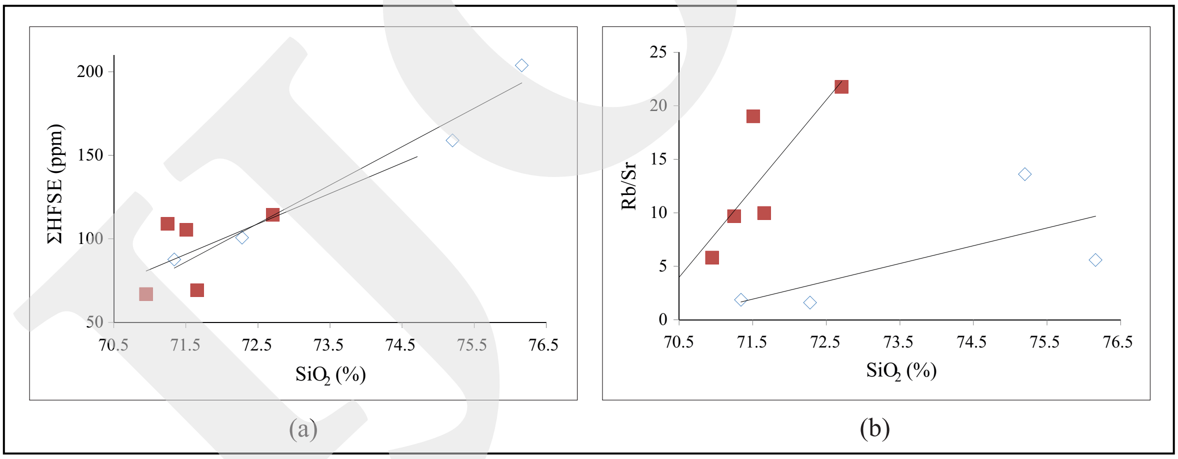

Figure 6. HFSE (a) and Sb/Sr (b) *versus* SiO_2 trend of granitic rocks samples *(open diamond=A facies, solid rectangle=B facies).*

trace element spider diagrams (Figure 7). However, A facies denotes positive anomaly of Rb, La, Nd, and Dy; while Cs, U, and Pb in B facies.

Even Rb/Sr ratios of both facies rise with increasing SiO_2, the coefficient correlations are different (Figure 6b). Precipitation of plagioclase is also evidenced from Rb/Sr ratio *versus* SiO_2 plotting. Only B facies has 'J' shaped trend of Rb/Sr ratio which suggests the importance of fractional crystallization process with plagioclase as the major precipitating felsic phase (Atherton, 1993; Cid *et al*., 2001; Ahmad *et al*., 2002; Ghani *et al*., 2013; Ray *et al*., 2011). The negative correlations of CaO and Al_2O_3 to SiO_2 are relevant with the fractional crystallization (Sun *et al*., 2010). This also means that granitic rocks of A facies is not highly differentiated compared with B facies (Sanematsu *et al*., 2009).

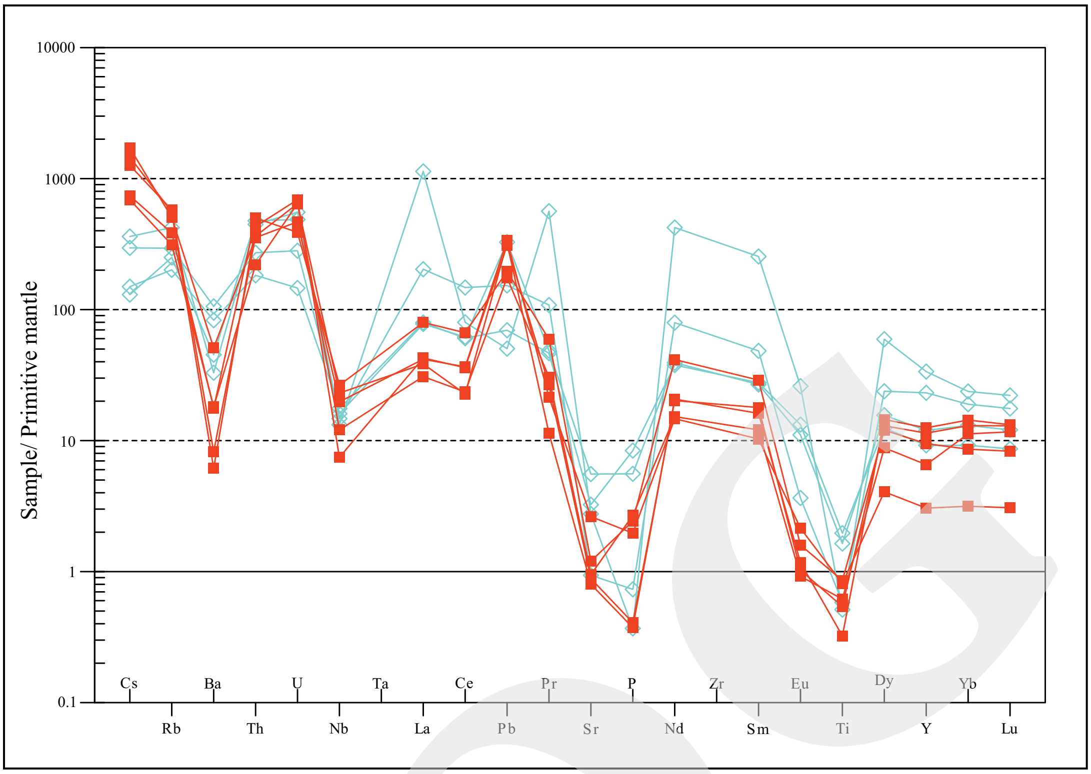

Figure 7. Trace elements spider diagram plot with the primitive mantle normalization (McDonough and Sun, 1995) for the Muncung Granite*(Blue is A facies, red is B facies).*

Batchelor and Bowden (1985) showed a bivariate graph using the plotting parameters R1 [(4Si − 11 (Na + K) − 2(Fe+Ti)] and R2 (Al + 2Mg + 6Ca) to discriminate five granitic groups related to the tectono-magmatic divisions. The granitoid samples are plotted in the syn-collisional field (Figure 8). This result agrees with the age of granite tectonic scenario of Peninsular Malaysia (Ghani *et al.*, 2013). The subduction of the Sibumasu eastward beneath the Indochina Blocks in Peninsular Malaysia during Permian to Triassic produced volcanic and granitic magmatisms broadly known as East Malaya Volcanic Arc and Eastern Belt Granite respectively (Metcalfe 2000).

Large contrast between the two facies could be observed in Rare Earth Elements (REE) plot *versus* SiO_2. REE classification to Light-REE (LREE: La, Ce, Pr, Nd, and Pm), Medium-REE (MREE: Sm, Eu, and Gd), and Heavy-REE (HREE: Tb, Dy, Ho, Er, Tm, Yb, Lu, Sc, and Y) of Koltun and Tharumarajah (2014) is used in this study. There is an enrichment trend of all group of REE from A facies, but a depletion of LREE and slightly enrichment of MREE from B facies. The total REE in granitic rocks from A facies raises with the increase of SiO_2, but no significant correlation is identified in B facies (Figure 9). The REE pattern in B facies is opposite to granitoids from Laos that are depleted in HREE and enriched in LREE (Sanematsu *et al.*, 2009).

REE Spider diagram clarifies the diversity of the plutons in this study. The A facies generally contains more REE than B facies which may correlate to peraluminous level (Figure 10). From A/CNK *versus* A/NK diagram, B facies is more peraluminous than A facies, confirming that it also possesses more S-type character. S-type granite could be identified from its low content of REE (Christiansen and Keith, 1996) as B facies in this investigation. Eu negative anomaly and bigger LREE composition than HREE could be noted in both groups. However, granitic rocks from Singkep Island show a slight enrichment pattern in HREE while A facies is depleted.

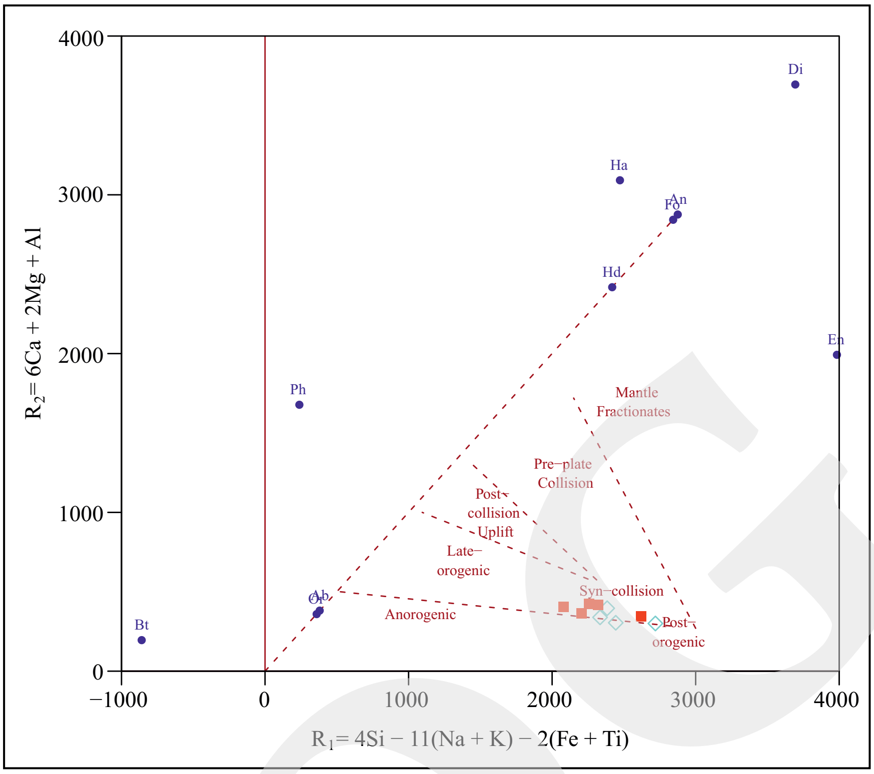

Figure 8. Tectonic classification using Batchelor and Bowden (1985) diagram. All samples are plotted in Syn-collision area *(open diamond=A facies, solid rectangle= B facies)*.

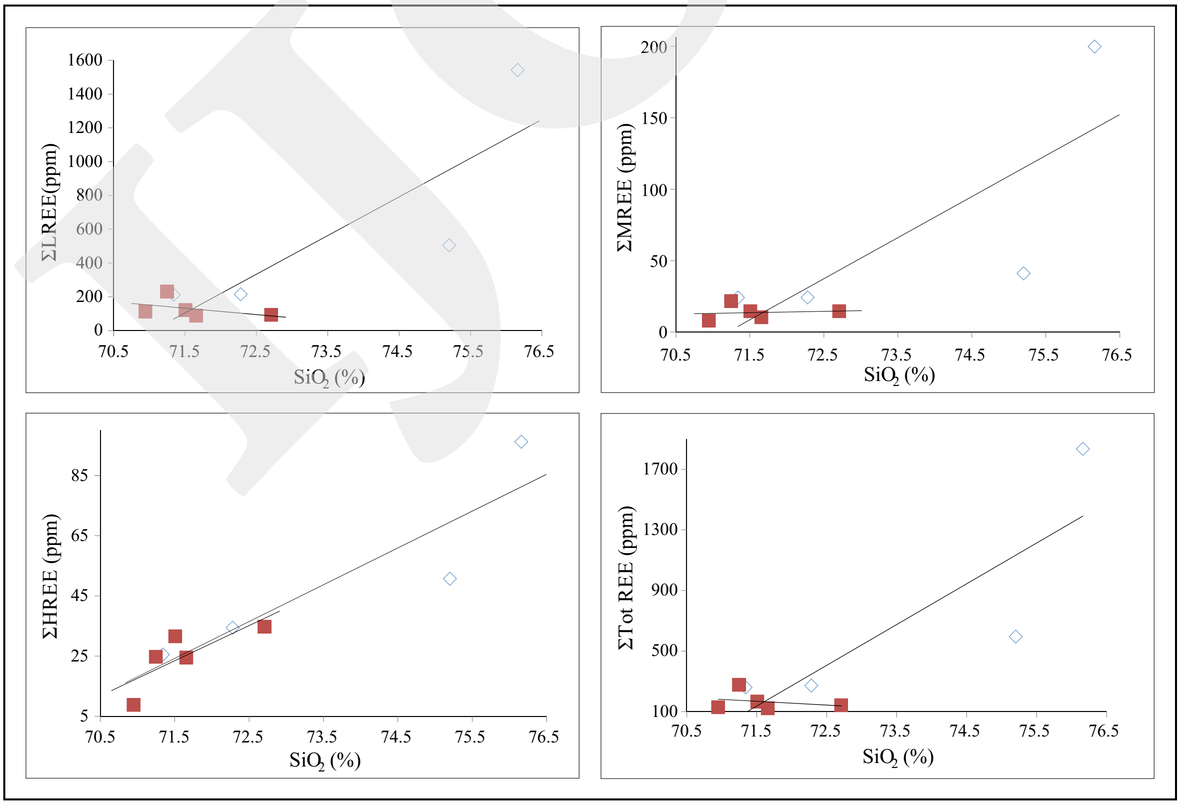

Figure 9. Variation of REE with SiO_2 in Muncung Granite *(open diamond=A facies, solid rectangle=B facies)*.

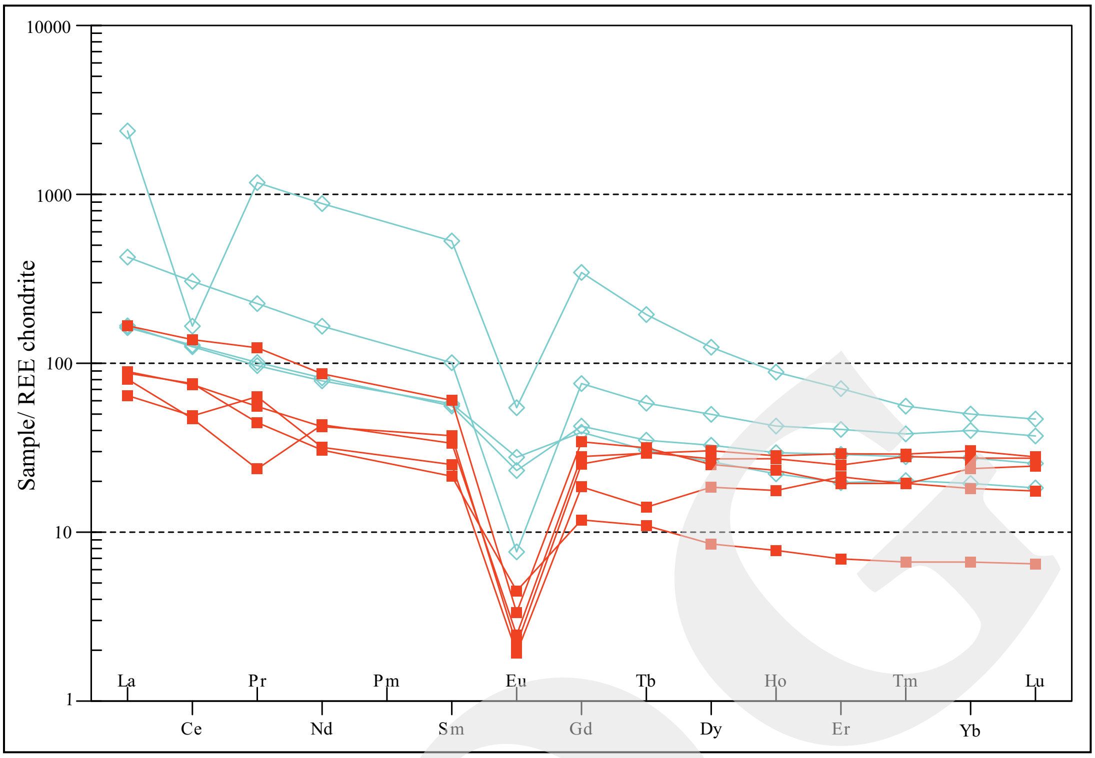

Figure 10. Chondrite-normalized rare earth element patterns of granitoid samples. Normalisation factors after Boynton(1984) *(Blue is A facies, red is B facies).*

Conclusions

On the basis of geochemistry, the Muncung Granite could be divided into two facies. Aluminium Saturation Index of granitic rock samples from Singkep Island (B facies) is higher than others from Lingga and Selayar Island (A facies). The greater level of peraluminous of facies B could be the reason respecting its lower REE contents. The two groups reveal more differences on their relation to SiO_2, where B facies has an identic character with granitoid from Peninsular Malaysia. The difference of A facies to granitoid from Peninsular Malaysia is the rise of Al_2O_3 with increasing SiO_2. The importance of fractional crystallization process with plagioclase as the major precipitating felsic phase is a B facies character. The REE pattern of A facies demonstrates similarity with granites from Laos. The REE pattern in B facies is opposite to granitoids from Laos that are depleted in HREE and enriched in LREE. Although trace element spider diagram tells slight contrast, however, both facies are syn-collisional and High-K calc-alkaline granites.

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