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Geology and granite petrology of the Besar Island, Johore

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Abstract: The Besar Island, located about 13 km off the east coast of Johore is one of the nearest islands off the coast of Johore. The island consists of metasediments, granite and intruded mafic dykes. The granitic rocks in the Besar Island is homogeneous, medium to coarse grained and mostly equigranular. Geochemical data of the granitic rocks show that the rock has a very high SiO_2 content more than 76%. The geochemical data suggest that the granite magma originated from anatexis of a homogenous source rock composition (or minimum melt).

Abstrak: Pulau Besar terletak 13 km dari pantai timur Johor dan merupakan salah satu di antara pulau yang terdekat dengan pantai Johor. Pulau ini terdiri daripada batuan metasedimen, granit dan diterobosi oleh daik mafik. Batuan granit di Pulau Besar adalah homogenus, berbutir sederhana ke kasar dan kebanyakannya adalah sama butiran. Data geokimia batuan granitik ini menunjukkan ianya mempunyai kandungan SiO_2 yang sangat tinggi iaitu lebih daripada 76%. Data geokimia mencadangkan bahawa magma ini berasal dari perleburan batuan punca yang homogenus (atau leburan minimum).

INTRODUCTION

The granitic rocks of the eastern part of Peninsular Malaysia are distributed as linear masses parallel to the medial collision suture. The province extends for a distance of about 600 km and has a typical exposed width of 80 km. The western margin of the Eastern Belt province is characterized by an abrupt development of a granitoid batholith along a line approximately 100 km from the medial suture. The granitic rocks of the Eastern Belt intruded into generally gently to tightly deformed weakly metamorphosed Carboniferous to Triassic sediments and volcanics. Biotite ± hornblende granodiorite to granite is the most common rock type but a single intrusive complex may consist of rocks ranging from gabbro to granite (*sensu stricto*). Mafic dyke swarms are common (Azman 1998, 2000, 2001, 2002; Azman *et al.*, 2001). The Besar granite is located at the southern part of the Eastern Belt granite. The island, situated about 13 km off the east coast of Johore is one of the nearest islands off the Johore coast. Regionally, the island is located in the Eastern Belt of Peninsular Malaysia surrounded by volcanic and intermediate to felsic plutonic islands (Figure 1). The granitic rocks of the island represent the eastern margin granitic body of the Eastern Belt. The metasediments in the island have been intruded by the granitic rock and the contact can be found along the west and southwest coast of the island. Both the granite and metasediments have been intruded by a set of northeast – southwest trending mafic dykes.

Geochemical data of the granitic rocks show that the rock has a very high SiO_2 content more than 76%. This is odd considering that the high SiO_2 granite (in Peninsular Malaysia) usually occurs as aplopegmatite or late stage veins cutting the main granite proper (e.g. Liew 1983). Our mapping indicates that the whole of Besar Island is made up of high SiO_2 type. This paper will present and discuss the major and trace element contents and will examine in detail the petrology, mineral chemistry and geochemistry of the pluton in comparison with the Western Belt granite.

FIELD OCCURRENCE AND PETROLOGY

The granitic rocks of Besar Island is homogeneous, medium to coarse grained and mostly equigranular. The granite generally is devoid of xenoliths and other enclaves, except for some veins composed of quartz and epidote seen cutting across the rock. The granite has been cut by NE-SW trending mafic dykes. Petrographic study indicates that the dykes are mainly doleritic and good outcrops can be found in Pantai Batu Hitam in the southwest of the island.

Modes were determined for medium and coarse grained rocks by point counting. The data were collected using a Swift Model E point counter fitted with an automated stage. Samples were either normal thin sections (area of rock approximately 30 by 40 mm) or polished thin sections that had been prepared for microprobe analyses. Usually the total counts were between 1500 - 2000 on each specimen in such a way that the whole surface of the thin section was covered. Minerals counted were alkali feldspar, plagioclase, quartz, biotite, hornblende, muscovite, sphene, allanite, zircon, epidote, Fe-Ti oxide, flourite and apatite. All Besar granite samples plot in the syenogranite field (Streckeisen, 1976) (Figure 2). The granite is made up of K-feldspar, plagioclase, quartz, biotite and accessory minerals. Generally, the biotite content is less than 3 % of the total rock and hence most of the granite appears leucocratic, whitish and lacks mafic minerals. Biotite usually occurs as individual flakes and is greenish as a result of chloritisation. Granophyric intergrowth (quartz and K-feldspar) is ubiquitous. The intergrowth sometimes can be seen in the hand specimen.

GEOCHEMISTRY

Analytical Procedure

Wherever possible, 2 kg samples of the freshest available material were collected; however, certain samples such as some of the aplites and dykes were considerably smaller. The samples were firstly trimmed in order to remove any altered/weathered material. Some of the removed sawn slabs were used for photographs. The clean and freshest samples were split into 1 cm cubes using a hydraulic jaw-splitter and an automatic jaw-crusher, washed to remove dust, and dried (at room temperature) overnight.

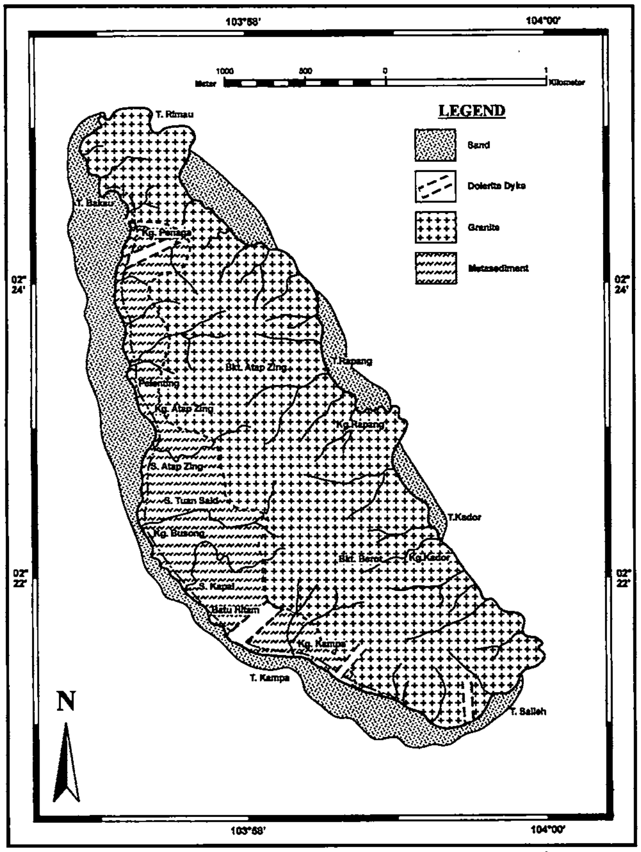

Figure 1. Simplified geological map of the western part of the Besar Island, Johore.

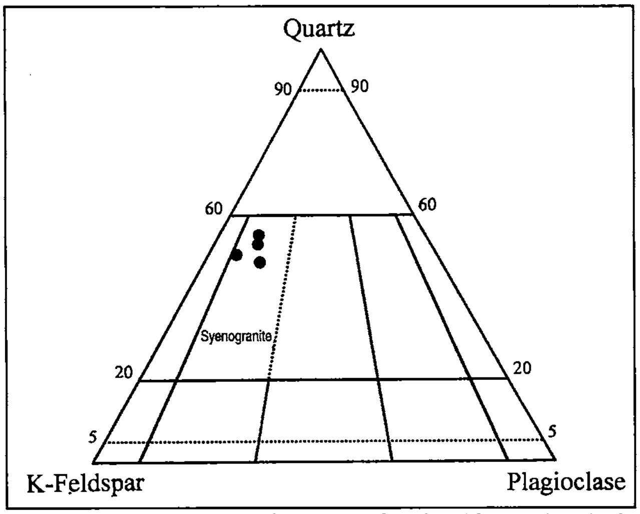

Figure 2. Q-A-P diagram of the Besar Granite. All samples plot in the syenogranite field.

The chips were then reduced to powder by grinding in a Tema laboratory disc mill using a tungsten-carbide barrel. W, Co and Ta are known contaminants that could be introduced at this stage. Milling time was 30 seconds (150 micron) and another 15 seconds to reduce the size to 53 microns. The sample powder was not sieved as it is believed that this procedure introduces unnecessary inhomogenity into the sample. The sample powder was then shaken and dried at 105°C ± 5 for 1-2 hours

Glass fusion discs were used in the analysis of major elements. Each disc was prepared by using a mixture of approximately 0.5 g (weighed to 4 decimal places) of 153 microns of rock powder with 3.3 g of lithium borate flux in a ratio of 5.4321 : 1 flux : rock, at 1150°C and casting the melt onto 4 cm diameter aluminium platterns. The resultant glass disc was then mounted on a backing disc for analysis. Powder pellets used in trace elements analysis, were prepared by mixing 7 g of 53 microns powder with 12 to 15 drops Moviol binder solution (4 g Moviol + 10 ml ethanol + 50 ml distilled water). The resultant mixture was pressed into a 4 cm disc under 5 tons pressure and left to dry before analysis.

Major oxide elements (SiO_2, TiO_2, Al_2O_3, Fe_2O_3 (expressed as Fe_{tot} in data tables), MgO, MnO, CaO, Na_2O, K_2O, P_2O_5) were analysed by X-Ray fluorescence Spectrometer 3080E of Japanese Rigaku Industrial Corporation with RSD (Relative Standard Deviation) $\leq$3% at the National Research Center of Geoanalysis of China.

Results

The major and trace element analyses of the Besar granite and mafic dykes are given in Table 1. Major element Harker variation diagrams for the granite and dykes are shown in Figure 3. The range of SiO_2 for each of the granite and mafic dykes is 76.24 to 77.73% and 47.09 to 56.40% respectively. The Harker diagrams also show that there is a gap between the granite and dykes at SiO_2 of 56.4 to 76.41 %. This compositional gap probably represent a true compositional difference between the two rock types and not because of under-sampling. In general, the dykes show clear trends of decreasing Al_2O_3, MgO and CaO with increasing SiO_2. K_2O shows no clear trend in the dyke. The granitic rocks have higher Na_2O and K_2O and lower Al_2O_3, TiO_2, Fe^{tot}, MgO and CaO contents compared to the dykes. The Besar granite is weakly peraluminous; the ACNK ranging from 1.04 to 1.16. Normative corundum ranges between 0.44 to 1.75 %. The rocks have high alkali contents, with K_2O ranging between 4.76 to 5.0 % and Na_2O ranging between 3.07 to 3.66. The granitic rocks have higher Th and Rb and lower Ba and Sr contents compared to the dykes. This is consistent with highly fractionated granite elsewhere.

Table 1. Major and trace element data for the Besar granite and associated dykes. Note: Gra = granite ; Dyke = mafic dyke.

Sample	M1 Gra	M2 Gra	M3 Gra	M5 Gra	M9 Gra	M10 Gra	M4 Dyke	M7 Dyke	M8 Dyke
In weight %									
SiO_2	76.43	76.24	76.52	77.39	77.73	76.41	56.04	52.92	56.4
TiO_2	0.11	0.10	0.11	0.12	0.10	0.11	1.64	1.32	1.44
Al_2O_3	12.0	12.48	11.9	12.19	11.33	12.08	15.02	15.27	16.79
FeO	0.63	0.48	0.81	0.59	0.63	0.77	6.11	5.03	5.91
Fe_2O_3	0.84	0.75	0.68	0.52	0.77	0.77	3.8	4.06	4.66
MnO	0.03	0.01	0.04	0.02	0.02	0.03	0.18	0.14	0.11
MgO	0.01	0.07	0	0.02	0	0.03	3.42	2.94	3.66
CaO	0.18	0	0.04	0.04	0.34	0.02	7.2	5.39	5.18
NaO_2	3.41	3.07	3.54	3.66	3.12	3.6	2.88	2.41	2.43
K_2O	4.96	5.25	4.99	4.93	4.76	5.0	0.98	2.74	2.72
P_2O_5	0	0	0	0.01	0.01	0.01	0.25	0.27	0.28
Total	99.07	99.91	101.14	100.17	100.39	99.44	99.52	99.49	99.58
In ppm									
Ba	1	0	0	7	28	25	155	105	154
Ce	337	262	498	309	649	689	394	7	337
La	133	100	113	122	127	113	79	135	109
U	19	20	22	20	21	17	12	14	16
Th	32	14	24	12	3	30	0	0	0
Cr	49	53	42	54	63	59	27	20	33
Zr	76	91	83	75	69	84	59	67	66
Sr	6	8	2	8	13	6	90	64	30
Rb	100	108	104	94	91	92	0	46	44
Ga	16	15	16	13	15	14	14	15	13
Zn	24	11	18	2	6	9	13	12	22

CONCLUDING REMARKS

In the Eastern Belt, high SiO_2 granite (72 to 74%) has been recorded in several granitic pluton such as Maras Jong and Kuantan granite (Cobbing *et al.*, 1992). New data indicate that the Besar granite has higher SiO_2 contents than the Maras Jong and Kuantan granitic plutons i.e. more than 76%. The composition of major and most trace elements of the Besar granite as well as of its constituting minerals appear to be very constant. This may imply that the original anatexis cannot have been developed in rocks of highly variable composition; otherwise melting would have produced large heterogeneities. Q-Ab-Or diagram can be used to determine the composition of minima melts at varying pressures in both H_2O-saturated and H_2O-undersaturated conditions (Figure 4). All the Besar granite samples plot in the granitoid composition limit as proposed by Winkler and Platen (1959) and in the granitoid triangle as proposed by Tuttle and Bowen (1958). Based on the diagram, it is inferred that the bulk of the rocks are granitoids in composition. Samples of the granite are clustered implying that they are from the same magma. It is inferred that the granitic rock had a minimum pressure of 0.5-1 kb, which is an indication of high-level emplacement. The granite plots lie closer to the 0.5 kb point (average Ab/An=2.33) suggesting a minimum temperature of 695° (Winkler, 1979). Compared to the high SiO_2 granite (SiO_2

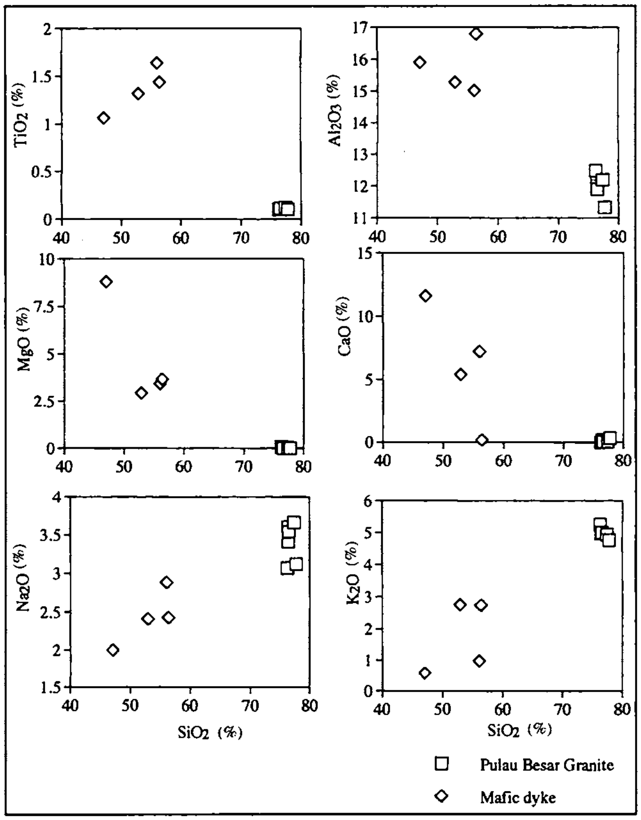

Figure 3. Major element Harker diagram for the Besar Granite and associated mafic dykes.

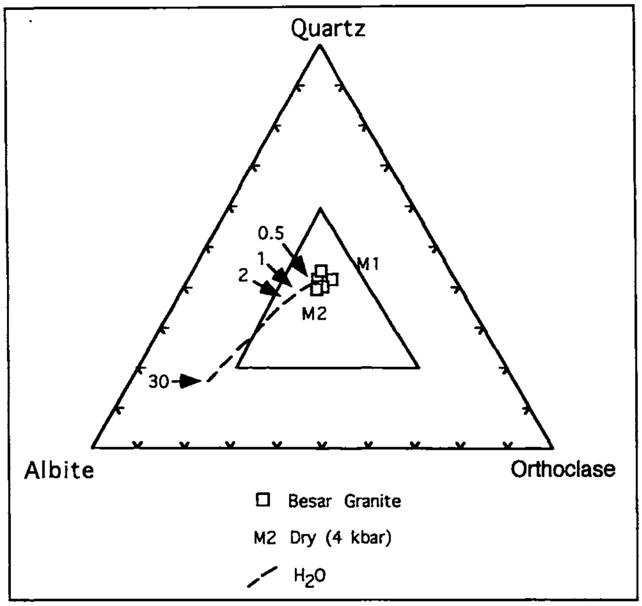

Figure 4. Quartz-Albite-Orthoclase diagram of the Besar Granite.

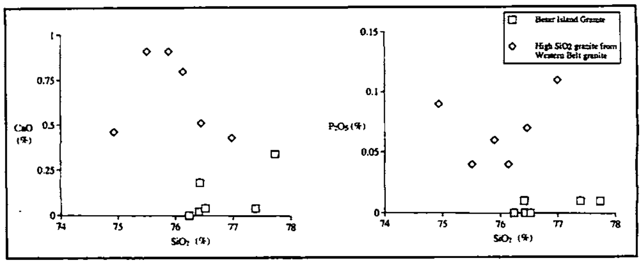
Figure 5. CaO and P_2O_5 vs. SiO_2 plots for the Besar Granite and high SiO_2 granite from the Western Belt of Peninsular Malaysia.

> 75%) from the Western Belt Granite (Fig 5), the Besar granite has less CaO and P_2O_5. The high SiO_2 of Western Belt granites occur as aplopegmatite dykes and veins.

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