Geological Society of Malaysia Annual Geological Conference 2002
May 26 – 27, Kota Bharu, Kelantan, Malaysia

Petrology of dioritic rocks from the Pemanggil Island, Johore

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Abstract: The three types of dioritic rocks occurring in the Pemanggil Island are pyroxene hornblende diorite, porphyritic pyroxene hornblende diorite and microdiorite. The rock intruded into the volcanic rock probably of Permian age. Geochemical data shows that the SiO_2 content increases from pyroxene hornblende diorite to porphyritic pyroxene hornblende diorite to microdiorite. LIL log-log plot suggests that crystal fractionation plays an important role in the magmatic evolution of the Pemanggil dioritic magmas and plagioclase, hornblende and biotite are the major precipitating phases.

INTRODUCTION

Pemanggil Island located about 45 km off southeast Mersing and 10 km to the south of Tioman Island. The island attracts many tourists, as it is one of the favourite deep- water fishing destinations in Peninsular Malaysia. The island forms a chain of three islands with Tioman and Aur off eastern Johore. 80% of the rock types in the three islands are igneous rocks mainly granite, diorite and gabbro (Fig. 1). This paper will report the geochemical characteristics of the dioritic rocks from Pemanggil Island.

GEOLOGICAL SETTING AND FIELD RELATION

The Eastern granitoid province, which consists of the Central Belt and the Eastern Belt (Cobbing *et al.*, 1992), comprises of an extended compositional spectrum from gabbro to monzogranite. The whole province consists of several batholith such as Boundary Range, Kapal and Stong complex to the north and Blumut-Muntahak, Mawang and Belungkor to the south. In common with other terrains, narrow sedimentary screens often separate these different units. The batholiths are surrounded by narrow contact metamorphism aureoles superimposed on low grade metamorphic country rocks (Hutchison, 1977). The Pemanggil Island, together with Tioman and Aur islands in the south and Perhentian and Redang islands in the north of the Peninsular Malaysia are the most easterly exposed of the Eastern Belt rock. The islands are underlain by variety of igneous rocks ranging in composition from syenitic to monzonitic and even dioritic and gabbroic composition. In southeastern Johore, majority of the rocks intruded the earlier volcanic rocks (both pyroclastic and lavas are present) known as Jasin Volcanic.

Three types of dioritic rocks occur in the island are pyroxene hornblende diorite, porphyritic pyroxene hornblende diorite and microdiorite. The rock intruded into the volcanic rock probably of Permian age. The contacts between the dioritic and their host rocks exposed at Teluk Lanchang. Fragments of the volcanic rock measuring between 10 to 20 cm across can be seen in the dioritic rock (Mohd Marzuki Asmuri, 2002; Mohd Basri Ismail, 2002).

The pyroxene hornblende diorite occurs mainly in the northern part of the island (e.g. Teluk Buau and Teluk Pontianak). The plagioclase in this rock may vary in colour from pinkish to black grey. The different coloured plagioclases, however appeared to have a same petrographic characteristics. The porphyritic pyroxene hornblende diorite occurs mainly in the southern part of the island (e.g. Teluk Sulit). No contact has been found between the pyroxene hornblende diorite and porphyritic pyroxene hornblende diorite, however at Pasir Sempit, the porphyritic rock gradually change to non porphyritic

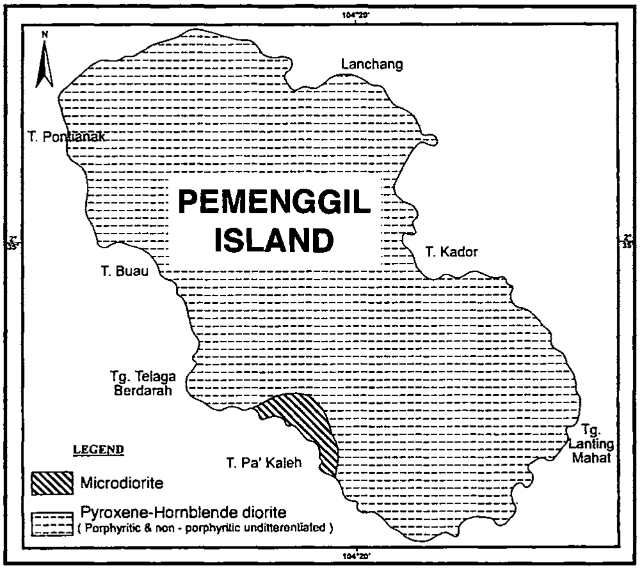

Figure 1. Geological map of the Pemanggil Island.

varieties. Both porphyritic and non-porphyritic varieties can be easily differentiated as the latter have bigger mafic clot and more equigranular.

Microdiorite occur at Telaga Berdarah and Teluk Pak Kaleh. The rocks have sharp contact with porphyritic pyroxene hornblende diorite. The microdiorite is fine grained and black greenish in colour. The dioritic rock in the Pemanggil Island is relatively homogenous. Enclave is rarely found except some small scale hornblende schlieren found in the pyroxene hornblende diorite at the eastern part of the island. Most schlieren in plutonic environment have been ascribed to partial digestion of enclave, sedimentation or flow differentiation of a crystal-charge magma The absence of this structure is likely to relate to the paucity of enclave, but may also indicate that any differential flow or convection took place while the magma was relatively crystal-poor.

PETROLOGY

Modes of the three rock types indicate that all the three rock types can be classified as diorite or gabbro according to Streckeisen (1976). In thin section all rocks generally have the same mineral composition that is plagioclase, quartz, K-feldspar, biotite, hornblende and epidote. Accessory phases are sphene, apatite, zircon and magnetite.

The fairly uniform pyroxene hornblende diorite consists in order of abundance : plagioclase (84-86%), K-feldspar (1-2%), quartz (1-2%), augite (1-2%), hornblende (8-10%), biotite (3-4%), opaque and zircon (trace). Plagioclase (An_{35} An_{66}) occurs as euhedral to subhedral crystals with the average size is from 1 mm to 2 cm. Quartz occurs as anhedral crystals or interstitially to plagioclase. The average size is from 0.5 to 1 mm.

The porphyritic texture of the porphyritic pyroxene hornblende diorite formed by phenocrysts of plagioclase (An_{37} An_{42}), set in a fine grained groundmass of plagioclase, hornblende, biotite and augite. The phenocryst is usually euhedral with average size ranging from 0.5 cm to 2 cm. The overall texture suggests that the dykes were quenched while partially crystallised. It was probably triggered by sudden loss of pressure (Pitfield *et al.*, 1990) for instance on faulting or rifting. Microdiorite consists of fine grained plagioclase (An_{34}-An_{63}), hornblende and pyroxene. The grain size is less than 1 mm.

GEOCHEMISTRY

All samples were analysed by X-Ray fluorescence (Philips PW 1480) at University Kebangsaan Malaysia. Glass fusion discs and powder pellets were used in the major and trace elements analysis respectively. 20 samples of the dioritic rocks were analysed for major and trace elements (Table 1). These samples were collected from the pyroxene hornblende diorite (10), porphyritic pyroxene hornblende diorite (8) and microdiorite (2). The range and mean (shown in brackets) of SiO_2 of the different units of the Pemanggil diorite are; pyroxene hornblende diorite: 51.01 to 63.03% (56.57% SiO_2), porphyritic pyroxene hornblende diorite: 59.68 to 63.15 (62.04% SiO_2),

Table 1. Representative chemical composition of major and trace elements for the dioritic rocks from Pemanggil Island.

Sample	TE1	TP2	TS2	TL1	TP1	TK2	TK1	TL22	B3	B5	B4	S1b	S2b	S2	TB1a	TB1b	TB1	TL1	TL2	TK
Rock types																				
wt%																				
SiO_2	63.03	56.9	53.72	51.01	56.37	62.57	62.97	54.05	59.68	63.15	60.96	62.3	62.09	66.41	57.56	60.92	65.89	56.22	55.99	62.62
TiO_2	1.06	1.42	1.3	1	1.47	1.06	1.1	1.72	1.24	0.98	1.22	1.18	1.15	0.76	1.55	1.17	0.8	1.26	1.57	1.07
Al_2O_3	15.93	17.47	19.42	15.49	17.42	16.36	15.76	18.66	17.2	15.7	16.39	16.21	16.34	15.42	18.18	16.59	15.64	18.33	17.5	15.61
Fe_2O_3	5.68	7.84	6.87	9.39	8.25	5.61	5.76	8.13	6.11	5.49	6	5.9	5.82	4.36	7.67	5.71	4.83	6.7	7.93	5.67
MnO	0.1	0.12	0.11	0.17	0.13	0.1	0.1	0.12	0.1	0.09	0.1	0.1	0.1	0.7	0.07	0.1	0.08	0.1	0.12	0.1
MgO	1.56	2.38	2.9	7.17	2.63	1.56	1.59	2.42	1.8	1.68	1.64	1.64	1.64	1.31	0.9	1.54	1.63	1.99	2.49	1.61
CaO	4.22	7.02	8.17	12.35	6.82	4.49	4.06	8.07	5.3	4.33	4.23	4.44	4.48	3.81	6.2	4.73	4.25	7.14	7.07	4.15
Na_2O	3.7	3.88	3.59	1.61	3.95	3.84	3.66	4.28	3.99	3.62	3.98	3.83	3.87	3.36	4.1	3.98	3.29	3.95	4.01	3.63
K_2O	4.06	2.68	1.18	0.16	2.59	3.91	4.33	1.39	3.67	4.12	4.19	4.33	4.29	4.19	3.4	4.07	4.16	2.58	2.59	4.28
P_2O_5	0.43	0.86	0.89	0.11	0.81	0.46	0.46	0.87	0.61	0.38	0.53	0.5	0.52	0.29	0.92	0.53	0.3	0.78	0.96	0.44
LOI**	0.39	0.13	2.54	0.6	0.17	0.35	0.37	1.05	0.3	0.37	0.68	0.4	0.23	0.35	0	0.24	0.32	1.33	0.12	0.42
Total	100.2	100.7	100.7	99.06	100.6	100.3	100.2	100.8	100	99.91	99.92	100.8	100.5	101	100.6	99.58	101.2	100.4	100.4	99.6
ppm																				
Ba	810	903	447	248	914	946	922	1324	1067	779	986	881	896	766	1011	936	741	956	1075	836
Ce	318	316	114	0	311	394	362	449	405	301	415	347	381	303	402	358	306	333	382	345
Co	15	34	25	36	15	23	17	18	12	17	11	14	8	9	24	11	6	11	32	15
La	60	43	20	3	28	48	66	14	45	72	41	58	57	41	47	36	51	32	40	59
Nb	82	80	80	78	81	82	83	78	82	83	81	83	83	80	82	83	81	79	81	83
Ni	22	19	45	188	21	21	21	20	20	25	21	21	21	26	17	18	24	21	29	25
Pb	28	0	4	0	7	32	43	0	13	19	33	23	18	21	3	33	33	5	28	22
Rb	129	47	16	0	42	123	138	14	83	136	118	119	124	150	57	94	159	44	41	135
Sr	1335	1678	2610	1246	1674	1503	1332	2295	1835	1348	1519	1510	1578	1176	1595	1551	1198	2377	2109	1368
Th	97	107	94	51	76	120	40	11	48	97	153	111	57	85	35	88	179	97	51	77
V	89	144	157	149	143	90	94	164	106	88	94	92	91	74	161	97	74	128	138	91
Y	38	20	4	0	14	41	42	7	30	40	32	38	43	40	38	34	41	20	20	43
Zn	91	84	81	70	85	86	90	92	70	81	103	94	94	76	81	89	62	77	82	88
Zr	354	239	143	126	261	348	409	159	346	345	307	358	365	318	331	343	322	222	230	384

microdiorite: 65.9 to 66.4% (66.15% SiO_2). The data show that the mean of SiO_2 increases from pyroxene hornblende diorite to porphyritic pyroxene hornblende diorite to microdiorite. The data also show that the porphyritic pyroxene hornblende diorite has more restricted composition compared to the pyroxene hornblende diorite. Harker diagrams for the major and trace element oxides of the Pemanggil diorite are shown in Figures 2 and 3 respectively. The diagrams show that the Al_2O_3, Fe(tot), CaO, Na_2O and P_2O_5 and to a lesser extent TiO_2 and MgO decrease in concentration with increasing SiO_2. Sample TL11 from the pyroxene hornblende diorite has the lowest SiO_2 content and extremely high MgO (7%), CaO (12%), Fetot (9.39%) and MnO (0.17%) compared to the other Pemanggil samples. On the other hand the sample recorded the lowest content of Al_2O_3 (15.49%), Na_2O (1.6%), K_2O (0.6%) and P_2O_5 (0.11%) compared to the other Pemanggil samples.

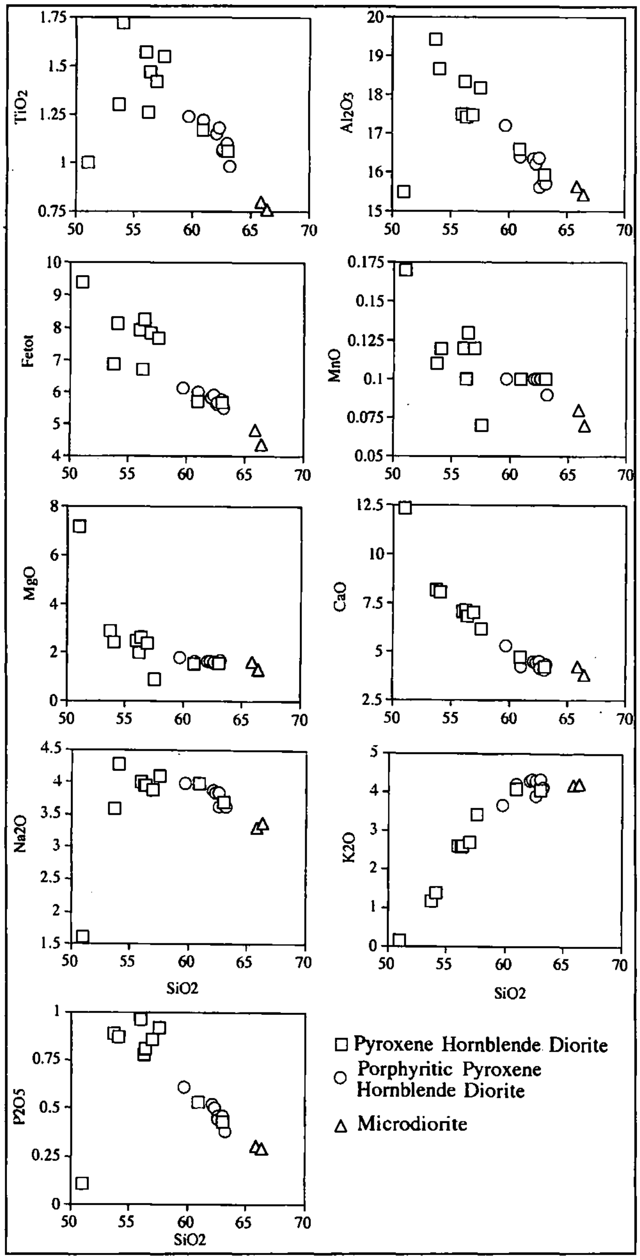

Figure 2. Major elements Harker diagram of the dioritic rocks from the Pemanggil Island.

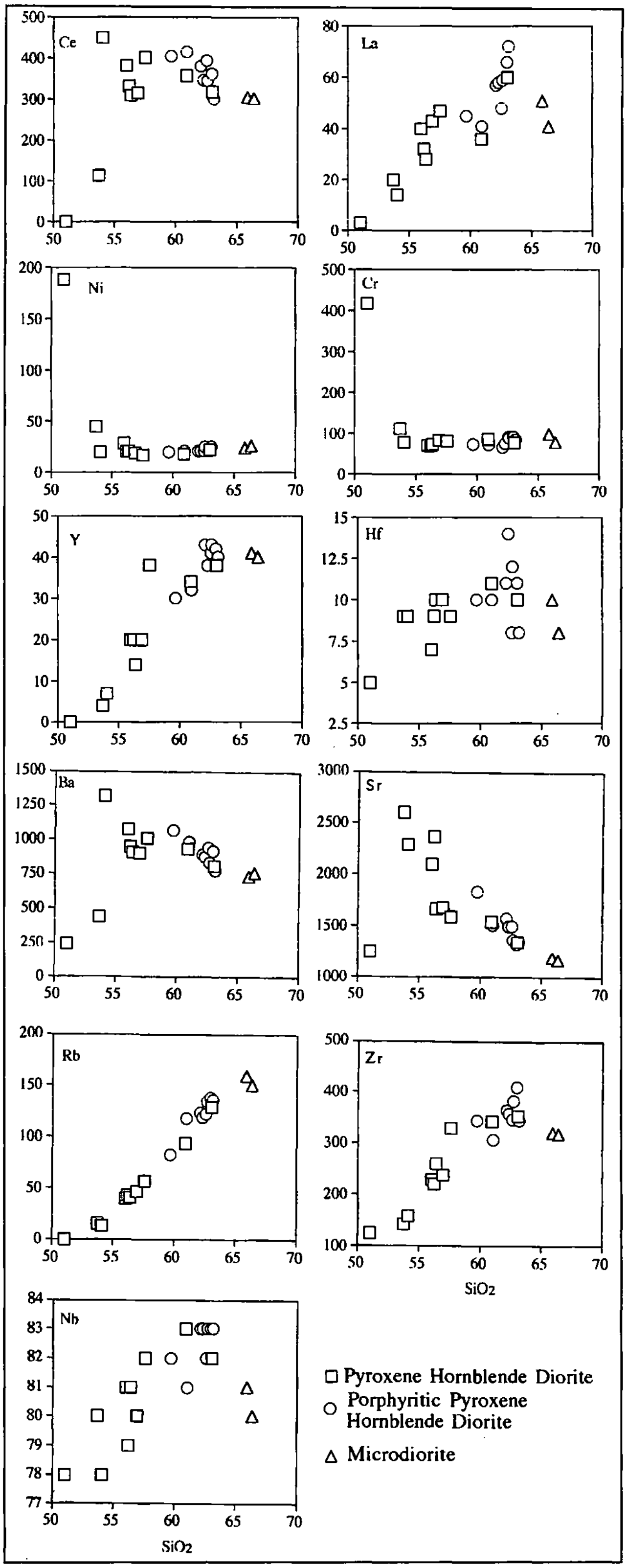

Figure 3. Trace elements Harker diagram of the dioritic rocks from the Pemanggil Island.

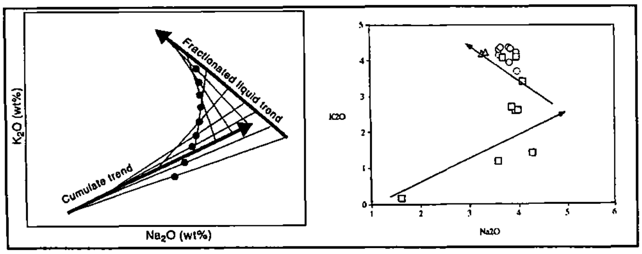

Figure 4. Na_2O vs K_2O diagrams of the dioritic rocks from the Pemanggil Island and theoretical plot showing tie lines connecting cumulates with fractionated liquid.

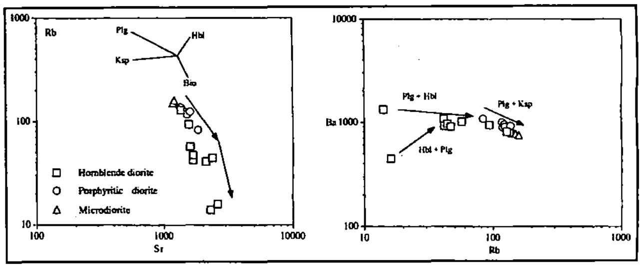

Figure 6. Log-log Ba vs Sr and Ba vs Rb plots of the dioritic rocks from the Pemanggil Island. Mineral vector indicate path evolved liquids for 30% of mineral precipitating.

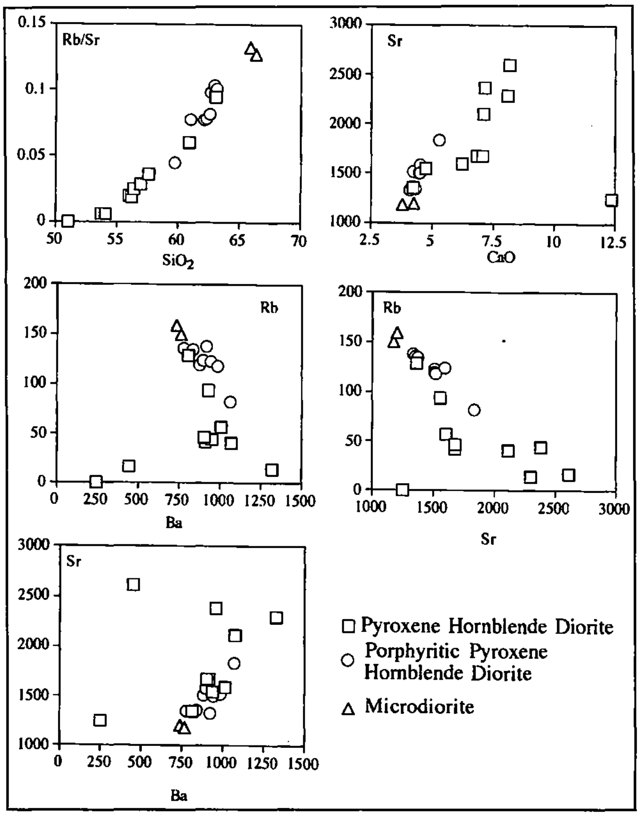

Figure 5. Various trace element plots of the dioritic rocks from the Pemanggil Island.

Extremely good correlation shown by the SiO_2 vs. CaO, Al_2O_3 and K_2O suggests that a connection exists between all the rocks at some stage of their magmatic evolution. The fact that they are co-magmatic is also support by the trace elements plots such as SiO_2 vs. Sr, Rb, Zr, La and Y. Zirconium content increase relatively linearly from mafic diorite to relatively felsic diorite of approximately 400 ppm at 63% SiO_2 (felsic part of the porphyritic pyroxene hornblende diorite) and then decrease in the microdiorite samples. The maximum is considered to be the point of zircon saturation

Na_2O vs K_2O diagram for the Pemanggil diorite is given in Figure 4. The mafic rocks plot along a trend where Na_2O and K_2O increase together, but the felsic rocks plot along a trend where K_2O continuous to increase, but Na_2O decrease. A possible interpretation of this pattern of variation is shown in Figure 4. The high Na_2O and porphyritic pyroxene hornblende diorite and microdiorite represent the differentiated melts that complements the most mafic dioritic cumulates. As the melts differentiates by some back mixing (Wyborn *et al.*, 2001), the cumulates increase in both Na_2O and K_2O, but parental melt does not change its Na_2O content substantially, so the differentiated melt decreases in Na_2O as the system evolves. This correlation is taken as prove of convective fractionation.

Good correlation shown by some inter-elements variation diagram such as Rb vs SiO_2, Zr vs SiO_2, Y vs SiO_2, Rb/Sr vs SiO_2 and Sr vs CaO suggests a connection exists between all the dioritic rocks at some stage of their magmatic evolution (Fig. 5). Positive slope of Sr vs CaO supports that plagioclase is being removed in the differentiation sequence.

The importance of hornblende and plagioclase in the differentiation is consistent with large ion lithophile element (LIL) modelling. Inter-element LIL variation diagram for pairs Rb-Sr and Ba-Rb are shown in Figure 6. Also shown in the Rb-Sr diagram is the vector diagram representing the net change in composition of the liquid after 30% Rayleigh fractionation by removing K-feldspar, hornblende, plagioclase or biotite. In all Ba–Rb diagram the trends are consistent with fractionation of plagioclase and hornblende. Biotite is also important crystallization phase as shown in Rb-Sr diagram. Thus the LIL log-log plot suggest that crystal fractionation plays an important role in the magmatic evolution of the Pemanggil dioritic magmas.

CONCLUSIONS

Three types of dioritic rocks occur in the Pemanggil Island are pyroxene hornblende diorite, porphyritic pyroxene hornblende diorite and microdiorite. The rocks intruded into the volcanic rock probably of Permian age. Geochemical data shows that the SiO_2 content increases from pyroxene hornblende diorite to porphyritic pyroxene hornblende diorite to microdiorite. The range and mean (shown in brackets) of SiO_2 of the different units of the Pemanggil diorite are; pyroxene hornblende diorite: 51.01 to 63.03% (56.57% SiO_2), porphyritic pyroxene hornblende diorite : 59.68 to 63.15 (62.04% SiO_2), microdiorite: 65.9

to 66.4% (66.15% SiO_2). LIL log-log plot suggest that crystal fractionation plays an important role in the magmatic evolution of the Pemanggil dioritic magmas. Plagioclase, hornblende and biotite are the major precipitating phases.

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