Geological Society of Malaysia Annual Geological Conference 2000
September 8–9 2000, Pulau Pinang, Malaysia

Petrography and Mineral Chemistry of the Perhentian Kecil Syenite, Perhentian Kecil, Besut, Terengganu

AZMAN A GHANI & KAMARUL HADI ROSELEE

Department of Geology, University of Malaya
50603, Kuala Lumpur, Malaysia

Abstract

The Perhentian Kecil syenite consists of a variety of igneous rocks ranging in composition from syenitic to monzonitic to gabbroic rocks. The essential minerals in Perhentian Kecil syenite are K-feldspar, plagioclase, hornblende, pyroxene, quartz, biotite, sphene, epidote, apatite, zircon and magnetite. Composition of K-fedspar in the Perhentian Kecil syenite is near to pure orthoclase with An percentage less than 1%. Plagioclase compositions range from oligoclase - andesine ($An_{27.2-37.3}$). Magnesio-hornblende is the main amphibole type and the crystals show an increase of TiO_2 and Al^{iv} and decrease in CaO from core to rim. The deduced magmatic crystallisation interval for the hornblende in the Perhentian Kecil syenite range from 660 to 780 °C (± 70°C). Composition of the sphene plot in the igneous sphene field are similar to those from the Victoria Range granitic rocks, south island New Zealand. Apatite can be divided into clear and clouded parts. Chemical analysis of the clouded part has higher SiO_2, K_2O, Fe^{tot} and BaO, and both CaO and P_2O_5 have wider range in the clouded part compared to the clear part.

Petrografi dan Kimia Mineral Syenit Perhentian Kecil, Perhentian Kecil, Besut Terengganu

Abstrak

Syenit Perhentian Kecil terdiri daripada pelbagai batuan igneus berjulat daripada komposisi syenit-monzonit-gabro. Mineral yang lazimnya wujud dalam syenit Perhentian Kecil terdiri daripada K-feldspar, plagioklas, hornblend, piroksen, kuarza, biotit, sfen, epidot, apatit, zirkon dan magnetit. Komposisi K-feldspar dalam syenit Perhentian Kecil hampir kepada ortoklas tulen dengan peratusan An kurang dari 1%. Komposisi plagioklas menjulat dari oligoklas-andesin ($An_{27.2-37.3}$). Hornblend-magnesio adalah jenis amfibolit utama dan kristal menunjukkan pertambahan TiO_2 dan Al^{IV} dan penurunan CaO dari pusat ke bingkai. Sela pengkristalan magmatik untuk hornblend dalam syenit Perhentian Kecil berjulat dari 660-780°C(±70°C). Komposisi sfen dalam plot lapangan sfen igneus mempunyai kesamaan dengan batuan granit Banjaran Victoria, di pulau selatan New Zealand. Apatit boleh dibahagikan kepada bahagian yang cerah dan berkabus. Analisis kimia bahagian yang berkabus mengandungi SiO_2, K_2O, Fe^{tot} yang tinggi, dan BaO dan P_2O_5 mempunyai julat yang luas dalam bahagian berkabus berbanding dengan bahagian yang cerah.

INTRODUCTION

The Perhentian Kecil syenite forms a circular outcrop at the central part of Perhentian Kecil Island. Although the map indicates that it appears to intrude the surrounding granitic body, field evidence shows that the Perhentian granite is relatively younger than the Perhentian Kecil syenite (Fig. 1). The pluton consists of a variety of igneous rocks ranging in composition from syenitic to monzonitic and even gabbroic rocks. The monzonitic rocks can be found at Tanjung Batu Nisan, about 10 m from the contact between Perhentian Kecil syenite and Perhentian granite. In terms of percentage, the syenitic rocks encompasses almost 90% of the pluton. Epidote nodules and veins (thickness from 2 to 5 cm) can be seen throughout the pluton. The gabbroic rocks are found as boulders mainly at Kampung Pasir Hantu and Pasir Patani and they usually contain hornblende as a main mafic phase. The mineralogy of this rock is similar to appinitic rocks described elsewhere (Pitcher and Berger, 1972; Wright & Bowes, 1979). Mahawat *et al.* (1990) reported the occurrence of appinitic rocks in the Tak batholith, Thailand.

Various types of structures can be found in the Perhentian Kecil syenite such as synplutonic dykes, hornblende rich enclaves and amphibolite blocks. The synplutonic dykes were found at Tanjung Batu Sireh and Tanjung Batu Peti. They usually show amphibolitic mineralogy suggesting a basic origin. They are also disrupted into several parts or sometimes necked along its length, which suggest that the dykes were intruded during the semi-solid state of the Perhentian Kecil syenite magma. Hornblende rich enclaves are invariably finer grained and darker coloured than their syenitic host. The enclaves were found at Teluk Aur and Tanjung Batu Peti. They usually show a sharp contact with their host. Mineralogically, the enclaves are similar to their host but in different proportions. The enclave consists of hornblende, plagioclase, opaque phase, sphene and K-feldspar with sizes up to 30 cm across.

The amphibolite blocks are found in Pasir Patani and Pasir Keranji. The blocks are larger than the hornblende rich enclaves and show a typical amphibolitic texture. The rock is usually medium grained equigranular and consists of accicular shaped amphibole crystals (up to 2 mm long).

The contact between Perhentian Kecil syenite and Perhentian granite is sharp and can be found at Pasir Karang, Pasir Patani, Tanjung Batu Nisan and along Tanjung Batu Peti to Tanjung Sireh. The Perhentian Kecil syenite forms a circular body at the central part of Pulau Perhentian Kecil. The relationship of the contacts suggests that the Perhentian granite is younger than the Perhentian Kecil syenite. Evidence supporting the younger age of the Perhentian granite is listed below (Azman and Khoo, 1998) :

1) occurrence of syenitic blocks in the granitic rock (Loc: Tanjung Batu Nisan),
2) cross cutting relationship of the contact between the rocks (Loc: Tanjung Batu Nisan, Pasir Patani, Pasir Karang and along Tanjung Batu Peti to Tanjung Batu Sireh),
3) offshoots of microgranite veins from granite to syenite (Loc: Tanjung Batu Nisan and Pasir Patani),
4) occurrence of microgranite and porphyritic rocks in the Perhentian granite at the contact, which suggests that the granitic magma quickly chilled against cooled syenitic rocks.

The Perhentian Kecil syenite is characterised by rocks with SiO_2 from 46.8 to 65.9% and can be classified as 'I' type according to the Chappell and White (1974) classification. The rocks are metaluminous with the ACNK value of 0.63 - 0.97. They also have high Ba,- Sr values and total REE content (224-450ppm) compared to other Eastern Belt igneous rocks. The aim of this paper is to present the petrography and chemistry of some of the major and accessory mineral phases of the Perhentian Kecil syenite. Detailed geology and petrochemistry of the syenitic rocks and its relationship to the granitic rocks has been presented by Azman & Khoo (1998) and Azman (2000; in press).

PETROGRAPHY

The essential minerals in the Perhentian Kecil syenite are K-feldspar, plagioclase, hornblende, pyroxene, quartz, biotite, sphene, epidote, apatite, zircon and magnetite. Large alkali feldspars, up to 3 cm across often give the rock a distinctly porphyritic appearance in hand specimen. It is subhedral to anhedral and sometimes highly sericitised. Plagioclase is subhedral to anhedral and ranges in size between 1 to 2 mm across. It usually shows albite, carsbad-albite and pericline twinning.

Biotite is subhedral to anhedral and occurs as elongate crystals or aggregates associated with hornblende and sphene. Hornblende is euhedral to anhedral.The most common pleochroic scheme is X = light yellowish green, Y = Z = dark green. It sometimes poikilitically encloses K-feldspar, apatite, sphene, zircon and anhedral quartz crystals. Prehnite is lens shaped or interleaved in biotite crystals and sometimes occurs as radiate crystals in the biotite. The long axis of the lens is parallel to the biotite cleavage. It is colourless in thin section and shows characteristic wavy extinction and sometimes show well developed cleavage. The cleavage appears to branch outwards from the middle of the lens, is also known as 'bow tie' texture.

Euhedral to subhedral sphene is the most common accessory mineral and is preferentially associated with hornblende and biotite or as individual crystals. It is sometimes cracked probably as a result of thermal shock during magma ascent. Apatite occurs as inclusions in hornblende, biotite, plagioclase, quartz and microcline. It occurs in two habits i.e small prismatic to acicular crystals and euhedral to anhedral squat shaped crystals. The apatite crystal commonly has a clouded core. Epidote is greenish yellow and occurs as anhedral crystals. It occurs in veins, as inclusions in biotite and in the sericitised part of plagioclase.

MINERAL CHEMISTRY

Analytical Procedure

The compositions of the plagioclase, K-feldspar, hornblende, apatite and sphene have been determined using an electorn microprobe located at the University of Manchester. All samples used were highly polished thin sections coated with 20 nm carbon film. The instrument (modified Cambridge Instruments Geoscan) was running under the following conditions: EDS analysis, 15 kv beam accelerating potential, 3nA specimen current on cobalt metal with count time of 40 liveseconds.

Plagioclase and K-feldspar

The elemental content of plagioclase and K-feldspar in the Perhentian Kecil syenite is given in Table 1. The K-feldspar and plagioclase data is plotted on an An-Ab-Or diagram (Fig. 2). The K-feldspar has very low An content (0.44 to 0.86%), and plot very near to the Or apex. This suggests that the composition of K-feldspar is nearly to pure orthoclase. It also has a higher large ion lithophile element content compared to the co-existing plagioclase. Thus, the Barium content in the K-feldspar ranges from 0.5 to 0.63% compared to plagioclase, which only recorded the highest value of 0.15% Ba. In terms of geochemical analyses, the plagioclase can be classified as oligoclase to andesine ($An_{27.2 - 37.3}$).

Hornblende

The elemental content of hornblende is given in Table 2. A plot of $Mg/(Mg+Fe^{tot})$ vs Si (Leake, 1978; Barnes, 1987) (Fig 3) shows that the main type of hornblende found in the Perhentian Kecil syenite are magnesio-hornblende and some are ferro-hornblende and actin-hornblende. The hornblende shows an increase of TiO_2 and Al^{iv} and a decrease in CaO from core to rim. Contents of

Table 1: Analytical results of plagioclase and K-feldspar from the the Perhentian Kecil syenite. Note: Samples 12 and 14: K-feldspar; others are plagioclase.

Sample No.	20	21	22	29	36	37	38	39	40	41	12	34
Location	Rim	Rim	Core	Rim	Rim	Core	Rim	Core	Rim	Half		
SiO_2	59.736	60.096	58.965	59.952	60.055	59.186	58.53	59.269	60.548	60.678	64.583	63.516
TiO_2	0	0	0	0.08	0	0.045	0	0.099	0	0.038	0.045	0
Cr_2O_3	0	0.138	0.022	0	0.53	0.156	0.109	0	0.027	0.072	0.069	0.084
Al_2O_3	24.658	24.958	25.494	24.883	24.643	24.742	24.77	25.315	23.709	23.654	18.181	17.883
FeO	0.173	0.085	0.253	0.355	0.33	0.219	0.29	0.414	0.166	0.202	0.141	0.056
MnO	0	0	0.016	0	0	0	0	0.073	0	0	0	0
MgO	0	0	0	0	0	0	0	0	0	0	0	0
Na_2O	7.485	7.476	6.873	7.298	7.987	7.255	7.246	7.753	8.018	8.082	0.59	0.624
K_2O	0.388	0.392	0.394	0.268	0.302	0.174	0.262	0.367	0.206	0.283	15.534	15.354
CaO	6.848	6.662	7.759	7.167	6.452	7.3	7.058	5.844	5.94	5.719	0.167	0.089
P_2O_5	0	0.058	0.049	0	0	0.055	0	0	0	0	0.254	0
BaO	0	0.149	0.012	0.009	0.122	0.032	0	0.042	0.009	0.11	0.502	0.633
Total	99.28	100.014	99.837	100.012	99.94	99.164	98.565	99.18	98.623	98.84	100.07	98.239

Structural formula on the basis of 8 Oxygen

Si	2.69	2.68	2.65	2.67	2.69	2.67	2.67	2.67	2.74	2.74	2.99	3
Al	1.31	1.31	1.35	1.33	1.3	1.32	1.33	1.34	1.26	1.26	0.992	0.996
Fe	0	0	0	0.134	0.012	0	0.011	0.02	0	0	0.0055	0.0022
Na	0.65	0.65	0.6	0.64	0.69	0.64	0.64	0.68	0.7	0.71	0.053	0.057
K	0.022	0.022	0.023	0.016	0.14	0.01	0.015	0.02	0.012	0.016	0.917	0.93
Ca	0.33	0.32	0.37	0.348	0.31	0.35	0.34	0.28	0.288	0.28	0.0084	0.0044
Total	5	4.982	4.993	5.138	5.142	4.985	5.006	5.01	5	5	4.966	4.99
(Ca+Na+K)	1.002	0.992	0.993	1.004	1.14	1	0.995	0.98	1	1.006	0.978	0.991
% An	32.9	32.3	37.3	34.7	27.2	35	34.2	28.6	28.8	27.8	0.86	0.44

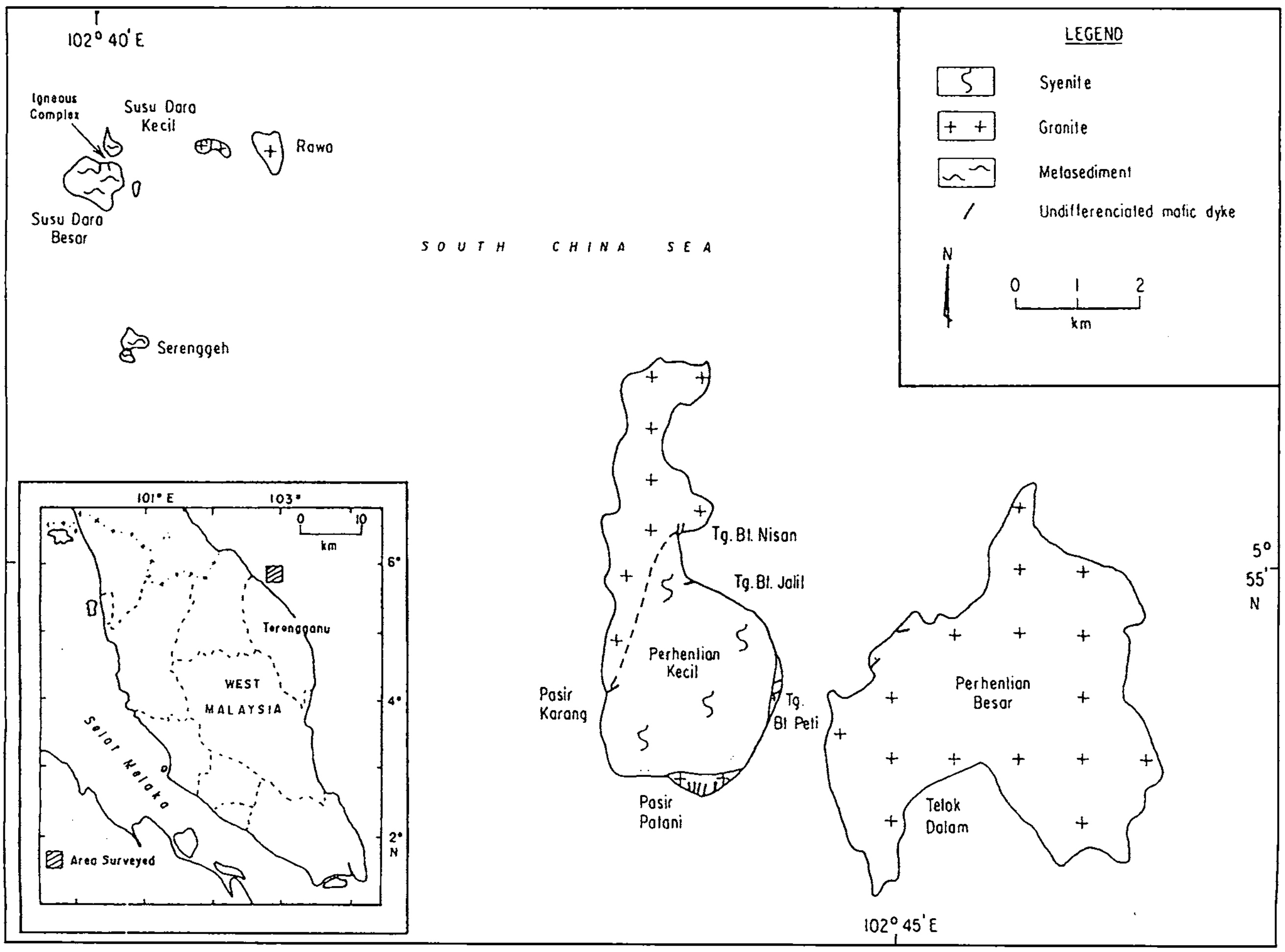

Figure 1: Geological map of the Perhentian Island showing the Perhentian Kecil syenite and Perhentian granite.

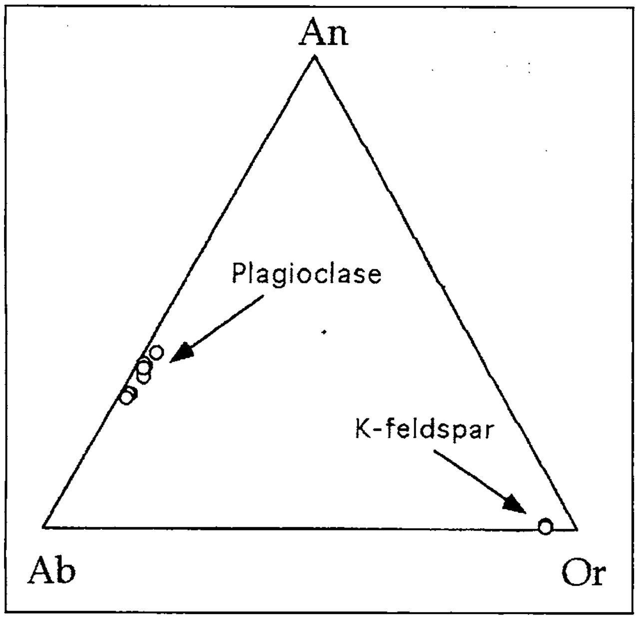

Figure 2: An-Ab-Or diagram for the plagioclase from the Perhentian Kecil syenite.

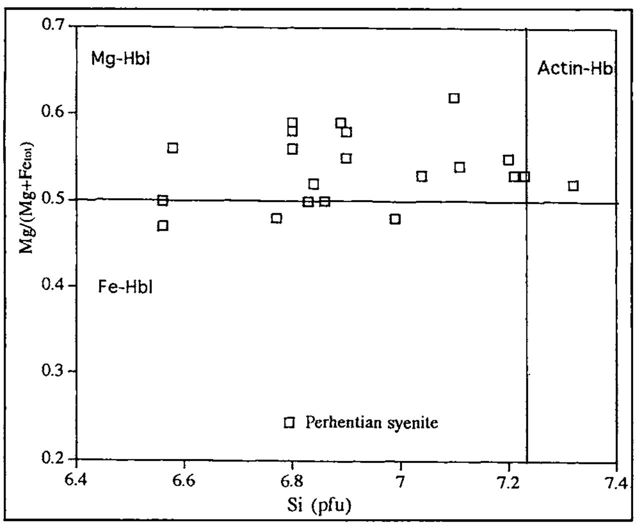

Figure 3: $Mg/(Mg+Fe^{tot})$ vs Si (pfu) diagram for the hornblende from Perhentian Kecil syenite. The hornblende plot mainly in the magnesio-hornblende field.

other elements are typically: 14.73 to 19.35 % Fe^{tot} , 10.6 to 12.3 CaO and 0.22 to 1.21 % K_2O. The thermal stability of the amphiboles from the Perhentian Kecil syenite was estimated in a plot of the T-sensitive cations Ti and Al^{4+} (Weiss and Troll, 1989) (Fig. 4). The largely empirical T-scale is based on the correlation of Al^{4+} vs Ti (Hammarstrom and Zen, 1986), which is largely independent of pressure (Nabelek and Lindsley, 1985). Generally, there is a positive correlation of Ti and Al^{4+} cations with temperature. The deduced magmatic crystallisation interval for the hornblende is in the range of 660 to 780 °C (± 70°C).

Sphene

The elemental content of sphene is given in Table 3. It contains 25.7 - 27.4% CaO and 0.63 - 2.4% BaO. Both elements are relatively lower compared to other sphene from calc alkaline granites (Azman, 1997). On a Al-Ti-Fe diagram (Fig. 5), which discriminates between igneous and secondary sphene in the Victoria Range granitic rocks, south island New Zealand, the sphene fall into the igneous field of this diagram (Tulloch, 1979).

Apatite

The elemental content of apatite in the Perhentian Kecil syenite is given in Table 4. The results have been divided into the clear and clouded parts of the apatite. Microprobe analysis shows that the clouded part has higher SiO_2, K_2O, Fe(tot) and BaO, and both CaO and P_2O_5 have wider range in the clouded part compared to the clear part of apatite (Azman, 1998). It contains 41.56 to 43.24% P_2O_5 and 53.37 to 55.81 % CaO. Interestingly, the apatites contain no MnO compared to the apatite analysis conducted by Deer *et al.* (1993), which contain considerable amounts of MnO (0.01 to 5.32%). This suggests that the replacement of Ca by Mn is not an important mechanism in the apatite from the Perhentian Kecil syenite.

Opaque Phase

Analysis of opaque phases in the Perhentian Kecil syenite is given in Table 5. Samples 5 and 6 occur as inclusions in hornblende. Magnetite is the most common opaque mineral in the syenite (Deer *et al.*, 1993 , Table 53 in p. 563). In general there are no significant differences between those samples compared to other opaque phases. All analysis have more than 90% Fe^{tot} except sample 33 which has 84% Fe^{tot}. Apart from the sample 33, all other samples have small amounts of Al_2O_3 (0.14 – 0.24%). This small amount of Al can substitute for Fe^{3+} and generally similar small proportions of Ca, Mn and Mg replace Fe^{2+}.

CONCLUSION

1) Composition of K-feldspar in the Perhentian Kecil syenite is near to pure orthoclase with An percentage less than 1%.
2) In term of geochemical analyses, the plagioclase can be classified as oligoclase - andesine ($An_{27.2-37.3}$)
3) The main amphibole type of the Perhentian Kecil syenite are magnesio-hornblende with subordinate Ferro and Actin-hornblende. The hornblende shows an increase of TiO_2 and Al^{iv} and a decrease in CaO from core to rim.
4) The deduced magmatic crystallisation interval for the hornblende in the Perhentian Kecil syenite range from 660 to 780 °C (± 70°C).
5) Composition of the sphene plot in the igneous sphene field and similar to those from the Victoria Range granitic rocks, south island New Zealand (Tulloch, 1979)
6) Apatite can be divided into clear and clouded parts. Chemically, the clouded part contains higher SiO_2, K_2O, Fe^{tot} and BaO, and both CaO and P_2O_5 have a

Table 2: Analytical results of hornblende from the the Perhentian Kecil syenite.

Sample No.	1	2	7	8	11	12	13	14	15	18	19	30	31
Location	Core	Rim	Core	Rim	Core	Rim	Core	Half	Rim	Core	Rim	Core	Rim
SiO_2	42.385	44.872	44.425	44.69	45.011	51.993	45.639	47.267	46.17	45.668	48.705	44.56	44.02
TiO_2	1.097	0.95	1.088	0.797	1.076	0	0.881	0.702	0.576	0.635	0.461	1.055	1.331
Cr_2O_3	0	0.203	0	0.074	0.084	0	0.057	0.044	0.1	0	0.117	0	0.05
Al_2O_3	8.927	7.649	7.675	7.811	7.988	2.774	7.43	0.461	7.39	7.22	5.547	8.014	8.033
FeO	16.93	16.73	15.341	17.706	15.675	14.955	17.321	14.826	16.092	15.393	14.729	16.238	16.266
MnO	0	0.081	0.058	0	0	0	0	0.061	0	0.2	0	0	0
MgO	11.933	11.918	12.224	10.954	12.285	14.34	12.196	13.297	12.537	13.074	14.034	12.162	11.872
Na_2O	1.851	2.06	2.054	1.778	1.894	0.939	1.576	1.74	1.685	2.002	1.464	2.108	1.855
K_2O	1.173	1.199	1.193	1.105	1.195	0.22	0.921	0.936	1.153	0.975	0.833	1.204	1.217
CaO	10.572	11.823	11.801	11.806	11.94	12.34	11.394	12.129	12.062	12.073	12.114	11.911	11.448
P_2O_5	0.061	0.069	0.085	0.074	0.063	0.015	0.194	0.025	0.045	0	0	0.07	0
BaO	0.127	0.147	0	0.14	0.083	0.21	0.037	0.065	0	0.298	0	0.312	0.5
Total	95.056	97.701	95.944	96.935	97.785	97.785	97.648	97.554	97.808	97.559	98.005	97.634	96.14

Structural formula on the basis of 23 Oxygen

Si	6.58	6.8	6.8	6.84	6.8	7.62	6.9	7.1	6.9	6.86	7.18	6.73	6.74
Ti	0.128	0.11	0.13	0.09	0.12	0	0.1	0.08	0.07	0.072	0.05	0.12	0.15
Cr	0	0.02	0	0.01	0.01	0	0	0.01	0.01	0	0.014	0	0
Al	1.63	0.37	1.39	1.41	1.42	0.48	1.32	1.14	1.31	1.28	0.96	1.426	1.45
Al^{IV}	1.42	1.2	1.2	1.16	1.2	0.38	1.1	0.9	1.1	1.14	0.82	1.27	1.26
Al^{VI}	0.21	0	0.19	0.25	0.22	0.1	0.22	0.24	0.21	0.14	0.14	0.16	0.19
Fe	2.2	2.12	1.97	2.27	1.98	1.83	2.2	1.85	2.02	1.93	1.82	2.05	2.08
Mn	0	0.01	0.01	0	0	0	0	0.01	0	0.025	0	0	0
Mg	2.76	2.64	2.8	2.5	2.77	3.13	2.7	2.96	2.81	2.93	3.08	2.74	2.71
Na	0.56	0.61	0.61	0.53	0.56	0.27	0.46	0.5	0.49	0.58	0.42	0.62	0.55
K	0.23	0.23	0.23	0.22	0.23	0.041	0.18	0.19	0.22	0.187	0.16	0.23	0.24
Ca	1.76	1.92	1.94	1.94	1.93	1.94	1.84	1.94	1.94	1.94	1.91	1.93	1.88
P	0	0.01	0.01	0.01	0.01	0	0.03	0	0	0	0	0	0
Ba	0	0	0	0.01	0.01	0.013	0	0	0	0.018	0	0.02	0
Total	15.85	14.84	15.89	15.83	15.84	15.324	15.73	15.78	15.77	15.82	15.59	15.87	15.78
(M+F)	4.96	4.76	4.77	4.77	4.75	4.96	4.9	4.81	4.83	4.86	4.88	4.79	4.79
M/(M+F)	0.56	0.55	0.59	0.52	0.58	0.63	0.55	0.62	0.58	0.60	0.63	0.57	0.57

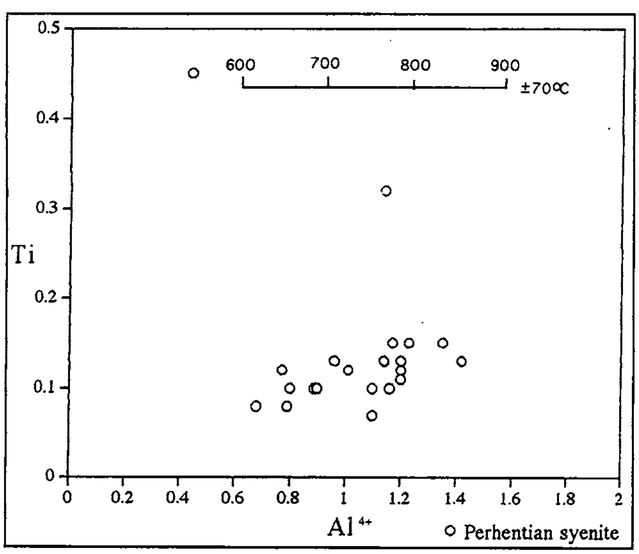

Figure 4: Ti vs Al^{4+} diagram for the hornblende from Perhentian Kecil syenite.

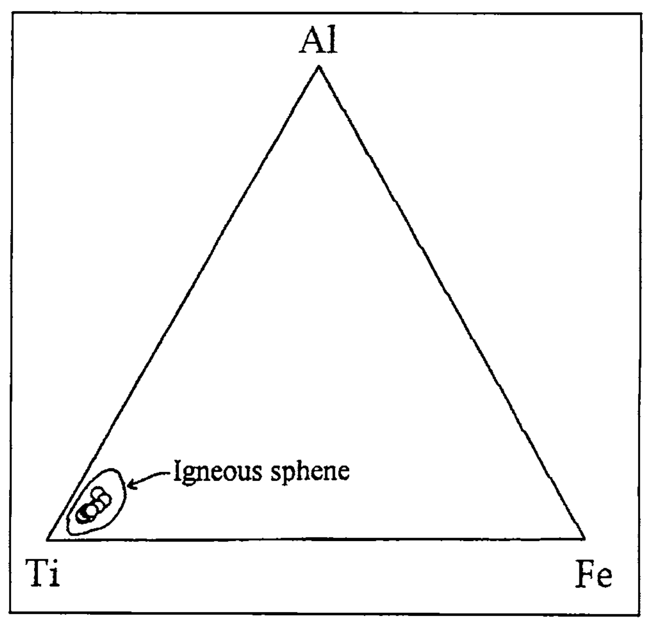

Figure 5: Al-Ti-Fe diagram for the sphene from the Perhentian Kecil syenite. Field of igneous sphene after Tulloch (1977).

Table 3: Analytical results of sphene from the the Perhentian Kecil syenite.

Sample No.	3AUR	4AUR	16AUR	17AUR	22AUR	23AUR	24AUR	25AUR	26AUR	27AUR	18TBN	19TBN	20TBN
SiO_2	29.353	30.393	29.968	29.82	29.72	29.852	29.638	29.201	29.405	29.072	29.807	30.053	29.258
TiO_2	35.161	35.426	36.064	36.68	35.735	34.237	36.183	34.929	35.908	35.026	33.164	34.589	34.51
Cr_2O_3	0	0.135	0.135	0	0.123	0.032	0	0	0	0	0	0	0
Al_2O_3	1.365	1.663	1.357	1.31	1.42	2.577	1.359	1.87	1.662	1.602	2.208	1.851	1.562
FeO	1.811	1.55	1.424	1.57	1.554	1.664	1.519	1.985	1.591	1.7	2.132	2.071	1.857
MnO	0	0	0	0.038	0	0	0	0	0	0	0	0	0
MgO	0	0.074	0.087	0	0.014	0.06	0.171	0.084	0.112	0.108	0.082	0.043	0.035
Na_2O	0.05	0.181	0.27	0.071	0.225	0.1	0.125	0.182	0.191	0.154	0.233	0.197	0.091
K_2O	0.06	0.026	0.072	0.078	0.011	0.057	0.016	0.028	0	0.031	0.013	0.063	0.059
CaO	26.456	27.43	27.145	27.437	27.056	27.269	27.384	26.28	27.156	26.712	26.782	27.071	25.676
P_2O_5	0.027	0.105	0.057	0.054	0.224	0.084	0.06	0	0	0	0.054	0.096	0.01
BaO	2.0105	2.369	1.602	0.856	2.017	1.296	0.651	1.243	0.625	1.302	1.35	0.832	1.781
Total	96.2935	99.352	98.451	97.914	98.1	97.23	97.106	95.8	96.65	95.71	95.83	96.79	94.84

Structural formula on the basis of 4 Oxygen

Si	0.8	0.807	0.8	0.797	0.798	0.8	0.796	0.802	0.795	0.799	0.815	0.81	0.814
Ti	0.7	0.707	0.72	0.737	0.722	0.7	0.731	0.722	0.73	0.724	0.682	0.7	0.722
Cr	0	0.003	0.003	0	0.003	0.001	0	0	0	0	0	0	0
Al	0.044	0.052	0.043	0.041	0.045	0.082	0.043	0.06	0.053	0.052	0.071	0.059	0.051
Fe	0.041	0.034	0.032	0.035	0.035	0.037	0.034	0.046	0.036	0.039	0.049	0.047	0.043
Mn	0	0	0	0.001	0	0	0	0	0	0	0	0	0
Mg	0	0.003	0.003	0	0.001	0.002	0.01	0.003	0.0045	0.005	0.003	0.002	0.001
Na	0.003	0.009	0.014	0.004	0.012	0.005	0.01	0.0097	0.01	0.008	0.012	0.01	0.0049
K	0.002	0.001	0.003	0.003	0.0004	0.002	0.001	0.0009	0	0.001	0.004	0.002	0.002
Ca	0.776	0.78	0.784	0.785	0.779	0.786	0.788	0.773	0.79	0.786	0.785	0.782	0.765
P	0.001	0.002	0.001	0.0013	0.01	0.002	0.0014	0	0	0	0.0013	0.002	0.0002
Ba	0.023	0.025	0.017	0.009	0.212	0.014	0.01	0.013	0.007	0.014	0.014	0.009	0.019
TOTAL	2.39	2.42	2.42	2.413	2.617	2.431	2.42	2.43	2.43	2.43	2.43	2.42	2.42

Table 4: Analytical results of apatite from the the Perhentian Kecil syenite.

Sample No.	32	33	23	28	29	1	2	5	8	9	10	11	17	18	21
Location	Clear	Clouded		Clear	Clear	Clear	Clear	Clouded	Clouded	Clouded	Clear	Clouded	Clear	Clouded	Clouded
SiO_2	0.642	0.876	0.668	0.285	0.374	0.57	0.446	0.397	0.474	0.534	0.251	0.928	0.15	0.441	0.211
TiO_2	0	0	0	0.34	0.104	0	0	0.076	0	0	0.067	0	0.016	0	0
Cr_2O_3	0	0	0.009	0	0	0	0	0	0	0	0	0	0.046	0	0
Al_2O_3	0.113	0.034	0.08	0	0.012	0	0.128	0.139	0.23	0.094	0.007	0.104	0.021	0.061	0.132
FeO	0.154	0.467	0.661	0.335	0.261	0.379	0.664	0.35	0.079	0.176	0.117	0.645	0.006	0.247	0.024
MnO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MgO	0.51	0.001	0.065	0.076	0.039	0	0.123	0.072	0	0.151	0.046	0.019	0	0.009	0.106
Na_2O	0.12	0.129	0.098	0.19	0.095	0.082	0.131	0.192	0.03	0.277	0.049	0.176	0.038	0.07	0.216
K_2O	0.051	0.117	0.057	0.078	0.074	0.094	0.114	0.151	0.048	0.094	0.032	0.106	0.073	0.066	0.052
CaO	54.287	53.37	53.715	54.957	54.525	53.92	54.075	53.396	54.638	54.49	55.11	53.812	55.416	54.131	55.098
P_2O_5	42.49	42.561	41.97	42.686	43.007	42.364	42.154	42.149	42.79	42.493	43.398	42.111	43.512	42.826	43.24
BaO	0.096	0	0.236	0	0	0.09	0	0	0.037	0.068	0	0	0	0.327	0.188
Total	98.003	96.555	97.558	98.641	98.49	97.498	97.292	96.92	98.12	98.38	99.08	97.9	99.28	98.18	99.27

Structural formula on the basis of 12.5 Oxygen

Si	0.053	0.074	0.056	0.024	0.031	0.048	0.038	0.034	0.04	0.043	0.02	0.078	0.0125	0.037	0.018
Ti	0	0	0	0.0023	0.0063	0	0	0.0045	0	0	0.004	0	0.0011	0	0
Cr	0	0	0	0	0	0	0	0	0	0	0	0	0.0028	0	0
Al	0.01	0.0034	0.008	0	0.0011	0	0.0125	0.014	0.0027	0.0091	0	0.01	0.0023	0.0063	0.013
Fe	0.01	0.033	0.047	0.023	0.018	0.027	0.047	0.025	0.0057	0.013	0.008	0.045	0	0.017	0.0017
Mn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mg	0.0063	0	0.008	0.0097	0.0045	0	0.015	0.0091	0	0.019	0.0057	0.0023	0	0.0011	0.0013
Na	0.019	0.021	0.016	0.031	0.015	0.013	0.022	0.031	0.0045	0.045	0.008	0.028	0.0063	0.001	0.035
K	0.0057	0.0125	0.063	0.0085	0.008	0.01	0.012	0.016	0.0051	0.01	0.0034	0.011	0.008	0.0068	0.0057
Ca	4.86	4.86	4.84	4.9	4.85	4.86	4.87	4.83	4.88	4.87	4.87	4.83	4.89	4.85	4.87
P	3.01	2.99	2.99	3.01	3.02	3.02	3	3.02	3.02	3	3.03	2.98	3.04	3.03	3.02
Ba	0.0034	0	0.008	0	0	0.028	0	0	0.0011	0.0023	0	0	0	0.011	0.0063
Total	7.98	7.99	7.98	8.01	7.95	7.98	8.02	7.98	7.91	8.01	7.95	7.98	7.96	7.96	7.94

Table 5: Analytical results of the opaque phases from the the Perhentian Kecil syenite.

Sample No.	5	6	33	34	35
Location	In Hbl	In Hbl			
SiO_2	0.344	0.252	2.366	0.294	0.238
TiO_2	0.377	0.339	0.12	0.219	0.059
Cr_2O_3	0.241	0.331	0.344	0.173	0.189
Al_2O_3	0.26	0.246	4.052	0.242	0.143
FeO	90.975	90.789	84.215	90.446	90.985
MnO	0	0	0	0	0
MgO	0.142	0.052	0.54	0.173	0.025
Na_2O	0.476	0.363	0.499	0.616	0.647
K_2O	0.101	0.074	0.092	0.031	0.018
CaO	0	0.105	0.241	0.062	0
P_2O_5	0	0	0.022	0	0.008
BaO	0	0	0	0	0
Total	91.54	92.55	92.49	92.26	92.313

Structural formula on the basis of 5 Oxygen

Si	0.022	0.016	0.142	0.02	0.015
Ti	0.018	0.017	0.0055	0.011	0.003
Cr	0.012	0.017	0.016	0.0091	0.0098
Al	0.02	0.018	0.29	0.019	0.011
Fe	4.92	4.93	4.2	4.95	4.97
Mn	0	0	0	0	0
Mg	0.014	0.005	0.048	0.017	0.0025
Na	0.06	0.046	0.058	0.078	0.082
K	0.0084	0.0061	0.007	0.0025	0.0016
Ca	0	0.0073	0.015	0.0043	0
P	0	0	0.0011	0	0.0004
Ba	0	0	0	0	0
Total	5.074	5.062	4.78	5.11	5.095

wider range in the clouded part compared to the clear part (Azman, 1998)

7) Magnetite is the most common opaque mineral in the Perhentian Kecil syenite.

REFERENCES

Azman A. Ghani. 1997. *Petrology and geochemistry of the Donegal granites*. Unpubl. PhD thesis, Univ. of Liverpool

Azman A Ghani. 1998. Occurrence and chemistry of clouded apatite from the Perhentian Kecil syenite, Besut Terengganu. *Warta Geologi*, 24(4):169 - 173.

Azman A Ghani. 1999. Contrasting chemical characteristics of granite and syenite from Perhentian islands, Peninsular Malaysia. *Programme and Abstract of papers, Ann. Geol. Conf. 1999, Desaru, Johore*, 45-46.

Azman A Ghani, 2000. Contrasting chemical characteristics of granite and syenite from Perhentian Islands, Peninsular Malaysia. *Bull. Geol. Soc. Malaysia*. (In press)

Azman A. Ghani & Khoo, T.T. 1998. Field relation and petrology of igneous rocks in the Perhentian island and its surrounding area, Besut Terengganu. *Warta Geologi*, 24(4):175-185

Barnes, C. G. 1987. Mineralogy of the Wooley Creek batholith, Slinkard pluton, and related dikes, Klamath Mountains, northern California. *Am. Mineral., 72*.:879 - 901.

Chappell, B.W. And White, A.J.R. 1974. Two contrasting granites types. *Pacific Geol., 8*:173-174.

Deer, W.A., Howie, R.A. and Zussman, J. 1993. *An introduction to the rock forming minerals*. Longman. 696 pp.

Hammarstrom, J. M. and Zen, E. A. 1986. Aluminium in hornblende: An emperical; igneous geobarometer. *Am. Mineral.*,71:1279 - 1313.

Leake, B. E. 1978. Nomenclature of amphiboles. *Can. Mineral.*, 16:501 - 520.

Mahawat, C., Atherton, M. P. and Brotherton, M. S. 1990 . The Tak Batholith: contrasting granites types and implication for tectonic setting. *Jour. Southeast. Asian Earth Sci., 4*:11 - 27.

Nabelek, C.R. and Lindsley, D.H. 1985. Tetrahedral Al in amphibole: a potential thermometer for some mafic rock. *Geol. Soc. Am.Abstr.with Prog. 17*, 673.

Pitcher, W. S . and Berger, A. R. 1972. *The geology of Donegal: A study of granite emplacement and unroofing*. Wiley Interscience, London. 435 pp

Tulloch. A. J. 1979. Secondary Ca-Al silicates as low grade alteration products of granitoid biotite. *Contrib. Mineral. Petrol., 69*:105-117.

Weiss, S. and Troll, G. 1989. The Ballachulish igneous complex, Scotland. Petrography, mineral chemistry and order of crystallisation in the monzodiorite suite and in the granite. *Jour. Petrol. , 30(5)*:1069 - 1115.

Wright, A. E. and Bowes, D. R. 1979. Geochemistry of appinite suite. In Harris, A.L., Holland, C.H. and Leake, B.E. (eds) The Caledonides of the British Isles - Reviewed. Spec. Publ. *Geol.Soc. Lond.*, 8:699 - 703