

AEGIRINE AND RIEBECKITE OF THE ALKALI GNEISS OF PIKKUKALLIO IN THE HONKAMÄKI—OTANMÄKI REGION, FINLAND

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Aegirine and riebeckite coexist in a Precambrian peralkaline gneiss. Chemical analyses of the gneiss and chemical and physical data on the aegirine and the riebeckite are presented. The compositions of the two minerals are compared with those of other sodic pyroxenes and alkali amphiboles from Finland. The authors know of only two other occurrences in Finland where sodic pyroxene and alkali amphibole coexist. The riebeckite of the present study and the ferro—ferri-barroisite of the adjoining Otanmäki are richer in iron and poorer in magnesium and calcium than the other known alkali amphiboles and sodic-calcic amphiboles from Finland. Zircon age of 2019 Ma has been obtained for a variety of the alkali gneiss of the region.

Key words: aegirine, riebeckite, chemical data, x-ray data, alkali gneiss, zircon age, Finland.

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Introduction

The alkali gneiss of this study has been described briefly in a paper on the granites of Honkamäki and Otanmäki by Marmo *et al.* (1966, *cf.* pp. 12—13 and 15, Table 2, photomicrographs Fig. 9 and Plate 1). The paper included an analysis of the rock, which was called alkali granite, and some optical data on the main femic minerals, aegirine and riebeckite.

Aegirine and riebeckite have since been analysed and studied by X-ray diffraction, and some trace elements of the rock determined. The present paper gives the results of these studies. Of the authors, Hytönen is responsible

for the X-ray work, optical data and writing, and Hautala for the microprobe analyses.

Material and methods

The subject of the present study is a specimen collected in 1963, and numbered 7—OM for the study by Marmo *et al.* (*op. cit.*), from the northern slope of the Honkamäki hill, which is situated about 8 km west-northwest of the Otanmäki titaniferous iron ore deposit and mine (Fig. 1). Named Pikkukallio (Fig. 2) on the topographic map, the outcrop has the following coordinates: map sheet 3413 11,

x = 7115.75, y = 497.40 or 64°08'28'' North, 26°56'48'' East.

The X-ray powder data were obtained with a Philips diffractometer, filtered Copper radiation. Silicon was used as the internal standard for aegirine and quartz for riebeckite. The microprobe analyses were conducted in 1975 using a Geoscan electron probe analyser with an accelerating potential of 20 kV and a specimen current of 3–4 mA. The standards were hornblende (no. 35) and oligoclase (no. 44, for so-

dium). The measured intensities were corrected using the Bence and Albee (1968) method.

Alkali gneiss

The rock of the Honkamäki hill in the Otanmäki region (Figs. 1 and 2) in the parish of Vuolijoki already drew some attention during the mapping of the general geological map of Finland. On map sheet C4 Kajaani (Wilkman

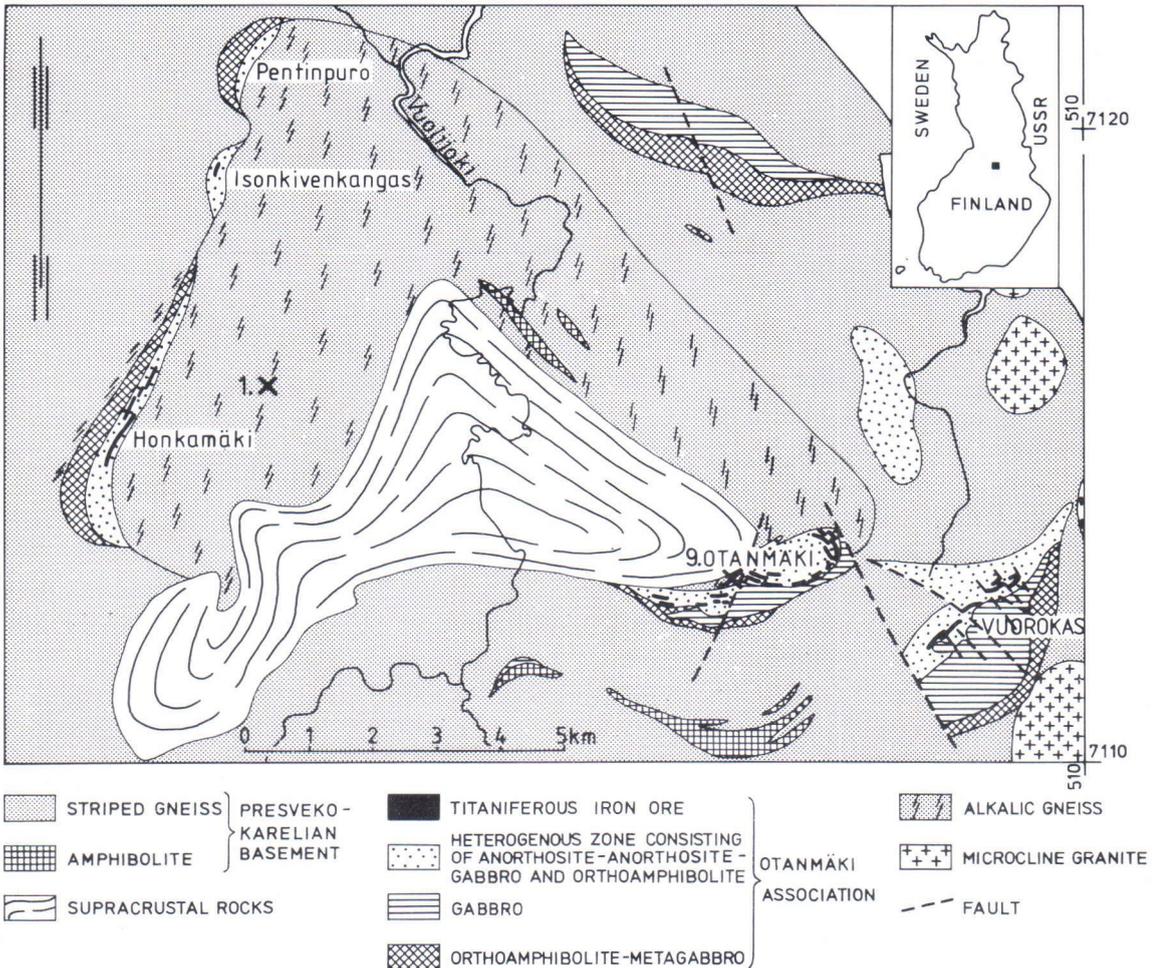


Fig. 1. Geological map of the Otanmäki region, according to Lindholm and Anttonen 1980. 1. Alkali gneiss of the present study (specimen 7—OM), containing aegirine and riebeckite. 9. Ferro-ferri-barroisite occurring as fissure fillings in alkali gneiss at the western foot of the Otanmäki hill (Hytönen and Heikkinen 1966).

The albite is usually twinned, and some antiperthite can be seen. Both feldspars contain abundant opaque inclusions. Quartz has undulatory extinction. The femic constituents usually occur as irregularly shaped crystal aggregates, arranged into irregular bands. Among the accessories, monazite forms quite large grains, approximately 0.2 mm long. A qualitative microprobe analysis of the monazite gave: Ce, La, Nd, Pr, Sm (?), Gd and P.

Table 1 gives the chemical analysis, CIPW norm, mode and Niggli values of the alkali gneiss. The peralkaline character is portrayed by the presence of acmite, $\text{NaFeSi}_2\text{O}_6$, in the norm.

Table 2. Comparison of some trace element contents (ppm) of the alkali gneiss, 7—OM, Pikkukallio, Honkamäki, Vuolijoki with those of the granite averages of Taylor (1964) and felsic rocks (granites, granodiorites, etc.) of Vinogradov (1962).

Alkali gneiss 7—OM	Taylor	Vinogradov
Li	36 ¹	30
Sc	<25 ²	5
V	<13 ²	20
Ni	<15 ²	0.5
Cu	<15 ²	10
Zn	340 ¹	40
Ga	60 ²	18
Rb	300 ³	150
Sr	16 ¹	285
Y	90 ³	40
Zr	620 ³	180
Nb	110 ³	20
Mo	<10 ²	2
Ba	<100 ²	600
La	191 ⁴	40
Ce	315 ⁴	100
Hf	22.9 ⁴	4
Ta	11.7 ⁴	3.5
Pb	5 ²	20
Th	29.3 ⁴	17
U	4.5 ⁴	4.8
Th/U =	6.5	3.5

¹ AAS analysis by Meeri Wallgren

² Optical spectrometric analysis by Ari Puisto

³ XRF analysis by Maija Hagel-Brunnström and Väinö Hoffrén

⁴ Instrumental neutron activation analysis by Rolf Rosenberg (Reactor Laboratory, Technical Research Centre of Finland)

Examination of Table 1 reveals that there is a difference between normative or modal microcline, between normative ab and modal albite and between the sum of the normative femic silicates ($\text{ac} + \text{di} + \text{hy} = 16$) and the sum of aegirine + riebeckite (22), which should approximately correspond with each other. The difference can be attributed partly to the difference in composition between the sample analysed (norm) and the thin section studied

Table 3. Aegirine, specimen 7—OM, Pikkukallio, Honkamäki, Vuolijoki. Chemical composition, numbers of ions on the basis of six oxygens, pyroxene end member composition and calculated density. 1. Average of four microprobe analyses (FeO = total iron); 2. Analysis of column 1, done using the ratio $\text{Fe}^{2+} : \text{Fe}^{3+} = 0.19$ (wet analysis); 3. Analysis of column 1, done using the values of Fe_2O_3 and FeO obtained in the wet analysis. Wet analyses by Pentti Ojanperä.

	1	2	3
SiO ₂	50.8	50.8	50.8
TiO ₂	0.3	0.3	0.3
Al ₂ O ₃	1.3	1.3	1.3
Fe ₂ O ₃		29.1	27.1
FeO	31.2	5.0	4.6
MnO	0.5	0.5	0.5
MgO	0.3	0.3	0.3
CaO	3.3	3.3	3.3
Na ₂ O	11.5	11.5	11.5
K ₂ O	0.1	0.1	0.1
	99.3	102.2	99.8
Si		1.94	1.97
Al		0.06	0.03
Al			0.03
Ti		0.01	0.01
Fe ³⁺		0.84	0.79
Fe ²⁺		0.16	0.15
Mn		0.02	0.02
Mg		0.02	0.02
Ca		0.13	0.14
Na		0.85	0.86
K		0.01	0.01
acmite	NaFe ³⁺	84	81
jadeite	NaAl	—	3
diopside	CaMg ²⁺	2	2
hedenbergite	CaFe ²⁺	10	10
ferrosilite	Fe ²⁺ Fe ³⁺	4	4
		100	100
D calculated		3.61	3.59

(mode), and partly to the fact that for the building of riebeckite some normative ab must be consumed and the perthitic microcline contains some of the normative ab, too.

In Table 2 some trace element contents of the alkali gneiss are given and compared with average contents in granites and felsic rocks from the literature. The alkali gneiss contains clearly higher Zn, Ga, Y, Zr, Nb, La, Ce, Hf and Ta, slightly higher Rb and Th, and much lower Sr, Ba and Pb than the granites and felsic rocks; the contents of Li and U are about the same.

Aegirine

Table 3, column 1 gives the chemical analysis of aegirine, carried out by microprobe. The oxidation state of iron was determined by the wet chemical method on an aegirine fraction separated out of the rock (Table 3, columns 2 and

3). The total iron values of the microprobe and wet analyses differ slightly from each other (31.2 % and 29.04 % as FeO, respectively). The difference can be attributed to the difference in both the analytical methods and the sampling. The microprobe analysis represents the average composition of four aegirine grains within a single thin section, whereas the wet analysis was done on a mineral concentrate of a few hundred milligrams. The two slightly different values for total iron are reflected as differences in the numbers of ions in the pyroxene formula, in the figures of the pyroxene end members and the calculated densities, as is shown in Table 3, columns 2 and 3.

The following unit-cell parameters for aegirine were calculated from the powder pattern, listed in Table 4: $a = 9.671$ (2) Å, $b = 8.820$ (2) Å, $c = 5.292$ (1) Å, $\beta = 107.11^\circ$, $V = 431.4$ Å³.

The cell data obtained agree well with those given by Nolan (1969) for a synthetic pyroxene on the join acmite-hedenbergite with the composition $Ac_{90.63}Hd_{9.37}$: $a = 9.671$ Å, $b = 8.820$ Å, $c = 5.293$ Å, $\beta = 107.21^\circ$, $V = 431.22$ Å³. For the synthetic end member, pure acmite (= Ac_{100}), the following cell parameters are given (Nolan, *op. cit.*): $a = 9.658$ Å, $b = 8.795$ Å, $c = 5.294$ Å, $\beta = 107.42^\circ$, $V = 429.1$ Å³.

The following optical properties were recorded: α (obs.) = 1.763 (3), β (calc.) = 1.799, γ (obs.) = 1.813 (3), $2V_x = 63^\circ$ (with universal stage), $c \wedge X = 1^\circ - 2^\circ$ (univ. stage); pleochroism: X green, Y green, Z yellowish brown; absorption $X > Y > Z$. The differences in the absorption between X, Y and Z are small.

For comparison, the aegirine has been plotted on a diagram (Fig. 3) in terms of (Na + K), Mg and (Fe²⁺ + Mn + (Fe³⁺)) together with some other aegirines, aegirine-augites and sodian diopsides from four other occurrences (nos. 2—5) in Finland. The localities are depicted on the map in Fig. 3. In the diagram the aegirine of the present study has been plotted using the averages of (Na + K), Mg and (Fe²⁺ + Mn) from Table 3, columns 2 and 3.

Table 4. X-ray powder pattern of aegirine from Pikkukallio, Honkamäki, Vuolijoki.

hkl	I	d _{meas.}	d _{calc.}
110	59	6.39	6.38
200	3	4.62	4.62
$\left. \begin{matrix} \bar{1}11 \\ 020 \end{matrix} \right\}$	82	4.41	$\left\{ \begin{matrix} 4.43 \\ 4.41 \end{matrix} \right.$
220	14	3.190	3.190
221	83	2.985	2.986
310	100	2.908	2.909
$\bar{1}31$	19	2.547	2.549
002	7	2.529	2.529
221	35	2.480	2.481
$\left. \begin{matrix} 040 \\ 112 \end{matrix} \right\}$	15	2.203	$\left\{ \begin{matrix} 2.205 \\ 2.203 \end{matrix} \right.$
$\bar{3}31$	55	2.121	2.121
421	26	2.097	2.097
041	17	2.021	2.021
241	11	1.938	1.937
150	37	1.733	1.733
531	39	1.613	1.613
440	42	1.595	1.595
$\left. \begin{matrix} 602 \\ 350 \end{matrix} \right\}$	31	1.531	$\left\{ \begin{matrix} 1.531 \\ 1.531 \end{matrix} \right.$
060	6	1.470	1.470
531	34	1.400	1.400

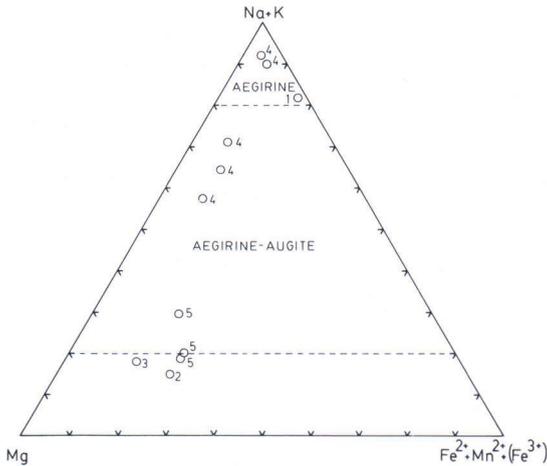


Fig. 3. Plot of aegirine of the present study (no. 1) together with other sodic pyroxenes from Finland in terms of (Na+K), Mg and $(\text{Fe}^{2+} + \text{Mn} + \text{Fe}^{3+})$. The components of the pyroxenes have been calculated following a proposal by Carmichael (1962). The last term (Fe^{3+}) is the excess, if any, of the trivalent iron over Na+K. The numbers of the plots refer to Fig. 4.

Riebeckite

Table 5, column 1 gives the microprobe analysis of riebeckite. The oxidation state of iron was determined by the wet chemical method from a riebeckite fraction separated out of the rock. The values for Fe_2O_3 and FeO obtained from the wet analysis were corrected for 7% aegirine (analysis in Table 3, column 3), occurring as impurity in the fraction. The total iron values of the microprobe and the corrected wet analyses differ from each other (37.1% and 34.3%, respectively). The difference can be attributed to the difference in analytical methods and sampling as in aegirine (page 173). The different values of total iron are reflected as differences in the numbers of ions in the amphibole formula and in the calculated densities (Table 5, columns 2 and 3). As the water plus halogen content was not determined, the standard amphibole formula was calculated on the basis of 23 oxygens according to the procedure recommended by the subcommittee on amphiboles of the International Mineralogical

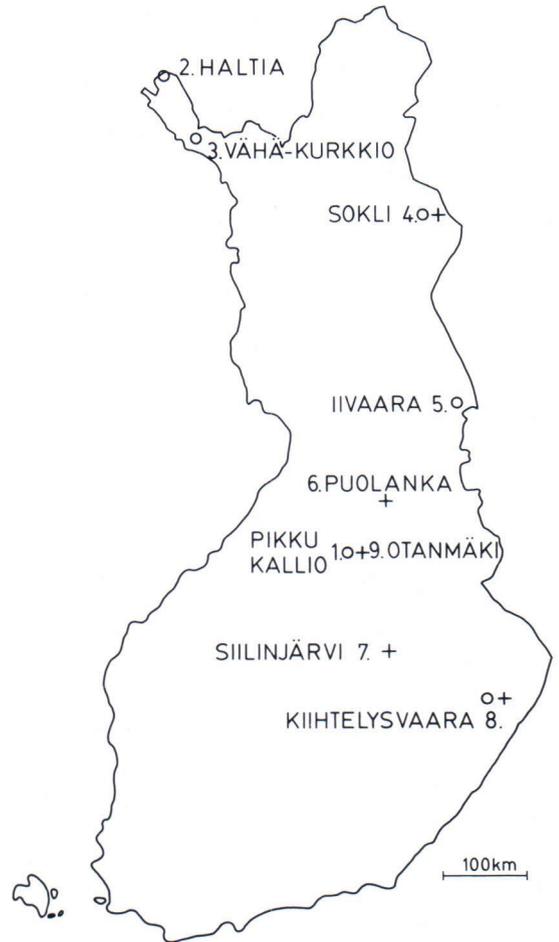


Fig. 4. Map of Finland showing the locations of the sodic pyroxenes (open circles), alkali amphiboles and sodic-calcic amphiboles (amphiboles = crosses) plotted in Figs. 4, 5 and 6. 1. Aegirine and riebeckite of Pikkukallio, specimen 7—OM, present study. 2. Sodian diopside from gabbro, Halditschokko (Haltia), Enontekiö (Hausen 1942). 3. Sodian diopside from amphibole-pyroxene-albite diabase of Vähä-Kurkkio, Enontekiö (Meriläinen 1961). 4. Aegirines, aegirine-augites, alkali-amphiboles and sodic-calcic amphiboles from the carbonatite and fenites of Sokli, Savukoski (Vartiainen and Woolley 1976 and Vartiainen 1980). 5. Aegirine-augite and sodian diopside from alkaline rocks of Iivaara, Kuusamo (Lehijärvi 1960). 6. Magnesian riebeckite from a shear zone of Puolanka (Laajoki and Ojanperä 1973). 7. Richterite from glimmerite of the carbonatite complex, Siilinjärvi (Puustinen 1972). 8. Arfvedsonite and aegirine from nepheline syenite gneiss (boulder) of Kiihtelysvaara (Eskola and Sahlstein 1930). 9. Ferro-ferri-barroisite of Otanmäki (Hytönen and Heikkinen 1966).

Association (Leake 1978). The mineral is rich in iron and poor in magnesium and its composition is thus quite close to the end member of riebeckite, $\text{Na}_2\text{Fe}_3^{2+}\text{Fe}_2^{3+}\text{Si}_8\text{O}_{23}$, written on a water- and halogen-free basis.

The following unit-cell parameters for the riebeckite were calculated from the powder pattern, listed in Table 6: $a=9.840$ (3) Å, $b=18.078$ (5) Å, $c=5.336$ (2) Å, $\beta=103.79^\circ$, $V=921.8$ Å³. The cell data differ slightly from those given by Hoffmann and Katz (1982) for an extrapolated riebeckite end member: $a=9.822$ Å, $b=18.07$ Å, $c=5.334$ Å, $\beta=103.52^\circ$, $V=919.0$ Å³. The cell dimensions a , b , c and V of the Pikkukallio

riebeckite are slightly larger than those of the end member. The expansion of the cell can be attributed to the potassium ion (Table 5), the largest cation present in excess in this mineral. As an example of the expanding effect of the potassium ion on the unit cell dimensions of amphiboles, we refer to a study on the synthesis and crystal chemistry of sodium-potassium richterite (Huebner and Papike 1970).

The following optical properties were recorded for the riebeckite: $\gamma=1.708$, $b=Y$, $c\Delta X=0^\circ-10^\circ$; pleochroism: X dark blue, Y dark grey-blue, Z yellow brown; absorption: $Y > X \gg Z$.

The very strong absorption and dispersion of light greatly hinders optical observations and measurements of the riebeckite. The optical

Table 5. Riebeckite, specimen 7—OM, Pikkukallio, Honkamäki, Vuolijoki. Chemical composition, numbers of ions on the basis of 23 oxygens and calculated density. 1. Average of four microprobe analyses (FeO = total iron). 2. Analysis of column 1, done using the ratio $\text{Fe}^{2+}:\text{Fe}^{3+}=1.48$ (wet analysis). 3. Analysis of column 1, done using the Fe_2O_3 and FeO values obtained in the wet analysis. Wet analysis by Pentti Ojanperä.

	1	2	3
SiO ₂	48.9	48.9	48.9
TiO ₂	0.8	0.8	0.8
Al ₂ O ₃	2.8	2.8	2.8
Fe ₂ O ₃		16.6	15.3
FeO	37.1	22.2	20.5
MnO	1.1	1.1	1.1
MgO	0.6	0.6	0.6
CaO	1.2	1.2	1.2
Na ₂ O	4.5	4.5	4.5
K ₂ O	1.3	1.3	1.3
	98.3	100.0	97.0
Si	7.51	7.66	8.00
Al	0.49	0.34	8.00
Al	0.02	0.18	
Ti	0.10	0.10	
Fe ³⁺	1.92	1.81	5.00
Mg	0.13	0.13	5.00
Fe ²⁺	2.83	2.68	
Fe ²⁺	0.02		
Mn		0.10	
Mn	0.14	0.05	1.97
Ca	0.20	0.21	1.90
Na	1.35	1.38	
K	0.26	0.26	
D _{calc.}		3.39	3.36

Table 6. X-ray powder pattern of riebeckite from Pikkukallio, Honkamäki, Vuolijoki.

hkl	I/I ₀	d _{meas.}	d _{calc.}
110	100	8.45	8.450
200	3	4.79	4.780
040	14	4.52	4.520
131	12	3.424	3.423
240	10	3.281	3.283
310	63	3.137	3.137
221	12	2.981	2.981
330	12	2.814	2.816
151	53	2.728	2.729
331			2.727
061	15	2.604	2.605
260	11	2.546	2.549
202			2.546
350	3	2.390	2.390
400			2.389
351	13	2.334	2.335
171	4	2.195	2.194
261	15	2.180	2.180
202	7	2.080	2.080
351	12	2.037	2.036
2.10.0	3	1.691	1.691
282			1.690
461	15	1.664	1.664
1.11.0	5	1.619	1.620
352			1.619
153	12	1.594	1.594
600			1.593
0.12.0	3	1.507	1.506
661	11	1.438	1.438

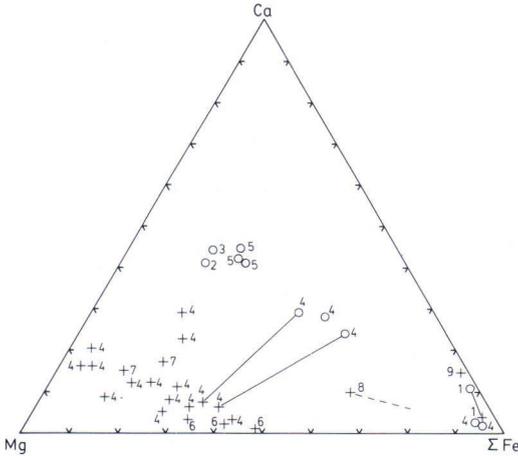


Fig. 5. Plot of aegirine and riebeckite of present study (no. 1) together with other sodic pyroxenes and alkali and sodic-calcic amphiboles from Finland in terms of Ca, Mg and total Fe. Pyroxenes = open circles, amphiboles = crosses. Coexisting pyroxene-amphibole pairs are joined by tie lines. The numbers of the plots refer to Fig. 4.

properties listed are therefore incomplete. On the other hand, it is known that very small variations in refractive indices within the grains of a single thin section can produce a dramatic

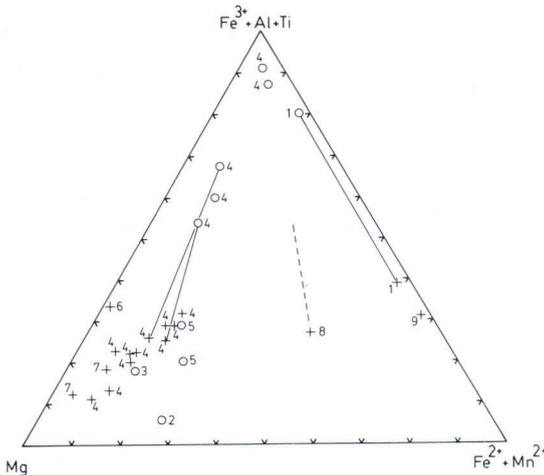


Fig. 6. Relation between octahedrally coordinated Mg, $(Fe^{3+} + Al + Ti)$ and $(Fe^{2+} + Mn)$ of aegirine and riebeckite of present study (no. 1) together with other sodic pyroxenes (open circles) and alkali and sodic-calcic amphiboles (amphiboles = crosses) from Finland. Coexisting mineral pairs are connected by tie-lines. The numbers of the plots refer to Fig. 4.

variation in optical orientation (Borg 1967). Some conflicting observations of the optical orientation suggest that the optical orientation of this riebeckite varies from grain to grain, even within a single thin section.

For comparison and to illustrate the chemical composition the riebeckite of Pikkukallio has been plotted in terms of Ca, Mg and total Fe (Fig. 5) and in terms of octahedrally coordinated $(Fe^{3+} + Al + Ti)$, Mg and $(Fe^{2+} + Mn)$ (Fig. 6) together with some other alkali amphiboles, sodic-calcic amphiboles and sodic pyroxenes from Finland. Triangular diagrams, e.g., those by Foster for trioctahedral micas (1960) and by Simonen and Vormaa for amphibole and biotite from rapakivi (1969), have been used to illustrate the proportions of the octahedrally coordinated cations.

The sodic-calcic amphibole occurring as fissure filling in alkali granite or alkali gneiss at the western foot of the adjacent Otanmäki hill has been described in a paper by Hytönen and Heikkinen (1966). The amphibole was called an alkali amphibole of intermediate composition slightly closer to the alkali amphiboles than the calcic amphiboles. For the present study this amphibole is renamed ferro-ferri-barroisite, using the nomenclature of amphiboles presented by the subcommittee on amphiboles of the International Mineralogical Association (*op. cit.*).

The riebeckite of the gneissose granite described by Pääkkönen (1956) from Katajankangas on the western side of the Otanmäki hill and, hence, not far from the outcrop studied by Hytönen and Heikkinen (*op. cit.*), has not been plotted in Figs. 5 and 6 because no chemical data were given. However, on the basis of the refractive indices listed, this alkali amphibole of Pääkkönen seems to be close to the end member riebeckite.

Examination of Figs. 5 and 6 reveals that the riebeckite of Pikkukallio and the ferro-ferri-barroisite of the adjacent Otanmäki are richer in iron and poorer in magnesium than the other

alkali amphiboles and sodic-calcic amphiboles from Finland. In the other amphiboles magnesium predominates over iron, except in the arfvedsonite from the nepheline syenite gneiss of Kiihtelysvaara (Eskola and Sahlstein 1930; No. 8 in Figs. 5 and 6).

Chemical relationship between aegirine and riebeckite

The present authors know of three occurrences in Finland where alkali pyroxene and alkali amphibole coexist: in the nepheline syenite gneiss of Kiihtelysvaara (Fig. 4, no. 8, boulder) (Eskola and Sahlstein 1930), in the carbonatite and fenites of Sokli, Savukoski (Fig. 4, no. 4) (Vartiainen and Woolley 1976 and Vartiainen 1980) and in the alkali gneiss of the present study (Fig. 4, no. 1).

Figs. 5 and 6 illustrate the chemical relationship between the aegirine-riebeckite pair of Pikkukallio and the other sodic pyroxenes and alkali and sodic-calcic amphiboles from Finland. Coexisting pyroxene-amphibole pairs are joined by tie-lines. As the aegirine of the nepheline syenite gneiss of Kiihtelysvaara (Eskola and Sahlstein, *op. cit.*) was not chemically analysed and thus its precise plot is unknown, the tie-line connecting the plot of arfvedsonite (no. 8) towards the plot of acmite, $\text{NaFe}^{3+}\text{Si}_2\text{O}_6$ (the Fe corner in Fig. 5 and the $\text{Fe}^{3+} + \text{Al} + \text{Ti}$ corner in Fig. 6, respectively) is shown as a dashed line.

Examination of Figs. 5 and 6 reveals that the aegirine-riebeckite pair of Pikkukallio differs in composition from the pyroxene-amphibole pairs of Sokli: both the pyroxene and the amphibole of Pikkukallio are richer in iron and poorer in magnesium and calcium than are the members of the two pyroxene-amphibole pairs of Sokli.

Figure 6 also illustrates the relative state of oxidation of iron: in the pyroxene-amphibole

pairs the pyroxene is more oxidized than the amphibole.

The mineral pair aegirine-riebeckite is known to be rather common in peralkaline gneisses from numerous localities of the world over (Floor 1974). However, further comparisons with other occurrences are beyond the scope of the present study.

Age of the Honkamäki granite

The age of the zircon from the Honkamäki granite, about 600 metres south of the Pikkukallio outcrop (Fig. 2), has been radiometrically determined at the isotope geology laboratory of the Geological Survey of Finland and the results have been published in two papers (Marmo *et al.* 1966 and Talvitie and Paarma 1980). The age was later checked from two zircon fractions, preleached in hydrofluoric acid. The new results, together with the earlier ones, are summarized in Table 7 and plotted in the concordia diagram in Figure 7.

Examination of Figure 7 reveals that the five zircon fractions form an excellent linear array, having an upper intercept age of 2019 ± 3 Ma (2

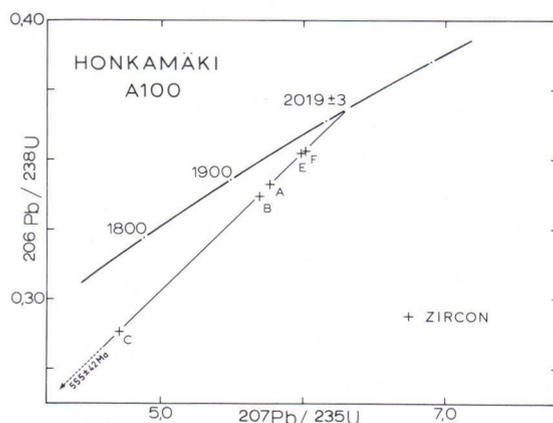


Fig. 7. Concordia diagram for zircons of the Honkamäki granite, Vuolijoki.

Table 7. Uranium-lead isotopic data and radiometric ages for zircons of the Honkamäki granite, Vuolijoki. Decay constants: Jaffey *et al.* 1971.

Zircon fraction	Concentration		Atom ratios						Radiometric age
	$\mu\text{g/g}$		measured	blank corrected			corrected for blank and common lead		Ma
	^{238}U	^{206}Pb radio- genic	$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$	$\frac{^{208}\text{Pb}}{^{206}\text{Pb}}$	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$
A $d > 4.2; \emptyset > 70$	500.1	147.54	2405	3626	.12637	.15113	.3410 ± 21	5.767 ± 58	1995 \pm 14
B $d > 4.2; \emptyset < 70$	502.6	146.85	2817	4665	.12526	.15071	.3377 ± 23	5.698 ± 77	1991 \pm 20
C $3.8 < d < 4.2$	1040.9	259.71	723	775	.13581	.24273	.2884 ± 23	4.711 ± 44	1933 \pm 9
E $d > 4.2; \emptyset < 70$ HF; uncrushed	419.6	127.88	20292	23040	.12382	.12542	.3522 ± 18	5.985 ± 32	2003 \pm 2
F $d > 4.2; \emptyset < 70$ HF; crushed	398.8	121.83	20852	23971	.12415	.12201	.3531 ± 18	6.016 ± 32	2008 \pm 2

sigma) and a lower intercept with concordia at 555 ± 42 Ma (2 sigma).

There is a direct correspondence between the uranium content and the degree of discordance (Table 7 and Fig. 7). The most concordant fractions, E and F, were preleached in cold 4 % hydrofluoric acid in an ultrasonic bath for ten minutes. The uranium content is lowest in these fractions, but the most distinctive feature is that the common lead content is drastically lower than in other fractions.

Both the Honkamäki granite and the alkali gneiss of the present study are varieties of the alkali gneiss of the Honkamäki—Otanmäki area. The age of 2019 Ma is quite close to the 2065 Ma of the gabbros of Otanmäki and Vuorokas (Talvitie and Paarma, *op. cit.*) (Fig. 1) but is distinctly older than the c. 1900 Ma of the synorogenic Svecokarelidic plutonic rocks.

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