LEIFITE, REVISED, AND KARPINSKYITE, DISCREDITED

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Leifite from the type locality, Narssârssuk, Greenland, has been found to be a beryllium mineral and its composition has been redetermined by spectrographic analysis, thermogravimetric analysis. electron microprobe measurements, and wet micro-chemical analysis. The formula can be written as:

$(Na, H_3O)_2\ [(Si, Al, Be, B)_7\ (O, F, OH)_{14}]$, Z = 3

The mineral is trigonal, the probable space groups are P321 and P312, and the unit cell dimensions are: a_0 = 14.351 Å and c_0 = 4.854 Å. The redefinition of Leifite has been approved by IMA.

Karpinskyite from the type locality, Karnasurt pegmatites, Kola, has been investigated by scanning electron microscope, optical microscope, X-ray diffraction and electron microprobe. The karpinskyite is shown to be a mixture of leifite, montmorillonite and sauconite. The name »karpinskyite« is discredited. The descrediting of karpinskyite has been approved by IMA. The leifite from Kola contains slightly less Si and slightly more Na and Al than the leifite from Greenland, and has the lattice constants a_0 = 14.400 Å and c_0 = 4.881 Å.

Leifite

At suggestion of Professor E. I. Semenov, IMGRE, Moscow, leifite was analysed for beryllium. A spectrographic analysis of the original material of Bøggild (1915) showed that leifite contains between 4 and 8 per cent beryllium, which was not looked for in the work of Bøggild. For this reason we decided to reinvestigate the mineral.

General description

Leifite was first described by Bøggild (1915). He stated that nothing was known for certain about the occurrence. The entire material, which consists of four small specimens weighing between 20 and 40 g, was collected by Greenlanders and sent to the Mineralogical Museum of Copenhagen together with minerals from Narssârssuk. Among the accompanying minerals there are none of the rare minerals particularly characteristic of the occurrence. The feldspar, however, is a microcline with the structure well known from Narssârssuk. The leifite is closely associated with the feldspar. The feldspar and the leifite may be intergrown in the manner of graphic granite. Aegirine, calcite and zinnwaldite (polylithionite) are other accompanying minerals.

Leifite occurs in the form of incompletely developed crystals with the form of a hexagonal prism, which is frequently strongly striated ‖ [001]. Plate 1, figs 1 and 2 show the detailed morphology of leifite as seen in the scanning electron microscope. The pictures show one end of a needle about 200 μm in thickness. The needle consists of parallel, poorly terminated hexagonal prisms, about 20 μm in thickness. The length of the crystals may attain about 20 mm. They may be 5 mm thick, but they may also be as fine as hairs. The mineral is colourless, transparent or white, with a vitreous luster. It has pronounced cleavage along the prism which bounds the crystals. On the material from Kola described on p. 143, this prism has been indexed as probably $\{11\bar{2}0\}$. Leifite has hardness 6 and its specific gravity is 2.565 – 2.578.

Optical properties

Bøggild (1915) states that leifite is optically uniaxial positive with n_e = 1.5224 and n_o = 1.5177. The figures have been determined on a polished section by means of a Pulfrich half-sphere refractometer. This gives $n_e - n_o$ = 0.0047, but a »direct« determination of the birefringence gave 0.0044. Our measurements were carried out with the immersion method using wavelength variation and optical glass as internal standard (Micheelsen, 1957). This gives $n_e = 1.5204 \pm 0.0010$, $n_o = 1.5162 \pm 0.0010$, and $n_e - n_o = 0.0042 \pm 0.0010$. The low accuracy is due to definite variations in the refractive indices of the mineral. The single measurements were made with a relative accuracy of ± 0.00002 using a new condenser system designed by Micheelsen.

X-ray diffraction

Gossner & Mussgnug (1927) made single crystal oscillation and Laue photographs of leifite. They showed the mineral to be trigonal with a hexagonal unit cell with a_0 = 14.34 Å (presumably kX) and c_0 = 4.93 Å (presumably kX). On the basis of these observations Strunz (1957) proposed one of the following crystal classes: $\bar{3}$m, 3m or 32. Strunz recalculated the unit cell constants of Gossner & Mussgnug to a_0 = 14.37 Å and c_0 = 4.94 Å. ASTM powder diffraction file, card no. 18–710 presents an indexed list of d-values and a_0 = 14.28 Å and c_0 = 4.81 Å. The values have been obtained by

Table 1

LEIFITE Narssârssuk					KARPINSKYITE Lovozero, Min. Mus. 1964.74						KARPINSKYITE Lovozero					
Int.	$\sin^2\theta_{obs}$	$\sin^2\theta_{calc}$	h k l	d_{hkl}	Int.	$\sin^2\theta_{obs}$	$\sin^2\theta_{calc}$	h k l	d_{hkl}	d†	Int.	$\sin^2\theta$ calculated from the d-values, Shilin, 1956	$\sin^2\theta_{calc}$	h k l	d_{hkl} Shilin, 1956	d†
5	.00386	.00385	1 0 0	12.41	4	.00381	.00382	1 0 0	12.49							
5	.01157	.01154	1 1 0	7.17	4	.01145	.01146	1 1 0	7.20							
5	.01540	.01539	2 0 0	6.21	5	.01529	.01528	2 0 0	6.23		4	.01509	.01532	2 0 0	6.274	
											2	.02177			5.224	5.224 β
											3	.02321			5.060	5.060 β
											2	.02526	.02507	0 0 1	4.850	
7	.02698	.02693	2 1 0	4.69	7	.02680	.02675	2 1 0	4.71		6	.02680	.02681	2 1 0	4.709	
7	.02910	.02907	1 0 1	4.52	7	.02883	.02877	1 0 1	4.54		4	.02869	.02890	1 0 1	4.551	
											1	.03297			4.245	4.245
7	.03463	.03462	3 0 0	4.14	7	.03444	.03439	3 0 0	4.15		3	.03455	.03447	3 0 0	4.147	
5	.03682	.03676	1 1 1	4.02	5	.03652	.03641	1 1 $\bar{1}$	4.03		1	.03659	.03656	1 1 1	4.030	
5	.04069	.04061	2 0 1	3.82	5	.04029	.04023	2 0 1	3.84							
					1	.04153				3.78						
											3	.04248			(3.740)	3.740 β
					2	.04433				3.66						
5	.04621	.04617	2 2 0	3.59	5	.04583	.04585	2 2 0	3.60		1	.04585	.04595	2 2 0	3.600	
											2	.04829			3.508	3.508 β
5	.04999	.05001	3 1 0	3.45	5	.04970	.04967	3 1 0	3.46							
10	.05214	.05215	2 1 1	3.38	9	.05169	.05169	2 1 1	3.39		7	.05177	.05188	2 1 1	3.388	
					3	.05744				3.22						
					3	.05835				3.19						
10	.05979	.05984	3 0 1	3.15	10	.05929	.05934	3 0 1	3.17		10	.05948	.05953	3 0 1	3.161	
7	.06154	.06156	4 0 0	3.11	5	.06109	.06114	4 0 0	3.12		2	.06156	.06127	4 0 0	3.107	
3	.07138	.07139	2 2 1	2.89							1	.07057	.07102	2 2 1	2.902	
3	.07299	.07310	3 2 0	2.85												
5	.07521	.07523	3 1 1	2.81	4	.07468	.07462	3 1 1	2.82		2	.07468	.07485	3 1 1	2.821	
4	.08081	.08079	4 1 0	2.71							3	.08039	.08042	4 1 0	(2.719)	

5	.08665	.08678	4 0 1	2.62	4	.08607	.08608	4 0 1	2.63		3	.08573	.08634	4 0 1	(2.633)	
9	.09824	.09832	3 2 1	2.46	7	.09749	.09755	3 2 1	2.47		7	.09796	.09783	3 2 1	2.463	
2	.10099	.10088	0 0 2	2.43												
7	.10370	.10387	3 3 0	2.39	5	.10302	.10317	3 3 0	2.40		6	.10369	.10340	3 3 0	2.394	
3	.10474	.10473	1 0 2	2.38	3	.10357	.10360	1 0 2	2.40							
5	.10587	.10601	4 1 1	2.37	4	.10522	.10519	4 1 1	2.38							
											1	.10928			(2.332)	2.332 β
1	.11626	.11627	2 0 2	2.26												
1	.11914	.11926	5 1 0	2.23												
7	.12131	.12140	5 0 1	2.21	5	.12045	.12047	5 0 1	2.22		6	.12080	.12081	5 0 1	2.218	
4	.12772	.12781	2 1 2	2.16	4	.12655	.12653	2 1 2	2.17		1	.12738	.12708	2 1 2	2.160	
5	.12885	.12909	3 3 1	2.15	4	.12799	.12811	3 3 1	2.16							
5	.13280	.13294	4 2 1	2.12	4	.13191	.13194	4 2 1	2.12				.13229	4 2 1		
											4	.13323			2.112	
5	.13550	.13550	3 0 2	2.09	5	.13404	.13417	3 0 2	2.11				.13474	3 0 2		
											1	.14365	.14378	5 1 1	2.034	
5	.15069	.15089	3 1 2	1.986	4	.14946	.14946	3 1 2	1.994		3	.15007	.15006	3 1 2	1.990	
3	.16226	.16243	4 0 2	1.914	3	.16102	.16092	4 0 2	1.921							
5	.16349	.16372	6 0 1	1.907	5	.16245	.16250	6 0 1	1.913		5	.16273	.16293	6 0 1	1.911	
1	.16502	.16543	6 1 0	1.898												
1	.16736	.16757	4 3 1	1.884												
3	.17382	.17398	3 2 2	1.849							2	.17345	.17304	3 2 2	1.851	
3	.18155	.18167	4 1 2	1.809	3	.17997	.18002	4 1 2	1.817							
4	.18448	.18467	4 4 0	1.795	4	.18337	.18341	4 4 0	1.800		2	.18423	.18382	4 4 0	1.796	
3	.18822	.18851	7 0 0 5 3 0	1.777												
4	.19042	.19065	6 1 1	1.767	2	.18918	.18925	6 1 1	1.772		1	.18905	.18974	6 1 1	1.773	
7	.19687	.19706	5 0 2	1.737	7	.19508	.19531	5 0 2	1.745		7	.19606	.19601	5 0 2	1.741	
1	.20464	.20464	3 3 2	1.704												
5	.20838	.20860	4 2 2	1.689	4	.20667	.20677	4 2 2	1.696		3	.20734	.20750	4 2 2	1.693	
1	.21346	.21373	5 3 1 7 0 1	1.669							1	.21284	.21271	5 3 1 7 0 1	1.671	
2	.21929	.21929	7 1 0	1.646							2	.21882	.21828	7 1 0	(1.648)	
4	.22498	.22527	6 2 1	1.625	3	.22356	.22364	6 2 1	1.630		2	.22450	.22420	6 2 1	1.627	
2	.23067	.23082	1 0 3	1.605	1	.22825	.22833	1 0 3	1.614							
5	.23918	.23938	6 0 2	1.576	5	.23721	.23734	6 0 2	1.583		5	.23836	.23814	6 0 2	1.579	

Table 1

LEIFITE Narssârssuk					KARPINSKYITE Lovozero, Min. Mus. 1964.74						KARPINSKYITE Lovozero					
Int.	$\sin^2\theta_{obs}$	$\sin^2\theta_{calc}$	h k l	d_{hkl}	Int.	$\sin^2\theta_{obs}$	$\sin^2\theta_{calc}$	h k l	d_{hkl}	d†	Int.	$\sin^2\theta$ calculated from the d-values, Shilin. 1956	$\sin^2\theta_{calc}$	h k l	d_{hkl} Shilin, 1956	d†
3	.24242	.24237	2 0 3	1.566	1	.23976	.23979	2 0 3	1.574							
2	.24586	.24622	8 0 0	1.555												
4	.25073	.25092	5 2 2	1.540	4	.24874	.24880	5 2 2	1.546		3	.24961	.24963	5 2 2	1.543	
4	.25965	.25990	5 4 1	1.513	2	.25834	.25803	5 4 1	1.517		3	.25927	.25867	5 4 1	1.514	
2	.26160	.26160	3 0 3	1.507												
5	.26730	.26759	6 3 1	1.491	4	.26547	.26567	6 3 1	1.496		4	.26625	.26633	6 3 1	1.494	
3	.27110	.27144	8 0 1	1.481							1	.27095	.27016	8 0 1	1.481	
											1	.28033			1.456	1.456 β
5	.28839	.28853	4 0 3	1.436	4	.28576	.28565	4 0 3	1.442		4	.28699	.28690	4 0 3	1.439	
											1	.29850			1.411	1.411 β
3	.30581	.30607	8 1 1	1.394							2	.30451	.30462	8 1 1	1.397	
4	.31145	.31162	9 0 0	1.381	3	.30949	.30951	9 0 0	1.386		4	.31071	.31019	9 0 0	1.383	
											1	.32036			1.362	1.362 β
5	.33104	.33085	3 3 3	1.340	5	.32787	.32768	3 3 3	1.346		4	.32851	.32902	3 3 3	1.345	
3	.33571	.33556	5 4 2	1.330												
5	.34350	.34325	6 3 2	1.315	5	.34070	.34051	6 3 2	1.321		4	.34159	.34153	6 3 2	1.319	
3	.35903	.35864	7 2 2	1.287							3	.35657	.35685	7 2 2	1.291	
					2	.36292				1.280						
3	.36608	.36548	6 0 3	1.274							2	.36386	.36349	6 0 3	1.278	
4	.37558	.37532	{9 1 1 {6 5 1	1.258							3	.37314	.37355	{9 1 1 {6 5 1	1.262	
											3	.38034			1.250	1.250
											1	.38964			1.235	1.235 β
4	.39666	.39626	9 2 0	1.224												
4	.39865	.39840	8 3 1	1.221							4	.39603	.39653	8 3 1	1.225	
4	.40451	.40481	7 3 2	1.212							1	.40257	.40281	7 3 2	1.215	
4	.41032	.40994	10 0 1	1.203							3	.40793	.40802	10 0 1	1.207	
4	.41287	.41250	9 0 2	1.200												
5	.41609	.41550	6 6 0	1.195	3	.41279	.41268	6 6 0	1.200		3	.41339	.41358	6 6 0	1.199	

† β-lines and lines which cannot be indexed either by means of the unit cell constants of leifite or by means of the unit cell constants of karpinskyite given by Shilin(1956)

Fe-Ka radiation and a powder camera with a diameter of 90 mm. The line at 3.70 Å, which has not been indexed, is likely to be a β-line and is absent in our diagrams.

E. S. Leonardsen and J. Rønsbo kindly made X-ray single crystal diffraction photographs of leifite. A rotation diagram gave $c_0 = 4.85 \pm 0.01$ Å. Two oscillation diagrams with the c-axis as oscillation axis and turned 60° with respect to each other showed the absence of sixfold symmetry and absence of a horizontal symmetry plane. Weissenberg photographs of equator, 1st and 2nd layer lines with the c-axis as rotation axis showed $a_0 = 14.32 \pm 0.03$ Å. Equator has symmetry lines with intervals of 30°; the 1st and 2nd layer lines have symmetry lines with intervals of 60°. This gives the classes $\bar{3}m$, 3m or 32, as already pointed out by Strunz (1957). Finally, a zero layer Weissenberg photograph about an a-axis gave $c_0 = 4.85 \pm 0.01$ Å and two symmetry lines at right angles to each other. Leifite has no systematic extinctions and the possible space groups are therefore: $P\bar{3}m1$, $P\bar{3}1m$, P3m1, P31m, P321 or P312. From the morphology of the Kola material, see p. 143. the class 32 seems to be the most probable.

Table 2. Lattice constants of leifite and karpinskyite

	Leifite Narssârssuk	Karpinskyite Min. Mus. 1964. 74	Karpinskyite, Shilin 1956	
			Shilin's values	Calculated from the given d–values
a_0	$14.351 \pm 1 \cdot 10^{-3}$ Å	$14.400 \pm 1 \cdot 10^{-3}$ Å	14.24 Å	$14.39 \pm 2 \cdot 10^{-2}$ Å
c_0	$4.854 \pm 1 \cdot 10^{-3}$ Å	$4.881 \pm 1 \cdot 10^{-3}$ Å	4.83 Å	$4.87 \pm 2 \cdot 10^{-2}$ Å
c_0/a_0	0.3382	0.3389	0.3392*)	0.339
Vol.	865.9 Å^3	876.6 Å^3	848 Å^3*)	873 Å^3

*) Calculated from the given a_0 and c_0 values.

The lattice constants were finally determined accurately from Guinier-Hägg photographs using the weighed mean of Cu-Kα_1 and Cu-Kα_2 radiation. The camera was calibrated using quartz as internal standard and using the lattice constants for quartz given by Swanson & Fuyat (1953). The d-values are given in table 1 and the lattice constants in table 2. In the final calculation the lattice constants were refined by the least squares method final calculation the lattice constants were refined by the least squares method to the observed $\sin^2\theta$ values. These calculations were carried on a GIER Foundation. A program (REFBASE-2) made by E. S. Leonardsen was used. The resulting calculated $\sin^2\theta$ values are compared with the observed values in table 1.

Chemistry

The analysis of leifite made by Christensen (in Bøggild, 1915) is given in table 4. As already mentioned, the composition has had to be redetermined, as we have found 6 ± 2 % BeO by spectrographic analysis. Unfortunately, the small amount of leifite available did not permit a total wet chemical analysis, and the revision was therefore carried out by spectrographic analyses, wet micro-chemical analysis, micro thermogravimetric analysis and electron microprobe.

The spectrographic analysis was kindly carried out by H. Bollingberg. With tourmaline as standard for B the analysis gave 0.1 – 1 % B_2O_3 or 0.5 % in table 4. With sorensenite as standard the analysis gave 4 – 8 % BeO. Furthermore 50 ppm of Mn was detected.

BeO was determined more acurately by wet micro-chemical analysis to 3.8 ± 0.2 % by N. Hansen. It was determined spectrophotometrically as acetyl acetonate.

The thermogravimetric analysis was kindly carried out by E. Pedersen on the micro thermobalance of Chemical Laboratory I of the H. C. Ørsted Institute. The thermogravimetric curve, which is given in fig. 1 was obtained on 2.76 mg leifite at a pressure of 405 mm Hg of air with 44 % humidity. The rate of heating was 10° C/min. 4 different reactions can be distinguished in the thermogravimetric curve:

Reaction I is a weight loss of 24 μg or 0.9 % between 60° C and 120° C. It is ascribed to adsorbed water and is disregarded in the calculation of the unit cell content in table 4. Bøggild (1915) gave an H_2O content of 0.77 %, which seems to be identical to our reaction I.

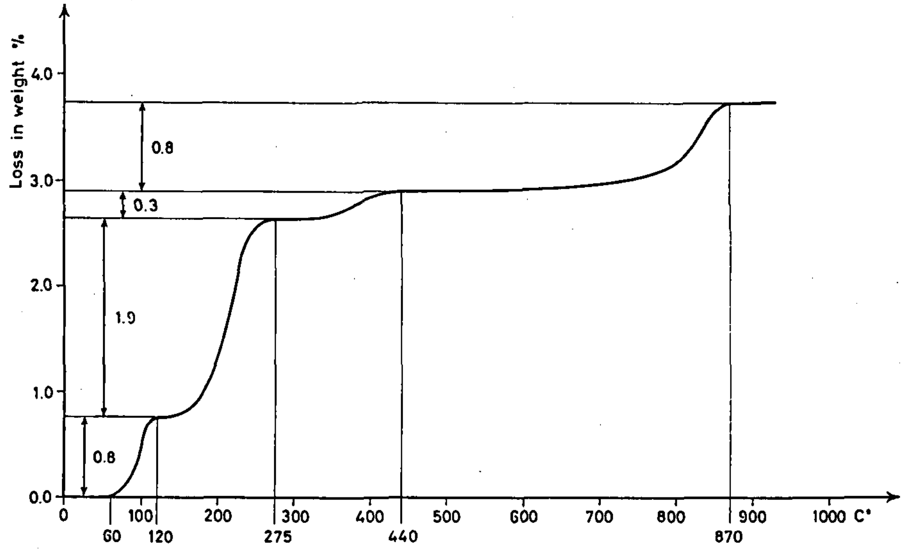

Fig. 1. Thermogravimetric analysis of leifite. Rate of heating 10° C/min. 405 mm Hg of air with 44 % humidity.

Table 3. Chemical analysis of tugtupite and electron microprobe measurements of tugtupite and leifite.

	Tugtupite Weight %*)	Tugtupite Counts per second from the Kα-lines	Leifite Counts per second from the Kα-lines
Si	24.09	921.2	1259.1
Al	5.90	201.4	169.5
Be	1.90		
Mg	0.12		
Na	18.93	1179.1	556.8
K	0.10		
Cl	7.28		
S	0.33		
O	41.05		

*) Analyst: M. Mouritzen.

Reaction II is a weight loss of 51 μg or 1.9 % between 140° C and 275° C; it is ascribed to water molecules and is given as H_2O^{II} in table 4.

Reaction III is a weight loss of only 7μg or 0.3 % between 340° C and 440° C. In spite of the low temperature of reaction we suppose this loss of weight to be due to OH-groups as: 1) the loss is too small to correspond to a whole number of water molecules in the cell and 2) the reaction is clearly separated from reaction II, which gives the water molecules, and from reaction IV, which gives the flourine. Reaction III is therefore listed separately as H_2O^{III} in the analysis in table 4.

Reaction IV is a weight loss of 23 μg or 0.8 % between 600° C and 870° C; it is ascribed to F for which element the electron microprobe gave 1.2 % ± 0.5 %. The correspondence between these two determinations enables us to discredit the 4.93 % F found by Christensen (In Bøggild, 1915).

The electron microprobe measurements were carried out on an ARL instrument at the Department of Metallurgy, The Technical University of Denmark. The samples were investigated for Na, Al, Si, F, Zn, K and Mg. Zn, K and Mg were absent. Tugtupite was used as standard for the determination of Na, Al and Si. The analysis of tugtupite is given in table 3 together with the intensities of the Kα-lines of Na, Al and Si for tugtupite and for leifite. The intensities measured were corrected for matrix effects on the IBM 7090 of NEUCC, Lundtofte. The program used was made by F. L. Nielsen.

The corrections are very small. In the calculation of the matrix effects we used the contents of H, Be, B and F as determined above, and the content of O calculated from an approximate analysis.

The F content was also determined approximately by comparison with narsarsukite (0.71 % F) and with fluorite (48.7 % F), without correction for

Table 4. Chemical analyses and the unit cell content of leifite

	Weight %*)	Weight %**)	Molecular ratio	Number of gramatoms of oxygen per 100 g	Number of gramatoms per 100 g	Number of atoms per unit cell Calculated	Number of atoms per unit cell Calculated × 42/41.54	
SiO_2	67.55	72.6	1.208	2.416	1.208	15.95	16.13	20.87 (Si, Al, Be, B)
B_2O_3	n. d.	0.5	0.007	0.021	0.014	0.18	0.19	
Al_2O_3	12.69	9.6	0.095	0.284	0.189	2.50	2.52	
BeO	n. d.	3.8	0.152	0.152	0.152	2.01	2.03	
MnO	0.41	0.0						
Na_2O	15.47	12.4	0.200	0.200	0.400	5.28	5.34	6.28 (Na, H_3O)
H_2O^{I}	0.77	0.8						
H_2O^{II}	n. d.	1.9	0.106	0.106	0.212	2.80	2.83	
H_2O^{III}	n. d.	0.3	0.017	0.017	0.033	0.44	0.44	1.00 (F, OH)
F^{IV}	4.93	0.8	0.042		0.042	0.55	0.56	
O	–2.08	–0.3	–0.021	–0.021	3.175	41.92	42.39	41.01 O
	99.74	101.6†)		3.175				
$\Sigma O + F - \frac{1}{3} H$ (from H_2O^{II}) = 3.146						41.54	42.00	

The ratio between the number of atoms in the unit cell and the number of gram atoms in 100 g is $= 0.6023 \times 10^{24} \times 865.9 \times 10^{-24} \times 2.572/101.6 = 13.20$

*) Analyst: Chr. Christensen, in O. B. Bøggild (1919).

**) New analysis, see text p. 139–143.

†) Sum without H_2O^{I}.

matrix effects. The result was 1.2 ± 0.5 $^{0}/_{0}$, which is replaced in table 4 by the 0.8 $^{0}/_{0}$ derived from the thermogravimetric analysis.

The content of the unit cell in table 4, column 7, is calculated on the basis of the new analysis, the density 2.572 and the unit cell constants in table 2, i. e. $a_0 = 14.351$ Å and $c_0 = 4.854$ Å. The volume of the unit cell is 865.9 Å^3. The formula must be written as for a tectosilicate. The water from reaction II and the sodium cannot individually make up whole numbers divisible by 3. Both determinations are considered to be reliable and these elements have therefore been grouped together as 6 univalent cations of roughly the same size. OH + F make up approximately one group in the cell but have been incorporated in the remaining 41.54 (O + F + OH) to make up roughly a whole number divisible by 3 in accordance with the symmetry. Column 8, table 4, shows the content of the unit cell recalculated to 42.00 (O + F + OH) – besides O in H_3O^+ – and column 9 gives a tentative grouping of the elements. The formula is:

$$(Na_{5.3}\ (H_3O)_{0.9})\ [(Si_{16.1}\ Al_{2.5}\ Be_{2.0}\ B_{0.2})\ O_{41.0}\ F_{0.6}\ (OH)_{0.4}],\ Z = 3,$$

which may be simplified to:

$$(Na,\ H_3O)_2\ [(Si,\ Al,\ Be,\ B)_7\ (O,\ F,\ OH)_{14}],\ Z = 3.$$

Karpinskyite

General description

Karpinskyite was first described by Shilin (1956). The paper has been abstracted by Fleischer (1957) and in Vlasov et al. (1956).

According to Shilin (1956) karpinskyite was found in the Karnasurt pegmatites, which are genetically connected with poikilitic sodalite syenite. A close association with albite and natrolite is characteristic, as karpinskyite is developed in small cracks in these minerals. Karpinskyite occurs in the form of elongated, prismatic or acircular, white to silky white crystals sometimes forming rosettes of radiate-fibrous structure.

In the scanning electron microscope the karpinskyite crystals described by Shilin (1956) turn out to be highly fibrous bundles, see plates 2 and 3. The single fibres, which are terminated by a trigonal pyramid or a rhombohedron, have a width of ca. 1 μm. The interfacial angle of the pyramid (or rhombohedron) is close to 90° as seen on plate 3, fig. 1, and the form can therefore be indexed as either $\{70\bar{7}2\}$ or $\{22\bar{4}1\}$, which give 88° 34' and 88° 11' respectively. Owing to the high indices of the first-mentioned form, the latter is regarded as the most probable. If true, the prism must be $\{11\bar{2}0\}$, and the mineral must belong to the crystal class 32, because $\{h, h, -2h, l\}$ will appear hexagonal in the other two of the three classes proposed by X-ray diffraction, see p. 135. The fibrous habit with needles in perfect parallel orientation may thus be due to twinning as a consequence of the high pseudosymmetry. The crystal bundle in plate 2, fig. 2 appears to be terminated by a poorly defined (0001) face, but this character is not general for the karpinskyite fibres, see plate 2, fig. 1.

The karpinskyite sample used in these investigation is from the original locality. The sample was presented to the Mineralogical Museum in Copenhagen and is registered as no. 1964.74.

Optical Properties

The optical constants or karpinskyite are given in table 5. Our data, which have been determined with wave-length variation and optical glass as internal standard (Micheelsen, 1957) agree with reasonable accuracy with those given by Shilin (1956), although impurities are abundant in our sample. The heterogeneity can be more easily observed in a polished sample with reflected light, see plate 4, fig. 1. Well polished areas – component A – are seen to be embedded in a frayed, badly polished, micaceous matrix – component B.

Table 5. Optical properties of leifite and karpinskyite.

	Leifite		Karpinskyite	
	Bøggild (1915)	Present authors	Shilin (1956)	Present authors
n_e	1.5224	1.5204 ± 0.0010	1.518	1.520 ± 0.0020
n_o	1.5177	1.5162 ± 0.0010	1.511	1.515 ± 0.0020
Δn	0.0044*)	0.004 ± 0.001	0.007	0.005 ± 0.003

*) Determined directly by means of a compensator.

X-ray diffraction

In order to show that our sample, which was labelled »karpinskyite«, was in fact karpinskyite we have listed the d-values obtained by Denisov (in Shilin, 1956) in table 1 together with the d-values for our sample. Denisov used Fe-Kα radiation and a Debye-Sherrer powder camera with a diameter of 65.8 mm. Our d-values were obtained with a Guinier-Hägg camera, and quartz was used as internal standard. The camera was calibrated by means of the observed quartz lines and the lattice constants for quartz recorded by Swanson & Fuyat (1953). In this calculation the weighed mean of the Kα_1 and the Kα_2 wavelengths for copper radiation 1.5418 Å, has been used.

The correspondence between the d-values of Denisov and our d-values is surprisingly good, when we disregard the β-lines given by Shilin (1956). Also, the intensities of the single lines correspond closely in the two samples apart from a few lines, which cannot be indexed, either by means of the lattice constants of karpinskyite given in Shilin or by the lattice constants of karpinskyite (leifite) obtained from our material. These additional lines, which must be ascribed to impurities, are not the same in the two samples, and we have not been able to identify them.

The differences between the lattice constants recalculated from the d-values given in Shilin and the lattice constants of our material are 0.015 Å on the a_0-axis and 0.012 Å on the c_0-axis, as shown in table 2. These lattice constants were calculated from the $\sin^2\theta$ values obtained from the d-values given by Shilin and from the observed $\sin^2\theta$ values of our material respectively. In the final calculations the lattice constants were refined by the least-squares method to the observed $\sin^2\theta$ values. These calculations were carried out on the GIER computer made available to the Copenhagen Observatory by the Carlsberg Foundation. A program (REFBASE-2) made by E. S. Leonardsen was used. The resulting calculated $\sin^2\theta$ values are compared with the observed values for both samples in table 1.

The Guinier-Hägg powder films may suffer strongly from orientation effects. To avoid these, we have run karpinskyite in the X-ray diffractometer, which gives a broad band from ca. 17–12 Å with a broad maximum at 16–14 Å and a line at 12.4 Å. This corresponds to minerals of the montmorillonite group.

We have thus found that our sample agrees in appearance, optical properties and X-ray data with the karpinskyite as described by Shilin (1956). Furthermore, in spite of the fact that our sample contains a montmorillonite mineral, it will be shown on p. 150 to correspond chemically to the material analysed by Shilin. We therefore conclude that our sample is karpinskyite although it contains some impurities, as does the karpinskyite of Shilin.

According to Strunz (1957) karpinskyite and leifite are isotypical as shown by the data in table 6. The reason for maintaining two mineral names is the

Table 6. Physical properties of leifite and karpinskyite given by Strunz (1957).

	Leifite	Karpinskyite
Symmetry	hexagonal D_{3d}, C_{3v} or D_3	hexagonal D_{3d}, C_{3v} or D_3
Habit	long-prismatic	prismatic-acicular
n_e	1.5224	1.518
n_o	1.5177	1.511
$n_e - n_o$	+ 0.0047	+ 0.007
a_0	14.37 Å	14.24 Å
c_0	4.94 Å	4.83 Å
c_0/a_0	0.344	0.339
Density	2.565 – 2.578	2.545

differences in the chemical composition, notably the contents of beryllium and zinc in karpinskyite. Strunz writes the formulas:

Leifite: ca. $Na_2 [(F, OH, H_2O)_{1-2} Si_5 (Al, Si) O_{12}], Z = 3$
Karpinskyite: ca. $(Na, K, Zn, Mg)_2 [(OH, H_2O)_{1-2} Si_4 (Al, Be)_2 O_{12}], Z = 3$

Our determinations of the refractive indices and the X-ray diffraction properties of leifite and of our sample of karpinskyite are given in tables 5, 1 and 2. Optically the minerals are identical. With regard to d-values, line intensities and lattice constants the minerals show very strong similarity, the essential differences being 0.049 Å or 0.3 % in a_0 and 0.027 Å or 0.6 % in c_0. This agreement leads to the conclusion that there can hardly be significant difference between leifite and karpinskyite. Furthermore in the first part of this paper leifite was shown to be a beryllium mineral free of zinc, and it was shown that the formula could be written as:

$$(Na, H_3O)_2 [(Si, Al, Be, B)_7 (O, F, OH)_{14}], Z = 3$$

Leifite and karpinskyite are thus even more similar chemically than known by Strunz (1957).

Chemistry

Owing to the above we decided to investigate the karpinskyite with the electron microprobe. These investigations were carried out on an ARL instrument at the Department of Metallurgy, The Technical University of Denmark.

The electron microprobe investigation showed immediately that karpinskyite is highly heterogeneous (see fig. 3 and plate 4, fig. 2) as already known from the optical examination (p. 144).

The well polished component – A – of the karpinskyite sample is nearly identical with leifite from Narssârssuk with regard to the contents of Na, Si, Zn, and Al (see fig. 2). The Si content seems to be slightly lower than that of leifite while the Na and Al content seems slightly higher. The A component makes up about one half of the volume of the karpinskyite sample.

The other, badly polished component – B – of the karpinskyite is poor in Na and Si but has a large and variable content of Al and Zn. The microprobe very often gives results which are intermediate between those of component A and B, indicating a fine-grained mixture of the two components. The composition of component B can here be estimated only roughly by comparison with standards of known composition but without corrections for matrix effects.

Na-Kα gives ca. 20 cps which correspond to less than 1 % of Na_2O when compared with 540 cps from the 12.4 % Na_2O of leifite.

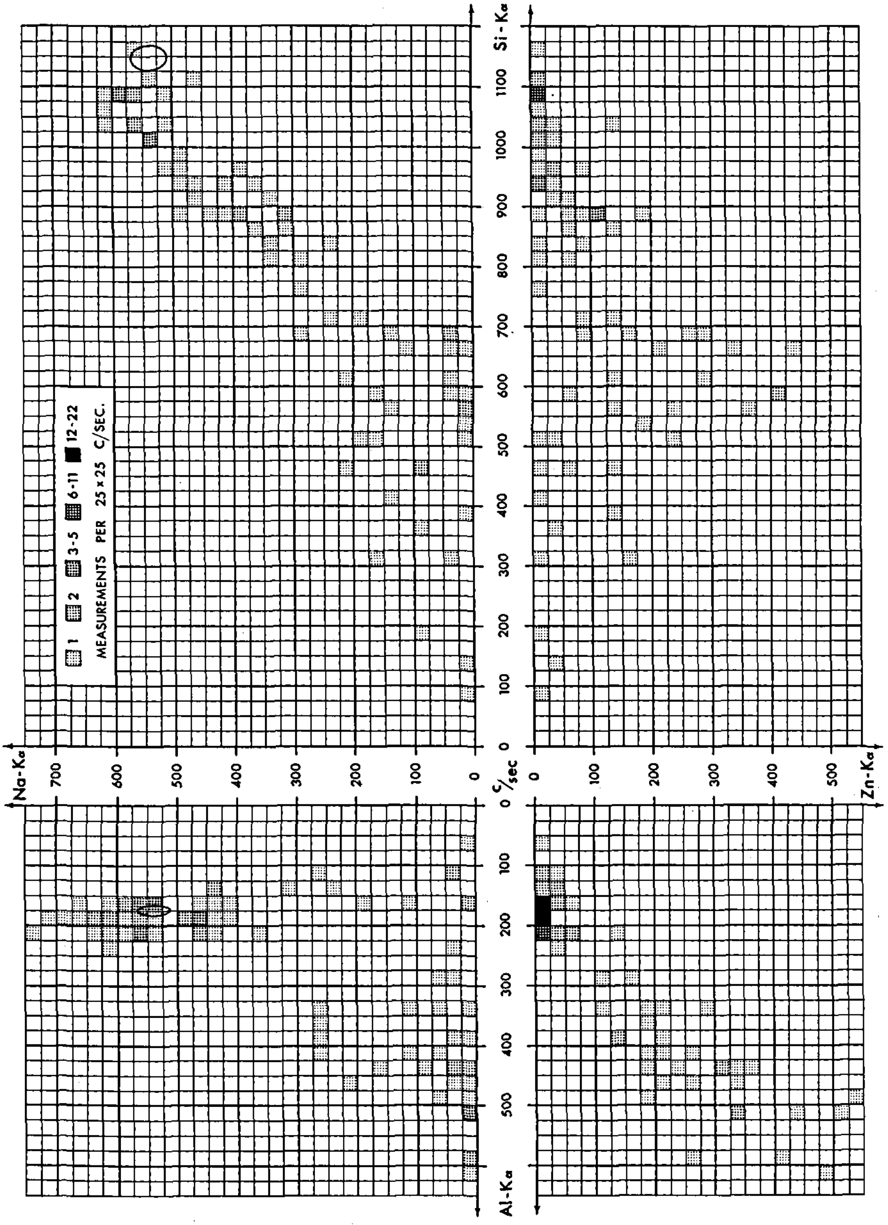

Fig. 2. Electron microprobe measurements of leifite and karpinskyite. Fields of leifite measurements are indicated by ellipses. Leifite is free of zinc. Densities of karpinskyite measurements are indicated by intensity of shading.

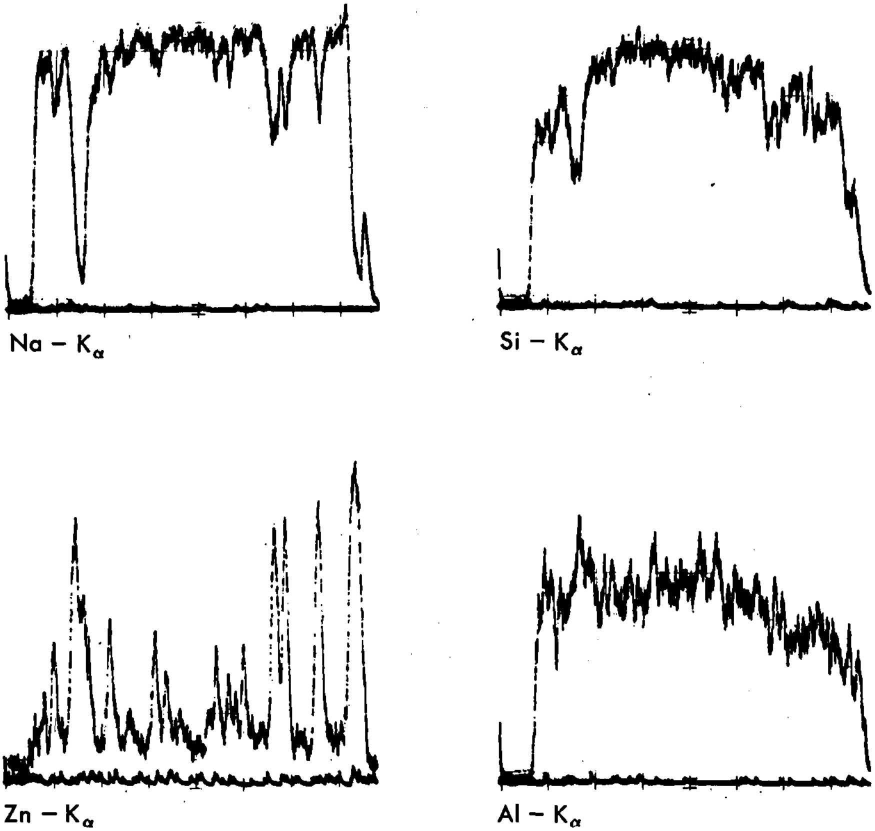

Fig. 3. X-ray intensity profiles across a grain of karpinskyite obtained by the electron microprobe. Base line indicates background intensity. The profiles are 0.36 mm long.

Si-Kα gives ca. 550 cps which correspond to ca. 35 % SiO_2 when compared with the 1148 cps from the 72.6 % SiO_2 of leifite.

Zn-Kα gives from 0 – 450 cps which correspond to 0 – 6 % ZnO when compared with the 10444 cps from a 99.9 % Zn standard. A few measurements in another series have given ZnO contents of up to 35 %.

Al-Kα gives 325–625 cps which correspond to ca. 18 – 35 % Al_2O_3, when compared with the 174 cps from the 9.6 % Al_2O_3 of leifite.

From this range of composition, from the micaceous morphology, and from the X-ray diffraction data on p. 145, we conclude that component B is a *mixture of montmorillonite with subordinate sauconite.*

The analyses of these minerals are given in table 7. The average composition of component B is close to the composition of the »zinc-montmorillonite« described by Kuz'menko (1959), but the variations in composition do not allow us to use a mineral name for the substance.

Table 7. Calculated and analysed composition of karpinskyite

	Leifite Narssârssuk (1)	Sauconite Lovozero (2)	Montmorillonite Lovozero (mean) (3)	Mixture of 60 % leifite + 10 % sauconite + 30 % montmorillonite	Karpinskyite Lovozero (4)
SiO_2	72.6	35.10	47.6	61.4	56.68
Al_2O_3	9.6	6.40	25.1	13.9	16.40
BeO	3.8	0.0	0.0	2.3	2.58
MgO + CaO + SrO	0.0	4.61	3.7	1.6	0.78
ZnO	0.0	35.74	0.0	3.6	3.26
Na_2O	12.4	0.25	0.8	7.7	9.18
H_2O total	2.2	16.97	21.7	9.5	7.50

1) This paper.
2) Semenov (in Vlasov et al., 1966, 467–469).
3) Mean of analyses by Semenov and by Kazakova (in Vlasov et al., 1966, 463–465).
4) Moleva (in Shilin, 1956).

The electron microprobe measurements have thus shown that the material labelled »karpinskyite« is a mixture of leifite, montmorillonite and sauconite. Table 7 shows the analysis of »karpinskyite« as given by Shilin, and the composition of a mixture of 60 % leifite, 30 % montmorillonite and 10% sauconite. In view of the variability of the clay minerals (Vlasov et al., 1966, 463–469) the correspondence between the composition of the mixture and the analysis of »karpinskyite« is acceptable.

Conclusions

From the data given in this paper we have to conclude:

1. Leifite from the original material described by Bøggild (1915) contains significant amounts of beryllium.
2. All physical properties and, in the main, the chemical composition agree with the description of Bøggild (1915).
3. The mineral name »leifite« must be retained, but the formula should be written as:

$$(Na, H_3O)_2\ [(Si, Al, Be, B)_7\ (O, F, OH)_{14}],\ Z = 3$$

4. »Karpinskyite« from Kola is a mixture, of which leifite is one of the main components.
5. The zinc content of »karpinskyite« derives from the zinc-bearing minerals in the mixture, probably montmorillonite and sauconite.
6. »Karpinskyite« must be discredited as a mineral species.

The redefinition of leifite and the discrediting of karpinskyite has been approved by IMA.

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Plate 1

Leifite

Fig. 1. One end of a needle seen perpendicular to [001]. Scanning electron micrograph (× 525).

Fig. 2. The above crystal seen obliquely. Scanning electron micrograph (× 525).

Karpinskyite

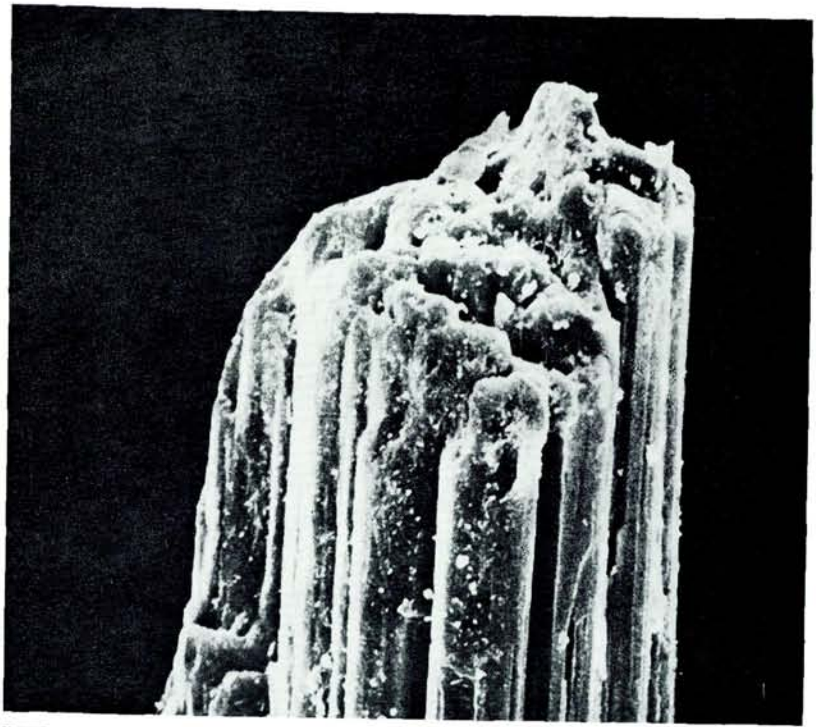
Plate 2

Fig. 1. Crystal bundles 50–350 μm in thickness. Scanning electron micrograph (× 215).

Fig. 2. The termination of a bundle of crystals seen obliquely to the [001] axis. Scanning electron micrograph (× 1000).

(See p. 151 for text to plates 3–4).

Plate 1



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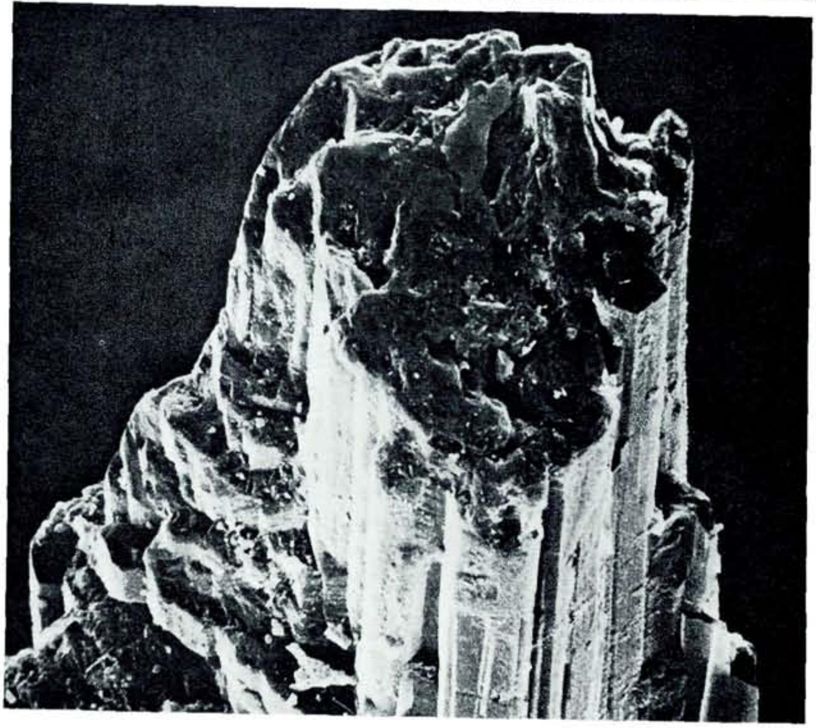

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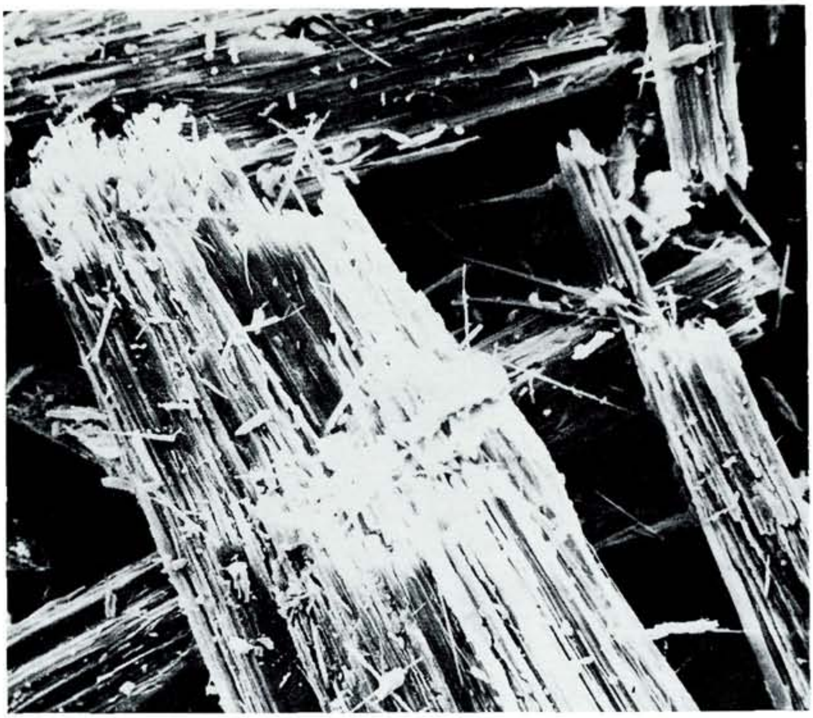

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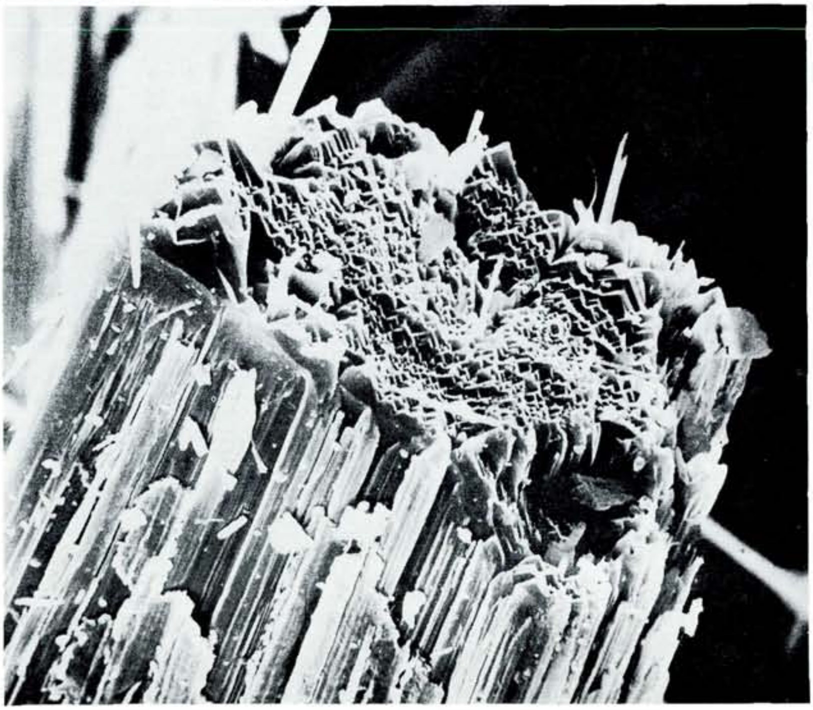

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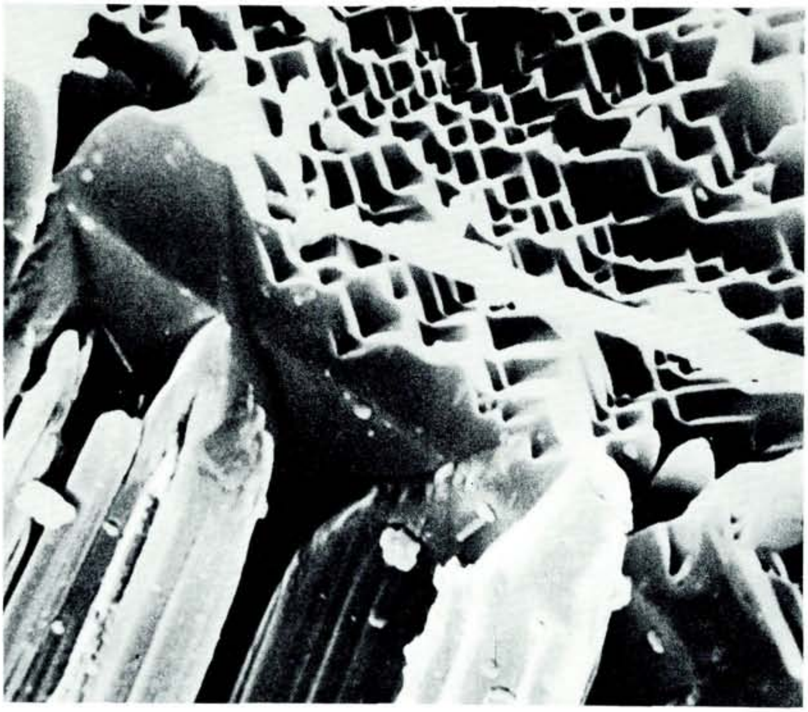

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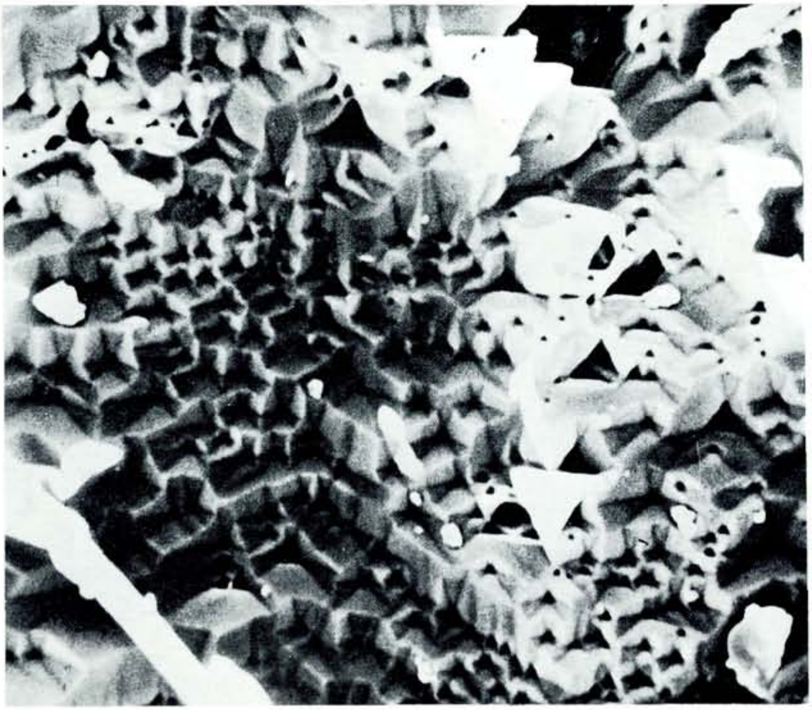

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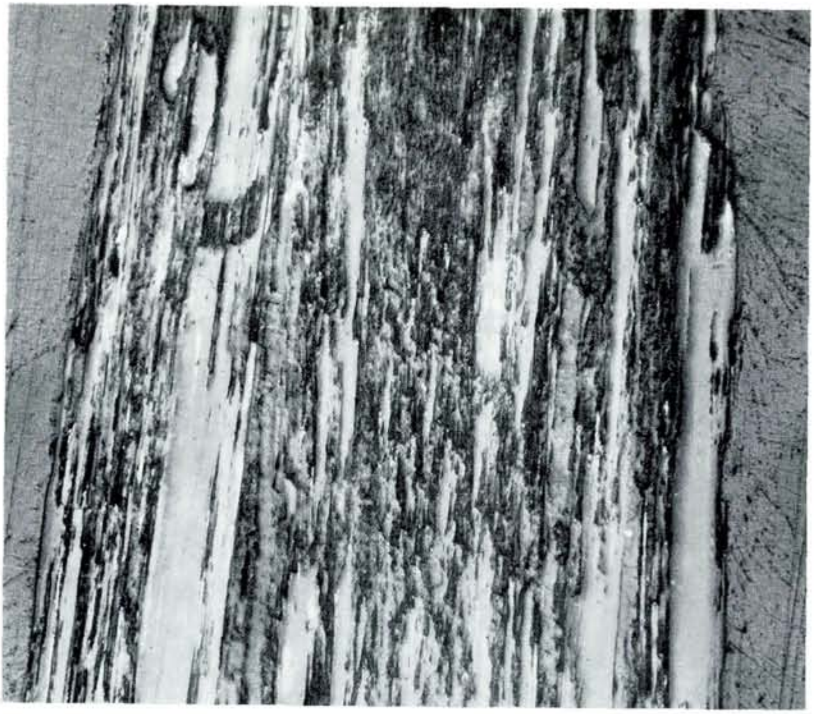

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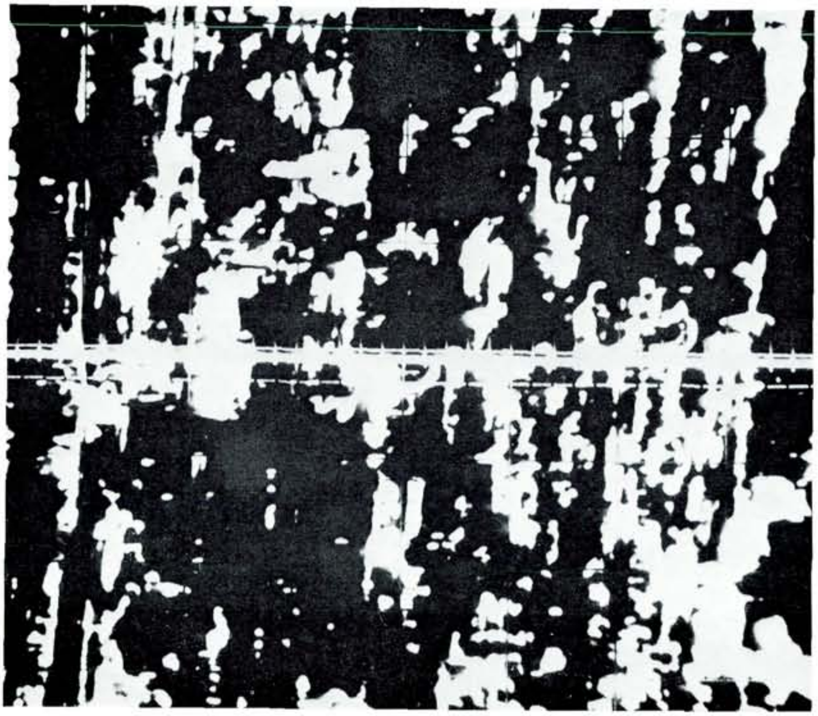

2

Dansk sammendrag

En undersøgelse af Bøggilds originale materiale af leifit fra typelokaliteten på Narssârssuk i Grønland har vist at mineralet indeholder væsenlige mængder af beryllium. Mineralets kemiske sammensætning er derfor blevet undersøgt systematisk med spektral analyse, termogravimetrisk analyse, røntgen diffraktion, elektronmikrosonde målinger og våd mikro-kemisk analyse. Formlen bliver:

$$(Na_{5.3}\,(H_3O)_{0.9})\;[(Si_{16.1}\;Al_{2.5}\;Be_{2.0}\;B_{0.2})\;O_{41.0}\;F_{0.6}\;(OH)_{0.4}],\;Z = 3,$$

hvad der kan simplificeres til:

$$(Na,\,H_3O)_2\;[(Si,\,Al,\,Be,\,B)_7\;(O,\,F,\,OH)_{14}],\;Z = 3$$

Leifit krystalliserer trigonalt, sandsynligvis i rumgruppen P321 eller P312. Enhedscellens axer er: a_0 = 14.351 Å og c_0 = 4.854 Å.

Karpinskyit fra type lokaliteten på Kola i U.S.S.R. er blevet undersøgt, fordi det hidtil har været anset for isotypt med leifit. I undersøgelsen er anvendt scanning elektronmikroskopi, røntgen diffraktion og elektron-mikrosonde. Karpinskyit har herved vist sig at være en blanding af leifit, montmorillonit og sauconit. Leifiten fra Kola indeholder lidt mindre Si og lidt mere Na og Al end leifiten fra Grønland, og den har gitterkonstanterne: a_0 = 14.400 Å og c_0 = 4.881 Å. Navnet »karpinskyit« kan derfor ikke opretholdes.

Mineralogisk Museum
Østervoldgade 5–7,
DK – 1350 København K
November 11th, 1969

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Plate 3

Karpinskyite

Fig. 1. Detail of the crystal bundle shown on plate 2, fig. 2. The direction of view is oblique to [001]. Scanning electron micrograph (× 5000).

Fig. 2. The same crystal bundle as above, but the direction of view is parallel to [001]. Scanning electron micrograph (× 5000).

Plate 4

Karpinskyite

Fig. 1. Optical micrograph of polished section. Reflected light (× 275).

Fig. 2. Electron picture of polished section (× 300). The horizontal white line indicates the position of the X-ray profiles given in fig. 3.