Bøgvadite, $Na_2SrBa_2Al_4F_{20}$, a new fluoride from the cryolite deposit, Ivigtut, S. Greenland

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Bøgvadite, ideally $Na_2SrBa_2Al_4F_{20}$ was found in the central part of a sample of the radiating aggregates in which jarlite occurs in the cryolite deposit, Ivigtut, S. Greenland.

Thin sections showed bøgvadite as rectangular, uniformly orientated crystals 0.1–0.2 mm across, arranged as a somewhat irregular pavement covering a few square centimetres. The crystals, partly overgrown with ralstonite crystals, were embedded in a matrix of a kaolin-like mineral interspersed with fine-grained barite. Fan-shaped jarlite grains were scattered in the matrix. Bands and strings of fine-grained, spherulitic K-mica transected the whole mass.

The composition of bøgvadite is derived from the average of 11 microprobe analyses: Na 5.57% (2.0% rel.), Sr 7.03% (9.6% rel.), Ba 32.17% (3.0% rel.), Al 12.45% (0.9% rel.); calculations gave F 42.85% (0.6 rel.). F was found to be between 40% and 45%, but direct determination together with the metals could not be executed satisfactorily. As standards were used cryolite (Na, Al), bøggildite (Sr), barite (Ba). No other elements were found in detectable amounts. Atomic absorptions spectrometry on a bulk sample showed Li to be below the detection limit (0.2 ppm). Gladstone-Dale calculations give $K_C = 0.1073$ and $K_P = 0.1118$. Assuming the presence of 2.55% OH (giving $F_{18.7}(OH)_{1.3}$ in the formula) results in $K_C = K_P$. Determination of OH/H_2O was not possible due to the presence of kaolin and ralstonite.

Bøgvadite is orthorhombic and the crystals show {010}, {110} and {012}. They are blocky, slightly platy after {010} and slightly elongated after [100]. It is transparent, colourless and has H > 3, $VHN_{25} = 300 \pm 50$. D = 3.85 ± 0.02 g/cm^3, D calculated is 3.898 g/cm^3.

Bøgvadite is biaxial negative, α = 1.4326, β = 1.4360, γ = 1.4389 all ± 0.0002; $2V\alpha = 87° \pm \frac{1}{2}°$, $2V_a$ calculated = 85° ± 6°; α = c, β = a and γ = b; O.A.P. = (100).

X-ray powder diffraction and single crystal studies give a = 7.110 ± 0.003, b = 19.907 ± 0.010, c = 5.347 ± 0.003Å; space group Pnmn or Pn2n.

The new mineral has been named after the late chief geologist Richard Bøgvad, of the cryolite company Øresund A/S.

Small groups of bøgvadite grains have been observed in thin sections from several samples of the radiating aggregates. This Ba-rich fluoride formed early in the Sr-Ba-rich accumulations within the fluorite cryolite of the deposit.

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Introduction

A new fluoride "for the present denoted mineral X" was mentioned in Bøgvad (1933) in the introduction to the description of the mineral jarlite. It was stated that jarlite occurred as free crystals together with thomsenolite in cavities in columnar aggregates. These aggregates were said to consist of a mixture of thomsenolite, fluorite, spherulitic topaz, barite, and a new fluoride (mineral X). Pyrite and small quantities of chalcopyrite are dispersed throughout the mass which also contains a green mineral then called "ivigtite", later found to be a K-mica (Bøgvad 1938); it is usually observed in thin sections as spherulitic grains. Quartz occurs here and there in the aggregates.

It is mentioned that a thorough description of mineral X and the columnar aggregates will follow in a later paper but this was never realized (Bøggild 1953).

Recently an examination was initiated with a view to understand better the nature of these columnar, or radiating as we prefer to call them, aggregates. The first two thin sections were cut from the central part of such an aggregate, the part from which the radiae so to say emerge (Fig. 1). These thin sections showed a most remarkable array of small crystals, up to 0.15 by 0.20 mm, covering most of the areas of the sections in parallel positions. Between crossed polars it is seen that the small crystals extinguish simultaneously within two or three areas, each of one square cm. The differences between the extinguishing direc-
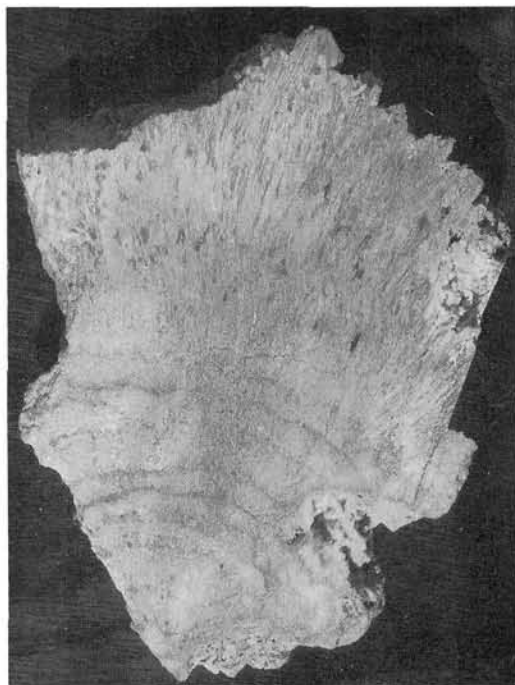
Fig. 1. View of section through radiating aggregate with jarlite druses in the upper (distal) part and to the right. Dark, brownish bands consist of fine-grained spherulitic K-mica. Bøgvadite crystals, 0.1–0.2 mm in length, are present in the light, fine-grained material between the bands. The sample is 13.5 cm high.

tions in the different areas are 5–10°. Fig. 2 shows the crystals embedded in a matrix of a very fine-grained barite and a kaolinite-like mineral, henceforth called kaolin because a proper clay-mineralogical determination has not been made due to the scarcity of material. In the specimen the matrix appears as a loose white powder. A small block of this part of the sample was found to weight 2.3 g/cm^3. The estimated mineral composition would rather indicate 3.7 g/cm^3. This points to a pore content of about 30–40%.

The microscopic examination showed the crystals to have refractive indices quite close to those of jarlite; they were optically biaxial and showed a rather large value for 2V as jarlite also does. They differed from jarlite in that they showed parallel extinction and a rather clearcut extinction as opposed to the wavy extinction exhibited by jarlite. X-ray examinations in a Gandolfi camera gave powder patterns distinctly different from jarlite and other known minerals. It seemed that the small crystals represented a new mineral species, and this was substantiated by the subsequent

studies. Examinations of thin sections of several other samples of the radiating aggregates have also demonstrated the presence of the new mineral in them. We assume that Bøgvad's designation "mineral X" comprises what we have found and do not hesitate in calling the new mineral bøgvadite, this also to recognize his dedicated work on the cryolite deposit from 1931 to August 1952 when – during field-work in the vicinity of Ivigtut – he died from a heart attack (Noe-Nygaard 1952).

The mineral and the name have been approved by the Commission on New Minerals and Mineral Names of I.M.A.

Separation of pure bøgvadite

Fig. 1 shows the remaining half of the sample which was cut along the middle plane of the rather flat sample in order to show the structure of the aggregate. The thin sections covering 2–3 cm^2 were from the apical part of the sample where the highest concentrations of bøgvadite occur. As no other samples were found to contain bøgvadite in such large amounts, we decided to establish material for analyses from the cut off pieces. Their rather friable character, due to the fine-grained matrix and high porosity, allowed us to establish a reasonable fraction through gentle crumbling and disintegration in an ultrasonic water bath.

The sample for analysis was dissolved with HNO_3/HCl leaving about 12% insoluble material (quartz, silicate etc.). Al was determined through titrations with CDTA, the other elements by atomic absorption spectrophotometry:

Na   4.6%
Li   nil
Mg   1.3%
Ca   0.2%
Sr   15.5%
Ba   16.2%
Al   11.2%

Because the mineral composition could not be established, these results could not be interpreted. When the composition of bøgvadite was found from the electron microprobe analyses, the above analysis was found to indicate the presence
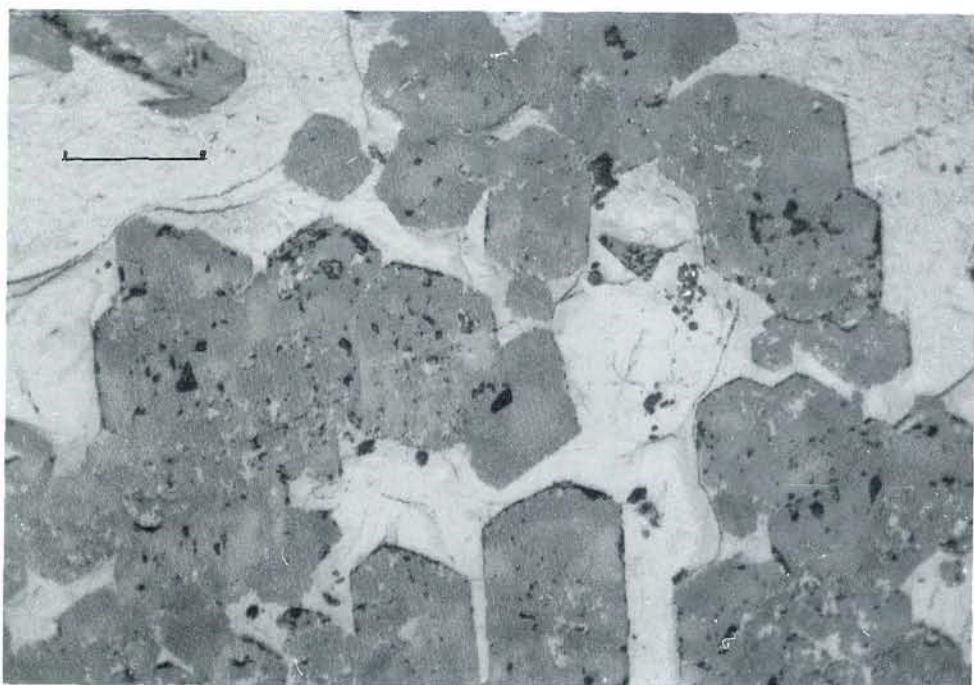
Fig. 2. Bøgvadite crystals in matrix of kaolin with ralstonite crystals attached. Note the rhomb shaped ralstonite crystal in centre. The matrix contains kaolin and barite (light grey), bøgvadite (darker grey) and ralstonite (slightly darker gray than bøgvadite). Vacuoles and inclusions cause the reflectance colours of the crystals to vary somewhat. Vertical illumination, plane light; bar 100 μm.

of about 53% bøgvadite, 26% jarlite and 12% ralstonite.

In order to get a pure fraction of the new mineral we had to resort to separation in Clerici heavy liquid mixtures. A pure fraction was obtained in a mixture with d around 3.88. The precipitate amounted to less than 15 mg. One reason for the poor recovery was intergrowths of bøgvadite with ralstonite and another was the presence of jarlite. Although this small amount served well for the physical determinations, the chemistry of bøgvadite had to be established using the electron microprobe.

Crystal morphology

The orientation of the unit cell axes – a, b and c – relative to the blocky, slightly platy crystals was established from oscillation-, Weissenberg-, and precession-photographs.

All the crystals are somewhat rounded with strongly corroded faces, see Fig. 3, and unsuitable for optical goniometry. Only two, selected from several hundreds, permitted measurements

on the goniometer of the angles in the zone [001]; comparison with angles calculated by means of the unit cell parameters unequivocally identified the forms present in the zone as {010} and {110}. Attempts to measure on the goniometer the angles in the zone [100] failed, and they were there-
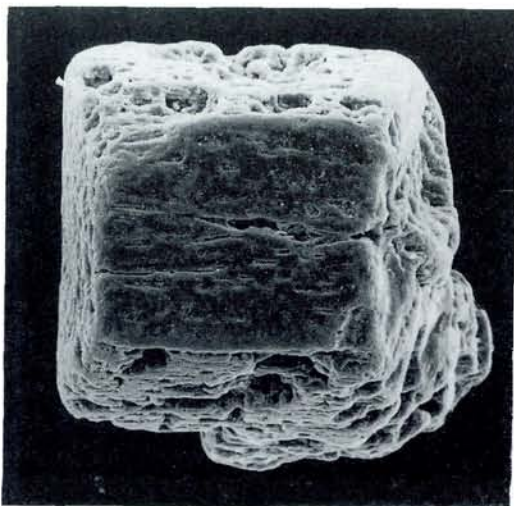

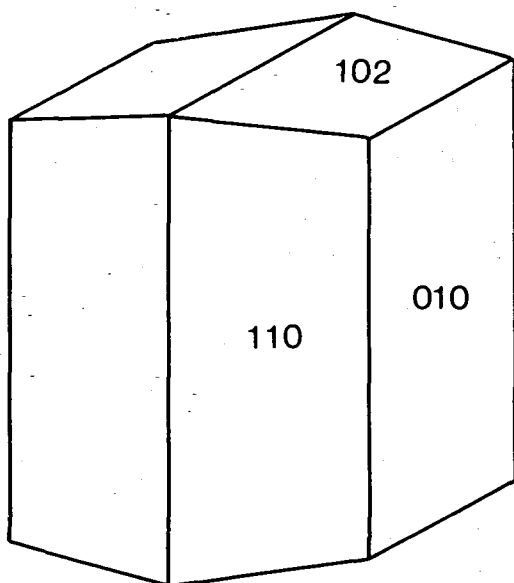Fig. 3. S.E.M. of typical, rounded and strongly corroded, bøgvadite crystal. Magnification = 340.

Fig. 4. Drawing of an idealized crystal of bøgvadite showing {010}, {110} and {012}.

Table 1. X-ray powder diffraction data on bøgvadite

h	k	l	d_{calc}	Gandolfi d_{obs}	I	Guinier-Hägg d_{obs}	I
0	2	0	9.9534	9.992	4	9.9681	4
1	1	0	6.6955	6.682	4	6.6886	4
n.i.				5.772	<1		
0	1	1	5.1592	5.170	1	5.1466	2
1	3	0	4.8510	4.861	<1		
1	0	1	4.2706	4.270	6	*	
0	3	1	4.1610			4.1642	1
1	2	1	3.9246	3.934	4	3.9243	3
2	0	0	3.5548	3.562	1	3.5619	2
1	5	0	3.4738	3.493	4	3.4736	2
n.i.						3.4489	1
2	2	0	3.3477	3.357	1	*	
1	4	1	3.2409	3.255 ⎫ b.d.	7	3.2403	10
0	5	1	3.1922	3.220 ⎭	7	3.1945	5
2	1	1	2.9272	2.936	5	2.9241	5
2	4	0	2.8947			2.8923	2
0	0	2	2.6708	2.671	3	2.6681	4
0	2	2	2.5796	2.574	<1	2.5856	1
0	7	1	2.5102	2.518	<1	2.5101	1
1	1	2	2.4807	2.475	<1	*	
2	5	1	2.3751	2.377 ⎫ b.	1	2.3758	4
0	4	2	2.3534 ⎫	2.362 ⎭	3	2.3543	2
3	1	0	2.3533 ⎭				
n.i.						2.2795	2
3	3	0	2.2318 ⎫	2.235	2	*	
1	4	2	2.2341 ⎭				
3	0	1	2.1663	2.171	2	2.1672	3
1	5	2	2.1173 ⎫				
3	2	1	2.1167 ⎬	2.125	4	2.1158	5
1	9	0	2.1120 ⎭				
2	2	2	2.0878	2.090	<1	2.0877	2
0	9	1	2.0436 ⎫	2.049	2	2.0408	3
2	8	0	2.0385 ⎭				
3	4	1	1.9863	1.996	2	1.9860	3
2	4	2	1.9623	1.965	1	1.9609	3
2	5	2	1.8818 ⎫	1.884	<1		
1	7	2	1.8834 ⎭				
0	8	2	1.8206 ⎫	1.826	<1	*	
3	7	0	1.8206 ⎭				
0	1	3	1.7735 ⎫				
3	0	2	1.7727 ⎬	1.779	4	1.7717	3
2	9	1	1.7717 ⎭				
0	11	1	1.7236 ⎫				
1	1	3	1.7216 ⎬	1.723	2		
0	3	3	1.7208 ⎭				
1	9	2	1.6628 ⎫	1.661	<1		
2	10	1	1.6600 ⎭				
3	5	2	1.6194	1.629 b.	2	1.6186	2
2	1	3	1.5869 ⎫	1.589	1	1.5893	1
1	5	3	1.5845 ⎭				
				1.556	1	*	
				1.509	1		
				1.482	2		
				1.450	<1		
				1.423	1		
				1.389	1		
				1.368	1		
				1.332	1		
				1.313	1		
				1.292	1		
				1.271	<1		
				1.201	1		
				1.189	1		

* coinciding with the quartz standard
b.d. broad double
b. broad
n.i. not indexed

fore determined from the outlines of the crystals seen along the zone-axis in the microscope. Comparison with angles calculated from the unit cell parameters suggests that the form present in the zone is {012} besides {010}.

The axial ratios, calculated from the unit cell parameters, are: 0.3572:1:0.2683.

A drawing of an idealized crystal of bøgvadite, showing {010}, {110} and {012}, blocky but slightly platy after {010} and slightly elongated after [100], is shown in Fig. 4.

Physical and optical properties

The crystals, ranging in size from 0.15 to 0.05 mm, show no obvious cleavage, the fracture is uneven. The Mohs hardness is > 3, determined by scratching the rhombohedral cleavage surface of Iceland spar, VHN_{25} is 300 ± 50. The density measured in Clerici's solution is 3.85 ± 0.02 g/cm³; D calculated is 3.898 g/cm³. As seen in Fig. 3, the crystals appear corroded and rather porous. This may explain the low value for d measured.

The crystals are colourless, transparant and have vitreous lustre. The streak is white; bøgvadite shows no fluorescence in either LW or SW ultraviolet light.

Bøgvadite is biaxial optically negative. The refractive indices for λ = 589 nm were determined by means of a microrefractometer spindle-stage, using mixtures of lavender oil (1.460) and refined petroleum (1.425), with nitratite as refractometer crystal (Medenbach, 1985) and under application of the λ-T variation method. The refractive indices are:

$n\alpha = 1.4326 \pm 0.0002$
$n\beta = 1.4360 \pm 0.0002$
$n\gamma = 1.4389 \pm 0.0002$

$2V_\alpha$ determined from the extinction measurements using the program EXCALIBR (Bloss & Riess, 1973; Bloss, 1981) is $87° \pm \frac{1}{2}°$, $2V_\alpha$ calculated from the refractive indices is $85° \pm 6°$. Dispersion is not perceptible.

The orientation of the indicatrix, determined on the spindle-stage, is: $\alpha = c$, $\beta = a$ and $\gamma = b$, O.A. plane = {100}.

X-ray diffraction

X-ray powder diffraction – Gandolfi and Guinier-Hägg –, single crystal studies – oscillation, with the 7.110 Å a-axis as the oscillation axis, Weissenberg, with the 7.110 Å a-axis as the oscillation axis, and precession, with the 19.907 Å b-axis as the precession axis –, show bøgvadite to be orthorhombic, with cell parameters: a = 7.110 ± 0.003, b = 19.907 ± 0.010 and c = 5.347 ± 0.003 Å; cell volume 756.1 Å³. These values were found by least-squares refinement using 24 indexed powder lines of the Guinier-Hägg diagram, individually weighed, and the program REFBASE written by E. S. Leonardsen. Possible space groups are Pnmn or Pn2n.

The powder data, Table 1 main column 1, were determined with a Gandolfi camera, $Cu_{K\alpha 1}$ radiation (λ = 1.54051 Å); main column 2 with a Guinier-Hägg camera, quartz as internal standard and $Cu_{K\alpha 1}$ radiation (λ = 1.54051 Å).

Composition

Preliminary electron microprobe analyses of bøgvadite crystals in thin sections from the apical part as well as from the distal part of the sample shown in Fig. 1 showed Na, Sr, Ba, Al and F to be the main and only elements present with atomic number above that of oxygen. It should be noted that we have specifically looked for K, Mg and Ca, but they were not found in detectable amounts.

Atomic absorption spectrophotometric analyses on a bulk sample from the apical part showed Li, as mentioned above to be below the detection limit.

The microprobe analyses were carried out on a Philips SEM 505 with a Microspec WDX 2-A spectrometer. Pure mineral samples of known composition were used as standards: cryolite for Na and Al, bøggildite for Sr and barite for Ba. The fluorides together with weberite and stenonite were checked against each other and also analysed with the use of conventional oxide standards. The results confirmed the compositions assigned to them.

The following results were obtained analysing 11 crystals of bøgvadite:

	11 crystals at 12 kV		3 crystals at 10 kV	3 crystals at 15 kV
Na	5.57%	2.0% rel.	5.54%	6.14%
Sr	7.03%	9.6% –	7.85%	7.64%
Ba	32.17%	3.0% –	30.59%	32.13%
Al	12.45%	0.9% –	12.05%	12.63%
(F	*42.85%*	*0.6% –*)	*(41.91%)*	*(43.96%)*
	100.07%		97.94%	102.50%

Preliminary determinations of F gave values between 40 and 45% but it was found convenient to omit its direct determination and carry out the analyses assuming all metals to be bound to F because the calculation programs used could not accept simultaneous determination of F, presumably because of inappropriate absorption corrections for this element. The analyses were carried out at 12 kV. Analyses on 3 crystals with 10 kV and 3 other crystals with 15 kV were also carried out. From these analyses it was judged best to proceed at 12 kV. In addition, 4 crystals have been analysed using conventional oxide standards (at 10 and 20 kV); these results were also satisfactorily close to the given analyses, i.e. within the spread of the determinations.

The analysis calculated on the basis of 20 F results in the following formula:

$$Na_{2.15}Sr_{0.71}Ba_{2.08}Al_{4.09}F_{20}$$

ideally: $Na_2SrBa_2Al_4F_{20}$.

Gladstone-Dale calculations based on the fluoride constants from Pauly (1982) give a $K_C = 0.1073$. Against $K_P = 0.1118$ the difference is marked although it lies in the category: good according to the compatibility index (Mandarino 1981), which is -0.042. We have no means of finding out whether some OH substitutes for F because kaolin and ralstonite are adhering to or included in the bøgvadite crystals. Assuming, however, the presence of 2.55% OH corresponding to $(OH)_{1.3}$ and $F_{18.7}$ K_C is found to be equal to K_P. The analysis gives M = 887.6 which with the unit cell volume 756.1 gives $d_x = 3.898$. The mentioned amount of (OH) would give $d_x = 3.882$.

EDAX analyses of the matrix showed it to contain areas giving signals only for Al and Si thus indicating the presence of kaolin. Other areas in the matrix gave signals for only Ba and S. This obviously indicates the presence of barite. The appearance of these parts seemed to indicate that barite occurs as curved elongated scales a few microns thick and 10–20 μm in length. WDX analyses of jarlite and ralstonite present in the bøgvadite section gave results closely fitting the formulae of these minerals. It may be mentioned that the ralstonite fitted a formula with 0.65 Na and Mg and 1.35 Al atoms. According to Pauly

(1965) ralstonite with this composition should have a refractive index close to 1.39 which in fact was the value observed for the ralstonite present with bøgvadite.

Paragenetic relations

In the two thin sections from the apical part of the specimen (Fig. 1), bøgvadite occurs as the dominating mineral and is present as numerous small crystals 0.1 to 0.2 mm in length. Their uniform orientation, clearly revealed between crossed polars, is continuous right through the two cm long thin section. With this arrangement they, so to say, constitute a pavement admittedly somewhat irregular because the small crystals in some places are closely linked to each other, whereas in other places they occur as small, isolated groups of crystals surrounded by the matrix. Attached to the bøgvadite crystals along their rims, ralstonite crystals protrude out into the kaolin. Isolated fan-shaped grains of jarlite, around 0.2 mm in length, have been observed here and there in the thin sections. Where such jarlite fans abut against crystals of bøgvadite one finds that the two minerals have refractive indices which cannot be distinguished from each other. Transecting the thin section occur bands or strings of spherulitic grains, 0.2 mm in diameter, of the mineral Bøgvad (1933) called "ivigtite". This is a widespread accessory in the fluorite-cryolite and has been found to be a K-mica (Bøgvad 1936). In this section, the strings of this K-mica constitute lines parallel to the longitudinal directions of the bøgvadite crystals. In hand specimen this direction is found to be the ray direction of the radiating aggregate. Concentrations of this K-mica form the bands seen in Fig. 1 where it recalls the annual rings found in cross sections of a tree trunk.

A 4.5 cm long thin section made to cover the apical as well as the distal part showed that the bøgvadite pavement stretched in the ray direction abutting on the part dominated by jarlite where the strings of the spherulitic K-mica clearly mark the radiating structure. In a 5 mm wide zone around the border between the two different parts, the rays appeared strongly deformed as if the material on both sides, in a plastic state, had moved in opposite directions. The deformation
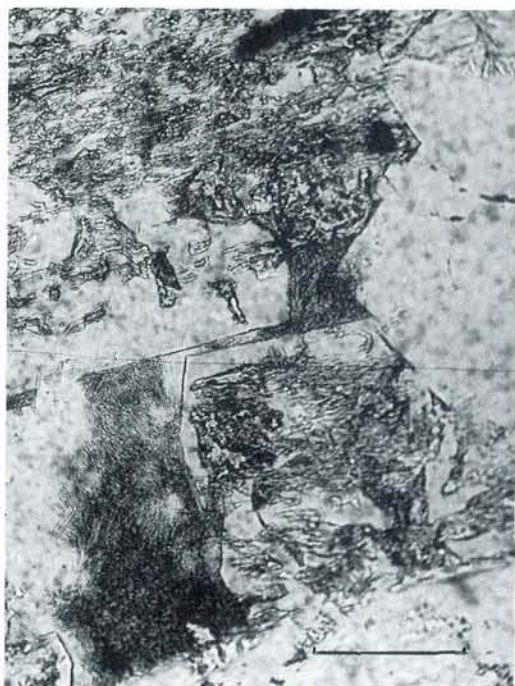
Fig. 5. Bøgvadite crystals with spherulitic thomsenolite (strongly pigmented) between them. In the middle: ralstonite, white, along the corner of the one bøgvadite crystal. Some of the inclusions in the crystals are barite. Transmitted, plane light; bar 100 μm.

mainly involved the rays with jarlite and K-mica. The part rich in bøgvadite was only slightly affected.

Two thin sections were made from the distal part of the sample shown in Fig. 1. The clear radiating structure seen here is composed of strings of the K-mica. Between these strings jarlite in fan-shaped grains orientated sub-parallel to the strings is the dominating mineral. Fluorite fills the interspace in some places. Quartz, in small grains and elongated aggregates of grains, follows the strings of the K-mica. In one part of one thin section crystals of bøgvadite lay between the strings. These crystals were rectangular having their longitudinal direction parallel to the strings. Microprobe analyses showed them to have the same composition as the bøgvadite crystals from the apical part of the sample. Ralstonite and kaolin are present in significant amounts in this part of the thin section.

In the other section from the distal part of the sample, bøgvadite was not observed but otherwise the same mineral assemblage was found.

Some cavities were found to contain crystals of ralstonite up to 0.5 mm across. Between crossed polars these crystals clearly exhibited the sectorial structure due to anomalous birefringence characteristic of this mineral. In this setting, areas thought to represent kaolin, n slightly above 1.56, showed well developed spherulitic structures but with much lower birefringence than those exhibited by the K-mica.

Pyrite, though sparse and in small grains, was found in all sections of the sample.

A block cut from the distal part of the sample, see Fig. 1, had a density of 2.9 g/cm^3. The estimated mineral composition would indicate 3.7. A porosity of about 20% is therefore likely for this part of the sample.

Looking for bøgvadite in other samples of the radiating aggregates proved rather difficult. It is possible to distinguish bøgvadite from jarlite in powdered chip-samples because jarlite has refractive indices like fluorite or lower, whereas bøgvadite has refractive indices coincident with and higher than fluorite. Generally, it must be admitted, thin sections are needed in order to demonstrate the presence of bøgvadite in these samples.

In thin sections from five different samples resembling the outer part of the sample shown in Fig. 1, bøgvadite was identified by its refractive indices being closely similar to those of jarlite (and fluorite) and more specifically by its crystal shapes and the strictly uniform arrangement of the crystals aligned parallel to the ray directions of the radiating aggregates. Moreover it occurred closely associated with ralstonite and kaolin.

Fig. 5 shows a group of bøgvadite crystals belonging to an area about 2 by 3 mm consisting essentially of such crystals lying closely together. Outside the area, fan-shaped jarlite grains lie in random orientations and strings of the spherulitic K-mica transect the section in the ray direction of the radiating aggregate. Similar areas were found in the thin sections of two other samples. The section from a third sample showed bøgvadite crystals in small groups lying between the strings of the spherulitic K-mica where randomly orientated fans of jarlite otherwise dominated.

In these samples, bøgvadite crystals were often found to border a mineral with lower refractive indices than those of bøgvadite. In some cases it was present as a well developed spherulitic aggre-

Fig. 6. Pseudomorphs after bøgvadite. Within the rectangular shapes of the original crystals the lightest grey patches correspond to barite. The light grey to white patches with concave borders are also barite. The darkest grey areas are ralstonite. Bøgvadite relics are slightly lighter than ralstonite. A quartz grain, somewhat darker than the barite areas, stands out in the middle of the picture because of its high polishing hardness. Vertical illumination, plane light; bar 100 μm.

gate showing a much lower birefringence than that of the K-mica. Powders of this substance were found to have refractive indices very close to 1.41 and resembling thomsenolite or pachnolite. As spherulitic thomsenolite has been found previously (Pauly & Petersen 1987), it is believed that it is this mineral which occurs here together with bøgvadite. The filling between the crystals seen in Fig. 5 is such a strongly pigmented mass of thomsenolite. Along the rim of one of the crystals, ralstonite was found between the thomsenolite and the bøgvadite. The refractive index of the ralstonite is lower than those of the thomsenolite.

The thin section from the fifth sample contained clearly recognizable bøgvadite crystals in patches of spherulitic thomsenolite. The dominating feature of the sample is aggregates of ralstonite crystals about 50 μm in diameter with intergranular masses of kaolin and scattered fanshaped jarlite grains. In their arrangement, these masses clearly follow the ray direction of the radiating aggregate and the curved jarlite grains to a certain degree follow the ray direction. In transmitted light in the ordinary microscope, one

notes strictly rectangular, pigmented features 100 to 200 μm long. Here and there they appear with shapes just like the bøgvadite crystals. Under vertical illumination in the ore microscope the rectangular bodies appear as seen in Fig. 6. They constitute a pavement structure just like the bøgvadite crystals in the thin sections from the apical part of the sample shown in Fig. 1. The reflectances indicated by the various grey tones in the picture are in agreement with the reflectance of ralstonite (the darkest grey), bøgvadite, quartz (the grain seen in the picture stands out because of the higher polishing hardness of quartz compared to the hardnesses of the other minerals present), kaolin and barite. The last two minerals are present as intergranular fillings. Kaolin shows the same reflectance as quartz. Barite is clearly lighter when viewed in the ore-microscope. In transmitted light, in the ordinary microscope, these patches of barite show aggregate polarization between crossed polars. Powder from such patches was found to have refractive indices close to 1.632 and X-ray examinations confirmed that it was barite.

The rectangular bodies are thought to be pseu-

domorphs after bøgvadite. From the reflectances of the various parts of these shapes, barite seems to make up the greater part of them whereas their darker parts seem to represent the remains of bøgvadite.

Returning to the crystals of the type shown in Fig. 5, it can be noted that they contain several types of inclusions. Some may be vacuoles, but most inclusions show a much higher refractive index than bøgvadite. Between crossed polars these irregular inclusions are found to extinguish simultaneously in all bøgvadite crystals viewed. Their extinguishing directions are parallel to those of bøgvadite and their fast directions are perpendicular to the fast directions of the bøgvadite crystals. The material of these inclusions is strongly pigmented. Powder scraped off from the counterpart of one of the thin sections was found to have n about 1.632 for which reason it is assumed to be barite. Barite may also occur as elongated groups of small, clear grains in bøgvadite, these groups having their fast directions parallel to the fast directions of the bøgvadite crystals.

Development of the bøgvadite paragenesis

Bøgvadite obviously nucleated and grew as essentially free crystals and was closely followed by the crystallization of ralstonite growing out from the already formed bøgvadite crystals.

Independent of the formation of these fluorides, the spherules of K-mica developed into long strings establishing the radiating appearance of these aggregates. The directions of the strings coincided with the longitudinal directions of the uniformly orientated bøgvadite crystals.

Small bundles of jarlite fans were formed here and there in the matrix.

The matrix consists of a loose mass of kaolin and small scales of barite and consolidated later than bøgvadite, but partly together with ralstomite because barite scales were found to transect the outer parts of the ralstonite.

The factor controlling the directional growth of bøgvadite and the spherulitic strings of K-mica affecting the jarlite only in the outer part of the sample has not been identified.

The very high concentration of Ba in bøgvadite is a most remarkable feature considering the solubilities of the simple compounds of the involved metals with ions of sulphate and fluor. It seems likely that bøgvadite can form only in an environment devoid of sulphate ions. The combination of jarlite and barite appears a reasonable one. The corroded appearance of the bøgvadite seen in some of the thin sections seems to reflect its instability in environments with appreciable concentrations of sulphate ions.

The interdependence between bøgvadite and barite observed in several thin sections by the common orientation of the extinction directions of the two minerals may be explained assuming barium to have been extracted from the bøgvadite and barite to have precipitated (crystallized) within the crystal. This would involve addition of sulphate ions after the formation of the bøgvadite. The presence of intergranular, extremely fine-grained barite indicates a rapid precipitation of $BaSO_4$; this also seems to indicate addition of sulphate ion-bearing fluids to the system at a late stage.

The jarlite bundles observed in the thin sections from the apical part of the sample shown in Fig. 1 are taken as indications for nearly contemporaneous crystallization of jarlite and bøgvadite and this also seems to be the case in other thin sections where the two minerals occur together though here one would take the idiomorphic development of bøgvadite and its strict orientation within the radiating aggregates to indicate formation before jarlite.

Further interpretation of the observed relations between the minerals present involves the nature of the radiating structure. As this is still under examination we refrain from further interpretations here.

Dansk sammendrag

I kryolitforekomsten i Ivigtut findes jarlit (Bøgvad 1933) blandt andet i strålede aggregater. Tyndsnit af den centrale del af et sådant aggregat viste en ganske påfaldende "brolægning" af 0,1–0,2 mm store, ens orienterede krystaller liggende i en meget finkornet matrix af et kaolinagtigt mineral, og mikrosondeanalyser viste, at baryt, som ca. 10 µm lange skællignende korn, fandtes spredt i det hvide, jordagtige materiale. Krystallerne udgjorde mere end halvdelen af tyndsnittenes arealer; de fandtes ofte overgroede af ralstonitkrystaller, jarlit som vifteformede kornaggregater sås her og der i matrix. Den finkornede, sfærulitiske K-glimmer, der tidligere kaldtes ivigtit, findes som strenge i stråleretningen og som tværgående bånd.

Sammensætningen bestemtes ved hjælp af elektron mikrosonden. Som standarder anvendtes kryolit (Na og Al), bøggildit (Sr) og baryt (Ba). EDAX analyser havde vist, at andre grundstoffer ikke var til stede eller kun fandtes i mængder under 0.1%. Atomabsorptionsanalyse på en prøve fra den central del af det strålede aggregat viste, at Li var under detektionsgrænsen. Som gennemsnit af 11 analyser fandtes Na 5.57%, Sr 7.03%, Ba 32.17% og Al 12.45%. F beregnedes til 42.85%, analysemetoden viste sig uegnet til en direkte, samtidig bestemmelse af F og metallerne. Indledende analyser viste, at F lå mellem 40% og 45%. Analysen svarer til formlen: $Na_{2,15}Sr_{0,71}Ba_{2,08}Al_{4,09}F_{20}$ eller idealt: $Na_2SrBa_2Al_4F_{20}$.

H_2O/OH kunne ikke bestemmes, da det ikke var muligt at etablere analysemateriale frit for ralstonit og kaolin. Beregninger af Gladstone-Dale konstanterne K_C og K_P viser, at der kan være et par procent OH svarende til $(OH)_{1,3}$ og $F_{18,7}$ i formlen.

Krystallerne er orthorombiske med flader fra {010}, {110} og {012}. De er farveløse, gennemsigtige og har H >3, VHN_{25} = 300 ± 50; d = 3.85 ± 0.02 g/cm^3, beregnet findes 3.898 g/cm^3. De er optisk toaksede, negative med $n_α$ = 1.4326, $n_β$ = 1.4360, $n_γ$ = 1.4389, alle ± 0.0002. $2V_α$ målt til 87° ± ½°, beregnet = 85° ± 6°. α = c, β = a og γ = b. Røntgenundersøgelserne viste a = 7.110 ± 0.003, b = 19.907 ± 0.010 og c = 5.347 ± 0.003Å. Rumgruppen Pnmn eller Pn2n.

Det forekommer naturligt at opkalde mineralet efter Richard Bøgvad og give det navnet bøgvadit, fordi han gennem sit mangeårige virke for Kryolitselskabet Øresund A/S som sel-

skabets chefgeolog, har ydet en stor indsats for arbejdet med kryolitforekomsten.

Bøgvadit er også fundet i andre tyndsnit af de strålede aggregater, hvor det forekommer som små grupper af ens orienterede krystaller, men kun i mindre mængder. I disse prøver er jarlit det dominerende mineral og forekommer som vifteformede eller delvis sfærulitiske korn. Baryt er altid til stede i disse prøver, undertiden som rækker af 50 µm store krystaller, men også som meget finkornet, jordagtigt, hvidt materiale identificeret ved røntgenpulverdiagram.

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