AN EXAMINATION OF SOME RARE MINERALS FROM THE NEPHELINE SYENITES OF SOUTH WEST GREENLAND

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WITH 3 FIGURES IN THE TEXT
AND 2 PLATES

CONTENTS

Abstract.

In the present paper the mineralogy and petrological importance of some minerals from the nepheline syenites of South Greenland are discussed. The first-named mineral, igalikite, is from the Igaliko batholith, the remainder are from the Ilímaussaq batholith (see USSING, 33).

Igalikite was described by BØGGILD from a boulder collected near Igaliko. On re-examination of this mineral it was shown to be a pseudomorph of analcime and "gieseckite" after nepheline.

Naujakasite was described by BØGGILD from a boulder collected at Naujakasik. The mineral has now been found in lujavrite at Tuperssuatsiaq and in the northern part of the Ilímaussaq batholith.

Monazite in small clusters of angular grains are quite common in the lujavrites. The erikite described by BØGGILD is shown to be a mixture of monazite and analcime and/or natrolite.

Britholite has been found as small crystals in a number of altered lujavrites.

Monazite and britholite are both considered to be formed at the expense of the material set free during the alteration of the eudialyte of the nepheline syenites.

Neptunite in macroscopic grains is rare, but the mineral is commonly seen in thin sections, especially in rocks with altered eudialyte. The neptunite was probably formed during hydrothermal alteration of the eudialyte.

A white mineral has been found at Igdlúnguaq associated with neptunite, epistolite and analcime. The mineral has a primitive cubic unit cell and is probably a Na- and Nb-rich perovskite mineral. A more detailed description of this possibly new mineral will be undertaken when a chemical analysis has been carried out.

Ussingite was described by BØGGILD from boulders. It has now been found in place at the head of Kangerdluarssuk where it occurs in a recrystallized zone of deformation in naujaite. It is associated with steenstrupine, lovozerite (?), and ægirine and is secondary after microcline and sodalite.

Lovozerite(?) a mineral resembling the lovozerite of the Kola peninsula has been found associated with the ussingite of Kangerdluarssuk and also with eudialyte in lujavrite. It is interpreted as a secondary mineral after eudialyte.

Epistolite is according to a preliminary examination a member of an isomorphous series of which the murmanite of the Kola peninsula is another member.

INTRODUCTION

In the summers of 1955 and 1957 one of the writers (H. S.) visited the Ilímaussaq batholith in the Julianehaab District, South West Greenland. In the course of the petrographic examination of the collected rocks it was found necessary to study some of the minerals more closely. In connection with this work material from the collections of the Mineralogical Museum of the University of Copenhagen was also examined.

All minerals but one described in this paper are from the Ilímaussaq batholith. The exception is "igalikite" from the Igaliko batholith situated a few kilometres to the east of Ilímaussaq.

The Ilímaussaq and Igaliko batholiths have been described by N. V. Ussing (33). The minerals have been described in a number of papers, first of all by Ussing, O. B. Bøggild and G. Flink.

In the present study the X-ray work has been carried out by M. Danø. The powder technique has been used with FeKα-radiation and camera diameters of 9 cm. The optical work and the petrological discussions are presented by H. Sørensen.

Professor H. Strunz, Berlin, Dr. H. Pauly and Mr. J. Bondam have supplied the writers with mineral samples, and from Mrs. Borghild Nilssen and Dr. H. Neumann the writers obtained X-ray powder diagrams of minerals and synthetic compounds examined in the Mineralogical Museum of the University of Oslo. These valuable contributions are gratefully acknowledged.

Thanks are due to Mr. H. Micheelsen for determining the refractive indices of some of the minerals, to Miss Me Mouritzen and to Mr. K. Ellitsgaard-Rasmussen for chemical and spectrochemical examinations, to Mr. V. Buchwald for autoradiographic examinations, to Mr. Chr. Halkier for the microphotographs and to Dr. E. Hamilton for reading the manuscript.

<div align="right">Copenhagen in April 1958.</div>
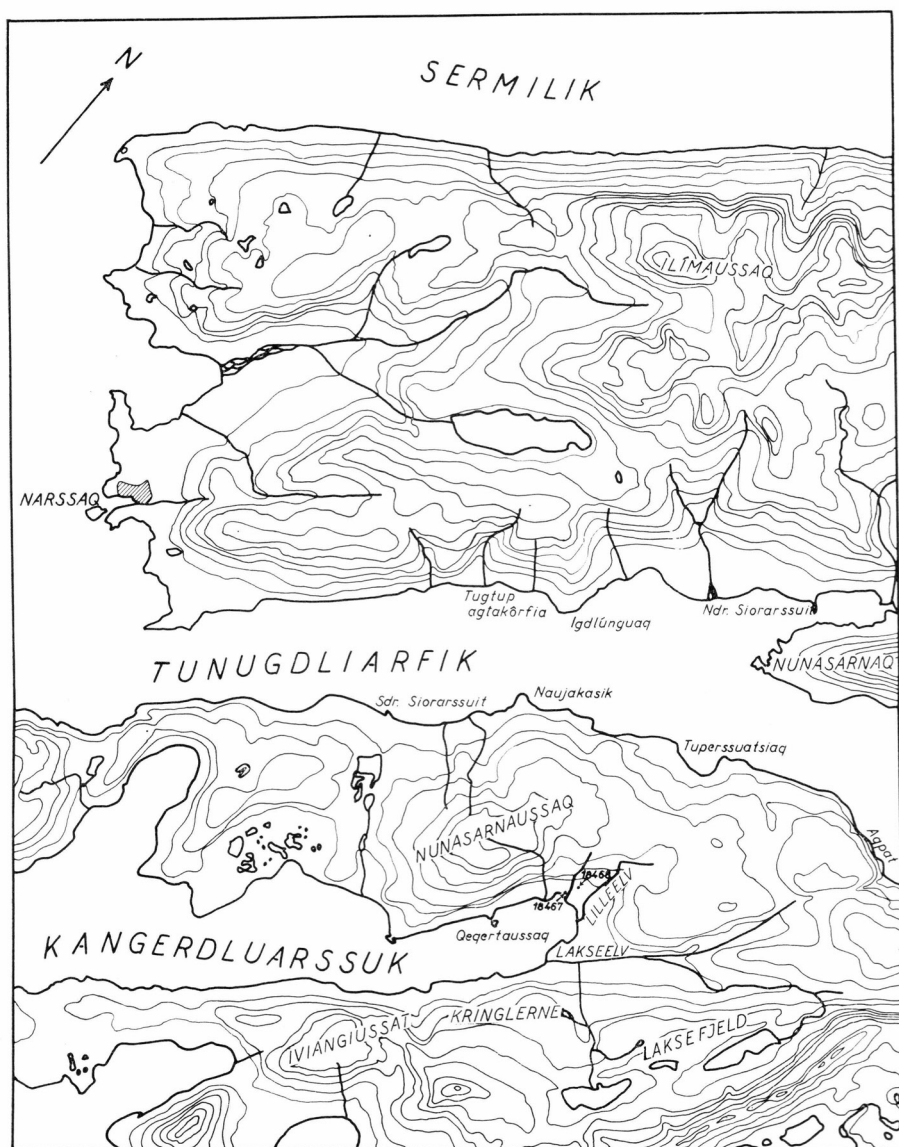
Fig. 1. Map showing the localities mentioned in the text (scale: ca. 1:143.000, equidistances 100 m). The map has been reproduced from SØRENSEN (Medd. om Grønland, bd. 162, 3), in which paper the scale of the map, unfortunately, has been incorrectly stated as ca. 1:160.000. Geological maps of the Ilímaussaq region have been published by USSING (33) and in the above-mentioned paper.

Igalikite.

In 1933 O. B. Bøggild (*9*) published the results of an examination of a boulder which had been collected by H. Ødum in 1926 at a point situated about 35 km to the east of the village of Igaliko in the Julianehaab District. The boulder was found in an area of coarse-grained nepheline syenites.

The greater part of the boulder consisted of a compact mass that was named igalikite by Bøggild. The compact mass was surrounded by an almost continuous layer of barkevikite, green augite, feldspar, biotite, magnetite, apatite and olivine in a matrix of igalikite. There were very few inclusions in the central parts of the mass of igalikite.

Bøggild found by means of goniometer measurements on the aphanitic mass, reflections from different faces arranged as a hexagonal prism and a basal pinacoid. Under the microscope, the aphanitic mass was seen to be made up of aggregates of very thin micaceous plates, often arranged parallel to the hexagonal prism. The plates were curved or branched in a feathery manner.

According to a chemical analysis undertaken by Chr. Dethlefsen the chemical composition of the igalikite is not very different from that of muscovite (see p. 10)

A routine examination of igalikite was carried out in the spring of 1953 by one of the writers (H.S.). The result suggested that igalikite was an alteration product of nepheline. This was confirmed by a more thorough examination in the spring of 1956.

An X-ray powder diagram of the aphanitic mass showed reflections corresponding to a mixture of analcime and "gieseckite".

The values of $\sin^2\theta$ of the reflections from igalikite, analcime and "gieseckite" are given in table 1, θ being the diffraction angle. As will be seen nearly all the lines on the X-ray diagram of igalikite are accounted for by assuming this "mineral" to be a mixture of the minerals analcime and "gieseckite".

There were a few lines on the igalikite film, which could not be found on the analcime or the "gieseckite" film, but they all had the description v v w or v w, except one with the intensity w. They were mostly

Table 1. Comparison of the values of $\sin^2 \theta$ for the minerals Igalikite, Analcime and "Gieseckite".

FeK_α — radiation, camera diameter 9 cm.

Igalikite[1]		Analcime[2]		"Gieseckite"[3]	
Intensity*)	$\sin^2 \theta$	Intensity*)	$\sin^2 \theta$	Intensity*)	$\sin^2 \theta$
w-m	.0091			w-m	.0096
s	.0305	s	.0298		
w	.0388			w	.0376
w	.0410	w	.0399		
m	.0479			m	.0470
w	.0510			v w	.0502
w	.0564			v w	.0556
m	.0724			s	.0715
v s	.0815	s	.0797		
w	.0862			s	.0849
v v w	.0951			v v w	.0931
w-m	.1028			s	.1007
s	.1117	m-s	.1099	v w	.1117
v w	.1173				
v w	.1220	v w	.1206		
m	.1324	w-m	.1313	w	.1324
s	.1459			s	.1427
w	.1522	m-w	.1510		
w	.1603	w	.1607	v v w	.1587
v w	.1681			w	.1668
v v w	.1719				
w-m	.1934	w	.1916		
w	.2057			w	.2053
v w	.2194				
m	.2362			m	.2357
w	.2501	v v w	.2520	v v w	.2481
w-m	.2636	m-w	.2621	v v w	.2636
w	.2740	w	.2715		
v v w	.2839			v v w	.2829
v v w	.2910				
m	.3130	m	.3109		
w	.3233	w	.3217	v v w	.3217
w	.3338	w	.3311		
w	.3427	v w	.3432	w	.3389
w (diff)	.3575	v w	.3612	w	.3554
w	.3725	w	.3720	v v w	.3736
v v w	.3833			v v w	.3833
v v w	.4034			v v w	.3996
s	.4242	v w	.4209	m-s	.4182
v w	.4330	w	.4308		
v v w	.4434	{ v v w	.4402		
		v v w	.4495		
v v w	.4578				

(continued)

Table 1 cont.

Igalikite[1]		Analcime[2]		"Gieseckite"[3]	
Intensity*)	$\sin^2 \theta$	intensity*)	$\sin^2 \theta$	intensity*)	$\sin^2 \theta$
w-m	.4745	m	.4706		
v w	.4934	v v w	.4901		
w	.5028	v v	.5001	w	.5012
w-m	.5144	m	.5106		
w (diff)	.5262			w	.5245
w	.5533	v w	.5505		
w	.5649			w	.5583
w	.5726	w	.5698		
w	.5934	w	.5901		
w	.6087			w	.6038
m	.6324	m	.6303	w (diff)	.6308
w-m	.6726	w	.6684		
v v w	.6830				
w	.6928				
v w (diff)	.7111			v w	.7101
v v w	.7389				
w	.7500	w	.7491		
v w	.7756				
v v w	.7884				
v v w	.8103				
v v w	.8193	v v w	.8171		
w	.8316	v v w	.8295		
v w	.8510				
w-m	.8983	m	.8966		
v w	.9176				
w-m	.9310	m	.9280		

[1]) Igalikite from *Ødums* "punkt 5"
[2]) Analcime from Igdlúnguaq, the Julianehaab District.
[3]) Gieseckite from Akuliaruseq.

*) The intensities are estimated visually. vs = very strong, s = strong, m = medium, w = weak, vw = very weak and vvw = very, very weak, diff = diffuse.

situated within the range of $\sin^2 \theta$, where the background of the "gieseck-ite" film was very high, because of the strong diffuse scattering from this mineral. Furthermore, all stronger reflections of the analcime and "gieseckite" patterns were found on the igalikite film. The few missing ones all had the description v v w except for two cases which had the description vw

A re-examination of thin sections of igalikite confirmed Bøggild's observations. A few supplementary notes may however be added.

The igalikite is either colourless or faintly brown. In the latter case it shows faint pleochroism from colourless to brown. The micaceous flakes are length-slow.

The intergrowth of the mica and the analcime is very intimate and in most cases the analcime is so crowded with tiny flakes of mica that only the mica is visible in thin section. The cubic cleavage of the analcime may however still be seen.

The igalikite is often streaked with an alternation of dark and light parallel streaks. The dark colour appears to be caused by an increase in pigmentation. The elongation of the flakes of mica may be parallel to the streaks.

Two pyroxenes have been found as inclusions in the igalikite, one of a diopsidic and the other of an ægirine-augitic variety. In some cases the grains of pyroxene are surrounded by rims of brown biotite. This biotite together with a green chlorite and iron ore is also found around grains resembling olivine.

The plates of feldspar in the igalikite are to a varying extent altered to a mica resembling that of the igalikite.

In powdered igalikite nepheline has been observed.

In conclusion: igalikite is a mixture of analcime and mica ("gieseckite") and is most probably (just as "gieseckite" according to Ussing (*32*)) a psedomorph after nepheline.

Ussing (*33*, pp. 227—280) described the various rock types of the Igaliko batholite. Nepheline in a state of alteration corresponding to that of the "igalikite" has been described from many rocks, namely nepheline porphyries (dykes), nepheline syenite and augite syenite. Is is therefore difficult to determine the exact site of origin of the boulder of "igalikite".

"Gieseckite": The igalikite greatly resembles gieseckite. In the hand specimen the two pseudomorphs may be distinguished from one another by means of the greasy look of the gieseckite. In thin section the two psedomorphs are almost identical, both being faintly brown in colour and composed of numerous tiny flakes of mica.

Ussing (*32*, pp. 121—126) described the gieseckite from dykes of nepheline syenite porphyry from Akuliaruseq in the neighbourhood of

Table 2. The chemical analyses of gieseckite and igalikite.

	gieseckite anal. Stromeyer (1819) (Ussing, *32*)	gieseckite anal. Pfaff (1825) (Ussing, *32*)	igalikite anal. Dethlefsen (Bøggild, *9*)
SiO_2	46.0798	48	45.85
Al_2O_3	33.8280	23.5	32.60
Fe_2O_3	3.3587	4	0.92
CaO	..	..	1.41
MgO	1.2031	1.5	0.15
Mn_2O_3	1.1556	..	..
K_2O	6.2007	6.5	6.29
Na_2O	..	..	5.92
H_2O	4.8860	5.5	6.80
	96.7119	98	99.94

Igaliko. Goniometer measurements of these pseudomorphs gave reflections from the hexagonal prism and a basal pinacoid of the original crystals of nepheline of which the gieseckite is an alteration product. In thin section the replacement is seen to proceed from fractures in the nepheline and may be more or less complete. There are inclusions of green and brown mica, feldspar, magnetite and apatite. Analcime is also present.

In the literature gieseckite is refered to as a variety of muscovite (cf. WINCHELL, *34*, p. 256 and STRUNZ, *30*, p. 375). The X-ray pattern of gieseckite, however, resembles the patterns of certain Li-micas more than that of muscovite, but according to a spectrochemical test the lithium content is only about 50 ppm.

We have compared our X-ray data with those given by HEINRICH, LEVINSON, LEVANDOWSKI, and HEWITT (*24*). and by NEUMANN, SVERDRUP and SÆBØ (X-ray powder patterns for mineral identification, III. silicates. Norske Vid. Ak. Oslo, I. Mat. naturv. Kl. 1957, no. 6). The best agreement was found with the muscovite 1 M (= lepidolite 1 M) published as no. 118 in the last-named publication.

Naujakasite.

Naujakasite was first described by BØGGILD (*9*) in 1933 from a specimen collected by FLINK in 1897 at Naujakasik where—according to BØGGILD—it was probably not found in situ. Half of the specimen in question consisted of naujakasite. Associated with the naujakasite were sodalite and arfvedsonite, the latter partly as granular masses between the flakes of naujakasite, partly enclosed in that mineral.

In the summer of 1955 a locality of arfvedsonite lujavrite rich in naujakasite was found in the eastern part of the bay of Tuperssuatsiaq. The lujavrite forms a layer, 5 m thick, in naujaite. The outer part of the layer is schistose. The naujakasite is quite conspicuous in the hand-specimens, being scattered all over the rocks as small shining flakes, often more than 0.2 cm across and often of rhomboid shape.

Under the microscope the lujavrite is seen to be composed of lath-shaped grains of albite and microcline, prismatic grains of arfvedsonite and occasionally of ægirine. The prisms of arfvedsonite are subparallel. Analcime and natrolite are secondary minerals. There are a few small yellow and isotropic grains of steenstrupine.

The flakes of naujakasite are larger than the average grain-size of the rock. They have inclusions of arfvedsonite and have a coating of a brownish-green alteration product. The colour of this alteration product is most intense around the inclusions of arfvedsonite. The naujakasite has lines of dark pigmentation and these lines are still present where the mineral has been totally altered.

In 1956 J. BONDAM found naujakasite to be quite common around Tuperssuatsiaq and the mineral was also found in the northern part of the Ilímaussaq batholith.

The distribution of naujakasite in the rocks is similar to that of the nepheline and it may therefore be an alteration product of that mineral. It should however be noted that an alteration product of ænigmatite resembling naujakasite has been found in one case.

Monazite and Erikite.

In the spring of 1956 Dr. HANS PAULY sent to the Mineralogical Museum for determination a small amount of tiny grains of a heavy, light-coloured mineral found in an arfvedsonite lujavrite from the Kangerdluarssuk Region.

By means of optical and X-ray determinations the mineral was determined to be monazite. See p. 13 for the results of the X-ray examination.

> The monazite-bearing lujavrite was examined in thin section. It is made up of laths of microcline and albite, cloudy nepheline and small needles of arfvedsonite. As secondary minerals interstitial analcime, acmite (in the sense of USSING, *32* p. 198) and a brown biotite are present. There are a very few small grains of steenstrupine.
>
> The monazite is present as scattered small clusters of tiny grains in a matrix of analcime. The individual grains may be of rhomboid cross-section or of an irregular, elongated habit (plate 1, fig. 1). The small grains of each individual cluster generally have different optical orientations, but in some cases adjacent and corroded grains are of the same optical orientation.
>
> The monazite is optically positive with a small axial angle, the refractive indices are higher than 1.74 and the interference colours are generally of the second order.
>
> Associated with the monazite are small prisms of schizolite, a brown mica and a brownish-black pigmentation.

The distribution in the rock of small clusters of monazite in a matrix of analcime might be regarded as a kind of pseudomorphs after one of the primary minerals of the lujavrite. The rock is as mentioned above in an altered state with analcime being formed at the expense of the light-coloured minerals and acmite at the expense of the arfvedsonite.

Similar small clusters have been observed in sections of arfvedsonite lujavrite from Igdlúnguaq on the north coast of the Tunugdliarfik Fjord, for instance in the rocks with the peculiar orbicular structure described by USSING (*33*, p. 82). These rocks have spheroids 2—20 cm

in diameter with the arfvedsonite replaced by acmite and the light-coloured minerals partially converted into analcime.

The normal lujavrite from this locality (no. 318 b) has in a matrix of anal-cime: arfvedsonite (partly altered to acmite), nepheline, microcline, albite, eudia-lyte (in scattered, highly altered grains), monazite in small clusters, britholite, and natrolite. There are a few small areas of pigmentation showing the outlines of eudia-lyte. In the altered eudialyte small plates of katapleite are found together with small grains of monazite. There are also small grains of a low birefringence and uniaxial negative which may be eucolite. The britholite is in places found in the clusters of monazite.

The altered lujavrite (no. 318 a) has the arfvedsonite almost completely replaced by acmite, and the eudialyte is almost entirely replaced by katapleite and analcime and it has areas of eucolite. There is a good deal of monazite in this rock, in part associated with the katapleite. The clusters of monazite may contain a few small grains of high refractive indices and low birefringence (see p. 18).

Small clusters of monazite grains of the same sort as the ones described above have been observed in thin sections of lujavrites from several parts of the Ilímaussaq Region. It is possible that the "zircon in minute grains crowded in small lumps which have probably originated by magmatic resorption of eudialyte" (USSING, 33, p. 173) may be monazite, since it is difficult to distinguish between these two minerals in thin section.

The mode of occurence of the monazite recalled that of the mineral **erikite** described by BØGGILD (5) in 1904 from Nunarssuatsiaq where it was found in pegmatitic veins in arfvedsonite lujavrite.

The yellow erikite is present as "pseudomorphs" of orthorhombic symmetry. In thin section it is seen to be heterogeneous and it is composed of interlacing strings of tiny grains in a matrix of hydronephe-lite. The small grains greatly resemble monazite, as already stated by USSING (33, p. 172), and they also occur in small clusters as those des-cribed above. GORDON (19, p. 10) described erikite as a mixture of monazite and hydronephelite.

A number of X-ray powder diagrams were taken of erikite from Nunarssuatsiaq and elsewhere and the powder diagrams of erikite taken in the Geological Museum in Oslo were kindly placed at our disposal by Dr. H. NEUMANN.

It was in every case found that the erikite pattern was identical with that of monazite.

In the table 3 the values of $\sin^2 \theta$ are given as measured from X-ray powder diagrams of monazite from Berg in Råde, Norway and erikite. The approximate intensities are indicated for each reflection. The two last columns give the corresponding values from a film of the monazite from arfvedsonite lujavrite of the Kangerdluarssuk Region (see p. 12). It will be seen from the table that the agreement is very good. Only

Table 3. Comparison of the values of $\sin^2 \theta$ for the minerals Erikite and Monazite.

FeK_α — radiation, camera diameter 9 cm.

Erikite[1]		Monazite [2]		Monazite[3]	
Intensity*	$\sin^2 \theta$	Intensity*	$\sin^2 \theta$	Intensity*	$\sin^2 \theta$
w	.0331	m (diff)	.0325	v v w	.0304
m	.0435	m (diff)	.0429	v v w	.0417
w (sharp)**	.0496				
m	.0545	m (diff)	.0553	v v w	.0566
w	.0765	w	.0776	w	.0776
m-s	.0871	m	.0884	m-s	.0871
s	.0988	s	.0997	s	.0991
v v w	.1069	v v w	.1072	v w	.1072
s	.1148	s	.1159	w	.1148
w	.1388	w	.1412	v v w	.1408
w-m	.1591	w	.1599	{ v v w / v v w	.1574 / .1623
w	.1964	w-m	.1982	w	.1964
m (double)	.2057	{ w-m / w-m	.2076 / .2111	m-s	.2062
m	.2448	m	.2467	w-m	.2433
v w	.2510			v w	.2496
v w	.2621			v w	.2612
s (double)	.2690	s (double)	.2710	{ m / v v w	.2695 / .2784
v w	.2925	v w	.2915	v v w	.2905
w	.3016	v w	.3067	w-m	.3067
m	.3119	s	.3135	w-m	.3135
w	.3274	w	.3322	w-m	.3280
v w	.3453			v w	.3443
v w	.3527	v v w	.3506	v v w	.3559
v w	.3677	v v w	.3666	v w	.3665
w	.3817	v v w	.3806	v v w	.3801
m (diff)	.3973	w	.4007	{ v v w / v w	.3920 / .4018
m (diff)	.4380	w	.4418	w (diff)	.4346
v v w	.4900				
v v w	.4990 }	w	.5050	{ w / v v w	.4984 / .5112
v v w	.5101 }				
s (broad)	.5262	s (double)	.5245	{ w-m / m	.5195 / .5317
				v v w	.5434
w	.5528			v v w	.5511
s (sharp)	.5726	m	.5776	w-m	.5726
v v w	.5814				
v v w	.6011			v w	.6026
s	.6157	s (broad)	.6211	m	.6141
v v w	.6388			v v w	.6484

(continued)

Table 3 cont.

Erikite[1]		Monazite[2]		Monazite[3]	
Intensity*)	$\sin^2 \theta$	Intensity*)	$\sin^2 \theta$	Intensity*)	$\sin^2 \theta$
w-m	.6621	w	.6679	w-m	.6616
m	.6867	w	.6908	w-m	.6835
v v w	.6984			w	.6984
v v w	.7091	w	.7096	w-m	.7086
				v v w	.7236
v v w	.7413	m	.7471	m-s	.7433
v v w	.7510				
***)		m	.7820	s	.7712
				m-s	.7902
		w	.8081(?)	m (diff)	.8146
		m	.8325	m (diff)	.8274
m	.8573	m	.8589	s	.8534
m	.8736			m-s	.8733
m	.8869			m-s	.8866
				m	.9043
w-m	.9142			m	.9148
				s	.9299
				m	.9505

[1]) Erikite from Nunarssuatsiaq.

[2]) Monazite from Berg i Råde, Moss, Norway.

[3]) Monazite from arfvedsonite lujavrite of the Kangerdluarssuk Region.

*) The intensity is visually estimated. s = strong, m = medium, w = weak, vw = very weak etc.

**) As this line has quite another character than the rest of the lines, it is probably caused by some impurity not characteristic of the mineral.

***) As the film is very heavily blackened from the diffuse scattering, it is impossible to distinguish any diffraction lines with values of $\sin^2 \theta$ between 0.7510 and 0.8573.

smaller discrepances may be found in the position of lines, not more than should be expected when measuring the rather diffuse lines given by the first two minerals.

The reflections on the X-ray pattern of the monazite from Kangerdluarssuk are much sharper than those which we found when examining the patterns of monazite from other occurences. Thus this monazite is better crystallized than most other monazites[1]). The presence of a few extra lines in the pattern of the monazite from Kangerdluarssuk may be explained in this way.

The intensity distribution among the reflections are, however, not quite the same for the three examined minerals. This fact may easily be accounted for by differences in the chemical composition of the minerals. (Cf. for instance BOWIE and HORNE, 3).

[1]) A thin section of the monazite-bearing lujavrite from Kangerdluarssuk has been examined by Mr. V. BUCHWALD by means of nuclear research film. The radioactivity of the monazite was found to be insignificant.

The monazite is, as discussed on p. 19, most probably formed at the expense of eudialyte.

It may be mentioned in this connection that BØGGILD (5, p. 93) has measured interfacial angles on the "orthorhombic erikite" and from these values calculated the axial ratio a: b: c equal to 0.5755: 1: 0.7580. As a rhombohedral lattice can be indexed on an orthorhombic lattice it was natural to examine the possibility of the "erikite" crystals being pseudomorphs after the rhombohedral eudialyte.

Eudialyte has the lattice constants a = 13.01 Å and α = 66°44′ (GOSSNER and MUSSGNUG, 22, p. 81). The corresponding hexagonal lattice has a = 14.31 Å and c = 30.15 Å, and this again corresponds to an orthorhombic lattice with a = 14.31 Å, b = 24.75 Å, c = 30.15 Å or a = 14.31 Å, b = 30.15 Å, c = 24.75 Å thus making the b-axis the longest axis. This last combination of axes gives a: b: c equal to 0.4776: 1: 0.8209. The orthorhombic reciprocal lattice can now be constructed. The three planes hko, okl and, hol are plotted and the first four inter-facial angles measured by BØGGILD (see the table below) are used in a trial and error process. Agreement was obtained when the following transformations were made

$$a_E^* = a_B^* \quad \text{or} \quad a_E = a_B$$
$$c_E^* = b_B^* \quad \text{or} \quad c_E = b_B$$
$$b_E^* = {}^2/_3\, c_B^* \quad \text{or} \quad b_E = b\,{}^3/_2\, c_B$$

where the subscripts E and B refer to the lattice derived from eudialyte and the lattice determined by BØGGILD respectively. The reciprocal values are starred.

By using the transformation rules given above all BØGGILD's indices were transformed into indices based on the orthorhombic lattice corresponding to eudialyte and the interfacial angles were calculated using a = 14.31 Å, b = 30.15 Å and c = 24.75 Å. In table 4 the results are given.

The agreement is as good as could be expected from measurement of interfacial angles on pseudomorphs. BØGGILD also reports that the faces generally were not well developed. Repeated measurements had deviations ranging from $^1/_2$—1° on measurements on the best faces, up to 3° on poorly developed faces. Besides, DONNAY and NOWACKI (11) report that the dimensions of the unit cell of eudialyte are probably too large. GOSSNER and MUSSGNUG (see above) measured the a and c-axis of the hexagonal lattice of eudialyte on a single crystal rotation photograph. As the c-axis is very large this value is the one most likely to be in error. In our attempt to determine the relations between BØG-GILD's reciprocal lattice and that of eudialyte we used the hexagonal c-axis as the orthorhombic b-axis, therefore we must expect angles

Table 4. Comparison of interfacial angles of erikite (measured) and eudialyte (calculated).

Axes based on Bøggild's measurements		Axes based on eudialyte	
Indices	Average angle measured	Indices	angle calculated
(010) : (110)	60° 7.5′	(001) : (101)	59° 58′
(010) : (130)	31° 28′	(001) : (103)	29° 58′
(010) : (012)	69° 17′	(001) : (031)	67° 54′
(010) : (021)	33° 35′	(001) : (034)	31° 35′
(010) : (120)	40° 59′	(001) : (102)	40° 51′
(010) : (270)	25° 31′	(001) : (207)	26° 18′
(010) : (011)	52° 39′	(001) : (032)	50° 55′
(010) : (032)	41° 20′	(001) : (011)	39° 24′
(010) : (052)	27° 21′	(001) : (035)	26° 12′
(010) : (031)	23° 46′	(001) : (012)	22° 27′
(010) : (111)	65° 38′	(001) : (232)	64° 47′
(001) : (101)	53° 7′	(010) : (230)	54° 34′
(001) : (201)	69° 9.5′	(010) : (430)	70° 25′
(001) : (114)	20° 39′	(010) : (161)	22° 05′
(001) : (111)	56° 49′	(010) : (232)	58° 22′
(100) : (111)	43° 43′	(100) : (232)	42° 29′

between faces with $k \neq 0$ to be most in error. This is actually the case, except for the interfacial angle (010) : (130), where the calculated and measured angles differ more than $1 \, ^1/_2°$. In his paper, Bøggild especially mentions the face (130) as a poorly developed one giving inaccurate measurements.

Monazite has formerly been found in Greenland in the Upernavik District (Bøggild, *10*, p. 75) and in the Sukkertoppen District (Sørensen, *31*, p. 233).

Gerassimovsky (*15*) reported the finding of erikite in the Lovozero Tundra in schlieren of sodalite syenite. It is associated with sodalite, ussingite, eudialyte, schizolite, murmanite, steenstrupine, neptunite, natrolite and sphalerite. It is considered to be a pseudomorph after some unknown mineral, or a primary mineral altered by later processes. The scarce material was insufficient for a final determination of the nature of the mineral.

Since the refraction of the mineral from the Kola Peninsula is lower than that of monazite (Ng = about 1.730 and Np about 1.700) it is apparantly not identical with the erikite from Greenland.

2

Britholite.

In the summer of 1955 britholite was only found once in macroscopic crystals, namely in a small boulder of arfvedsonite lujavrite at the head of the Kangerdluarssuk Fjord. The arfvedsonite lujavrite is much transformed, of a light colour and with star-like groups of ægirine needles.

The britholite crystals are up to 0.3 cm long. They are prismatic and of a brownish red colour. They occur in a light-coloured, pegmatitic portion of the lujavrite associated with large plates of microcline, large crystals of arfvedsonite, ægirine and analcime.

The powder diagram of this britholite was identical with that of the original britholite described by Chr. Winther (35).

Small crystals of britholite have been noted in thin sections of lujavrites from various places of the Ilímaussaq region.

Britholite is quite common in sections of the much altered vein of lujavrite in the naujait at Lilleelv, Kangerdluarssuk (cf. p. 25).

The britholite occurs as small hexagonal, prismatic crystals in the analcime groundmass of this lujavrite (plate 1, fig. 2). Further components of the rock are: microcline, acicular arfvedsonite and ægirine, corroded grains of nepheline, steenstrupine, schizolite, sphalerite, and neptunite.

The britholite is uniaxial negative with high refraction and low birefringence. The interference colour is grey of the first order. The mineral is almost colourless and does not show pleochroism.

Britholite has also been found in altered lujavrite from Igdlúnguaq associated with monazite, katapleite etc. in grains of altered eudialyte (see p. 13).

The lovozerite-bearing ægirine lujavrite from Lilleelv (see p. 29) also contains britholite.

A mineral resembling britholite was found in several rocks, but always in so small grains that it so far has been impossible to separate it for a more detailed examination.

This mineral is in thin section of a faint brown colour, it is not pleochroic. It is found in prismatic crystals which may show hexagonal cross sections. There are traces of prismatic cleavage.

The mineral is uniaxial, or biaxial with a small axial angle, it is optically negative. The refraction is high (of the same order as that of britholite), its birefringence very low, dark grey of the first order with an abnormal bluish tinge.

The britholite-like mineral has been found: In association with monazite in Naujakasik, with monazite in Igdlúnguaq (see p. 13), with ussingite, lovozerite? and steenstrupine at Lilleelv (see p. 29), and with rinkite, neptunite, apatite etc. at Qeqertaussaq (see p. 20 and plate 1, fig. 4).

The Origin of the Monazite and the Britholite.

Monazite and britholite are both phosphates of rare earths and they may occur together as in Igdlúnguaq (p. 13).

The only common primary mineral of the nepheline syenites of the Ilímaussaq region that contains rare earths in conspicuous amounts is the eudialyte. Other minerals containing rare earths are rinkite, steenstrupine, britholite, and monazite, but these minerals are most often found in the altered nepheline syenites and in the veins in the syenites, and they are therefore secondary in most cases.

An inspection of the analyses of the rocks of the Ilímaussaq Region given by Ussing (*33*, pp. 369—72) shows that all the nepheline syenites are free of P_2O_5, while the augite syenite, the nordmarkite, the essexite and the porphyries may contain as much as 1.57 $^0/_0$ P_2O_5.

Phosphates are rare constituents of the syenites. The writer has only found apatite in the rinkite-eudialyte pegmatite of Qeqertaussaq and in a couple of boulders.

Dahllite has however been observed in a number of cases as agate-like crusts on the nepheline syenites. The crusts are built up of alternating layers of dahllite and natrolite. This apatite mineral is clearly of secondary origin (Bøggild, *8*, p. 180).

It should also be mentioned that the steenstrupine may be fairly rich in P_2O_5 (up to 8.19 $^0/_0$).

The monazite (and in part the britholite) are in the above-mentioned rocks from Igdlúnguaq associated with aggregates of katapleite, a mineral that is definitely secondary after eudialyte.

It seems then most reasonable to assume that the monazite and the britholite are formed from the rare earths set free during the decomposition of the eudialyte.

The P_2O_5 of these minerals may either be introduced during the alteration of the rocks that accompany the formation of the veins in the syenites, or it may perhaps be a question of redistribution and concentration of the insignificant amount of P_2O_5 present in the nepheline syenites.

Neptunite.

During the present examination neptunite has been found to be of wide spread occurrence in the Ilímaussaq area. It is present as macroscopic grains only in a few localities, but is very commonly seen in thin sections of the rocks of the region.

Neptunite in macroscopic grains.

In the naujaite of the small island of Qeqertaussaq in the Kangerdluarssuk fjord there is a pegmatite rich in eudialyte (fig. 2). The pegmatite is almost horizontal being parallel to the pronounced parting of the naujaite (Ussing, 33, p. 35). Its upper part is composed of a rock made up of fine needles of ægirine. The eudialyte below this rock is cut by thin fractures parallel to the zone of ægirine. These thin fractures may contain small grains of neptunite. Some of the fractures are filled with acicular ægirine and they may then be connected with the larger zone of ægirine mentioned above.

The neptunite in the fractures is present as small prismatic grains of a rather irregular shape. They are associated with ægirine, schizolite, dark pigmentation and monazite (no. 18460).

In restricted parts of the eudialyte pegmatite there are concentrations of rinkite in the eudialyte. Along the borders of and in fractures in the rinkite small grains of neptunite occur. These grains are often surrounded by opaque rims and they are associated with schizolite and the mineral resembling britholite mentioned on p. 18 (see plate 1, fig. 4).

In this pegmatite there are occasionally small grains of neptunite present in fractures in the larger prisms of ægirine.

The most spectacular samples of neptunite were found at Igdlúnguaq on the north coast of Tunugdliarfik, a locality in which Gordon (21, p. 196) has already reported the presence of this mineral.

Igdlúnguaq is situated in the "breccia zone" of Ussing (33, p. 82), that is in a zone composed of lujavrite with inclusions of naujaite. The lujavrite is seen to be younger than the naujaite and there are transitional forms between the two rocks. All rock types are cut by pegmatitic and hydrothermal veins.

The neptunite was found in coarse-grained pegmatites which according to the field evidence appear to be recrystallized inclusions of naujaite in the lujavrite. In particular these rocks are present in the outer parts of the lenses of naujaite adjacent to the lujavrite. Neptunite has also been found in zones of hydrothermal alteration of the naujaite.

The pegmatitic rocks consist of large yellow grains of sodalite, green natrolite in long prismatic crystals (Bøggild, 10, p. 399), steen-
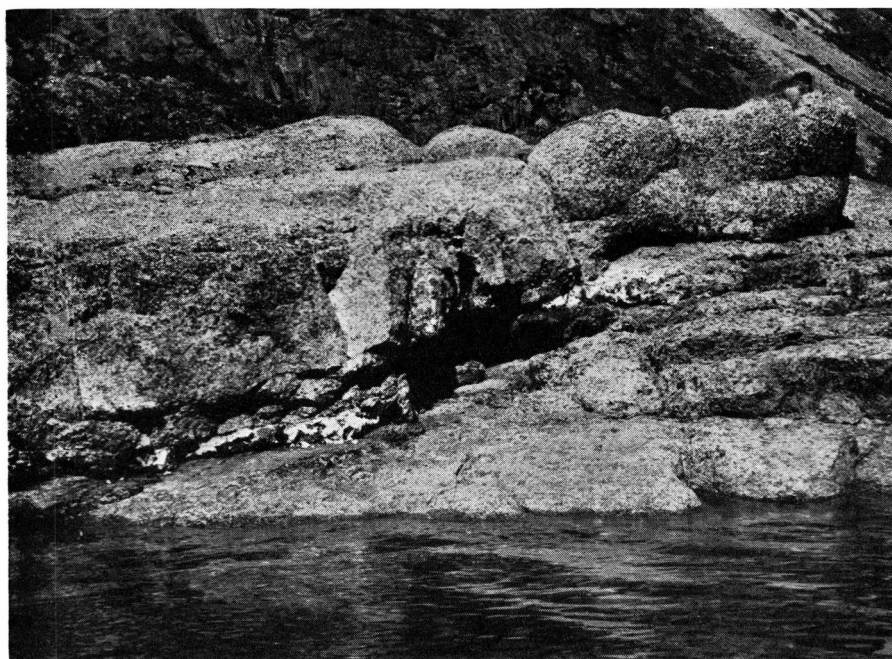
Fig. 2. Eudialyte-rich pegmatite in naujaite, Qeqertaussaq (see Ussing, *33* fig. 3).

strupine, ægirine, and eudialyte, all enclosed in a matrix of coarse-grained, greyish-green analcime.

The neptunite was found in very restricted parts of the pegmatites, being present as elongated crystals, up to 1 cm long. The separate grains of neptunite are surrounded by a white mineral occurring in thin streaks, parallel in some parts of the rock, radiating in others. The white mineral will be described on p. 25.

Under the microscope it is observed that the elongated grains of neptunite are somewhat irregular and that they may be built up of several subparallel crystals. The neptunite is generally enclosed in an aggregate of the white mineral, but may also have contact to the analcime of the matrix and to fibrous aggregates of epistolite. In some grains there are rows of inclusions of the white mineral and of thin flakes of epistolite (plate 1, fig. 3). Sphalerite is also present.

The neptunite has (+) 2V about 60°, v > r, very strong. The pleochroism is pronounced with α yellowish orange, β orange, and γ red. $n\beta = 1.700 \pm 0.001$, $n\gamma = 1.737 \pm 0.002$. The grains show faint zoning.

Bøggild (*10*, p. 256) reports the finding of macroscopic grains of neptunite at Tugtup agtakôrfia and at Tuperssuatsiaq.

Neptunite in microscopic grains.

Small grains of neptunite have been observed in thin sections of many rocks of the region.

Igdlunguaq: Neptunite is present in lujavrites, naujaites, and pegmatites.

a) **Lujavrite:** In two specimens (nos. 18512 a and b) of pale lujavrite, neptunite is a constituent of small pseudomorphs (of katapleite, a colourless mica and analcime) after eudialyte.

The eudialyte is in some zones of this rock strongly altered into katapleite. These zones have also areas of pigmentation larger than the small crystals of eudialyte. These areas of pigmentation consist of analcime, brown pigmentation, tiny flakes of a colourless mica (often in radiating groups), and neptunite; the latter is especially found along the borders of the pigmented areas. Eudialyte has not been observed in these areas, but katapleite, arfvedsonite and ægirine are present. Associated with the areas of pigmentation a mineral resembling eudialyte occurs. It is uniaxial negative and is most probably eucolite. Neptunite has also been found in schizolite-bearing zones of deformation in these rocks.

No. 18516 is a steenstrupine-bearing arfvedsonite lujavrite. There are areas of pigmentation with inclusions of arfvedsonite, ægirine, microcline, a slight amount of eudialyte and with neptunite along the margins. They have a matrix of analcime. Small crystals of eudialyte are present in the groundmass of the rock. They are partially replaced by analcime.

Naujaite: The neptunite is associated with altered grains of eudialyte. In no. 18512 c zoned eudialyte is present as large and small grains and it is observed to be in all stages of alteration. In the first stages small plates of katapleite are formed, in later stages the plates of katapleite increase in size and the eudialyte is furthermore replaced by analcime, mica and schizolite. Small grains of neptunite occur along the borders of the most transformed grains which may still preserve their original outlines (plate 2, fig. 1). A bleached ægirine and steenstrupine are occasionally associated with the areas of secondary minerals. This naujaite is cut by a zone of intense deformation in which there is a concentration of small crystals of eudialyte and strongly altered prisms of arfvedsonite in a matrix of analcime. The eudialyte may be strongly altered to katapleite and in a single zone there are pseudomorphs after eudialyte made up of dark pigmentation and a few cloudy grains of neptunite. These psedomorphs are similar to the earthy decomposition products described by USSING (*32*, p. 172).

In a crushed zone rich in ægirine (no. 18506 b) there are pseudomorphs of the type described above and with neptunite along the margins. They are associated with and in part enclosed by large grains of steenstrupine.

No. 18508 is a naujaite rich in steenstrupine. It has large, rather corroded grains of eudialyte that have a finely distributed black pigmentation. They are more or less decomposed and the transformed parts of the grains usually have sharp borders towards the fresh mineral. The alteration proceeds along fractures in and along the borders of the grains.

The alterations of the eudialyte may be complete, but even then the original outlines of the grains are preserved in most cases. The most transformed grains are "hollow" with a core of analcime surrounded by the other alteration products,

which are: brown or black pigmentation, stellate groups of flakes of a colourless mica, katapleite ($(+)$ $2V = 30—40°$) and schizolite. Neptunite is scarce and is especially found where the eudialyte is most transformed.

Kangerdluarssuk: In the vein of crushed lujavrite near Lilleelv refered to elsewhere in this paper (specimen no. 18467) neptunite is present in fairly large grains in crushed aggregates of arfvedsonite and ægirine and associated with strongly altered grains of eudialyte. Neptunite may also be associated with and enclosed in steenstrupine in these zones of arfvedsonite and ægirine.

Tugtup agtakôrfia: In the albite pegmatites of this locality (USSING, *33*, p. 83) there are pseudomorphs of pigmentation with small marginal grains of neptunite. The pseudomorphs are composed of a colourless mica, a brown mica, katapleite, and schizolite in a matrix of analcime.

On the origin of the neptunite.

The modes of occurrence of the neptunite are as follows:

1) in fractures in eudialyte,

2) associated with a white mineral in coarse-grained rocks which according to the field evidence are recrystallized inclusions of naujaite in the lujavrite. The associated minerals are epistolite, steenstrupine, analcime and yellow sodalite (without the numerous minute needles of arfvedsonite and ægirine that are so characteristic for the green sodalite of the naujaite).

3) in fractures in rinkite in the eudialyte pegmatite of Qeqertaussaq.

4) as marginal grains in pseudomorphs that in many cases can be proved to be transformed grains of eudialyte.

5) as small irregular grains in felt-like masses of ægirine and arfvedsonite, and less frequently in fractures in the ægirine.

In all the cases mentioned neptunite appears to be a secondary mineral formed as a result of the alteration of the primary minerals of the rocks. Its formation took place at a late stage in the alteration, and it is simultaneous with the formation of analcime, natrolite and schizolite, that is: it has been formed under hydrothermal conditions.

The nepheline syenites of the Ilímaussaq batholith are all poor in titanium and poor or relatively poor in manganese (cf. USSING, *33*, pp. 369—71). The augite syenite, nordmarkite, essexite, and the volcanic rocks are fairly rich and the magnetite-pyroxenite very rich in titanium (12.97 $°/_0$ TiO_2). The last-named rock greatly resembles the Afrikanda

pyroxenite of Kola (KUPLETSKY, 25). All the non-agpaitic rocks mentioned are poor in manganese.

The only minerals of the nepheline syenites rich in titanium are ænigmatite, astrophyllite and rinkite. The first-mentioned is a primary constituent of the rocks, the second is certainly formed during the alteration of the primary minerals; the rôle of the rinkite is so far uncertain. The writers have only studied one occurrence of rinkite in the field, namely the pegmatites of Qeqertaussaq where the rinkite is associated with eudialyte and schizolite. It may be a secondary mineral formed at the expense of the eudialyte and absorbing the rare earths, the titanium, the zirconium, the calcium and sodium of the last-named mineral. The neptunite present along fractures in the rinkite may then be a result of further alteration processes.

The only minerals with more than $2\,^0/_0$ MnO are schizolite (with crusts of MnO_2), steenstrupine, and ilvaite and all of them are secondary products.

Of the rock-forming minerals arfvedsonite has from $0.78—2.09\,^0/_0$ TiO_2 and $0.45—1.26\,^0/_0$ MnO (BØGGILD, 10, p. 293), and ægirine (from Narssârssuk, since there are no reliable analyses of unaltered ægirine from Ilímaussaq) $1.60\,^0/_0$ TiO_2 and $0.72\,^0/_0$ MnO (BØGGILD, op. cit. p. 272). The MnO content of the eudialyte from Ilímaussaq is about $1\,^0/_0$; TiO_2 was not determined in the old analyses of the mineral, Miss ME MOURITZEN has determined the TiO_2 content in the eudialyte from Qeqertaussaq and found it to be $0.01\,^0/_0$. The eudialyte and eucolite from Kola has according to FERSMAN (13, p. 103) $0.24—1.51\,^0/_0$ TiO_2 and $0.28—3.00\,^0/_0$ MnO.

It is therefore quite probable that the small amounts of manganese and titanium released during the transformation of arfvedsonite, ægirine and eudialyte are responsible for the formation of the neptunite. Macroscopic grains of neptunite occur along fractures in eudialyte on Qeqertaussaq. Similar grains, but not directly associated with eudialyte, occur at Igdlúnguaq. It is not unlikely that they were formed when the eudialyte was transformed during the recrystallization of naujaite into the analcime rock. The niobium of the epistolite associated with the neptunite may also, at least in part, be derived from the eudialyte.

Neptunite has been described from a few other regions.

First of all *Narsârssuk* a few miles to the east of Ilímaussaq should be mentioned. FLINK (14) states that the neptunite in this locality occurs as crystals formed on some of the other minerals of the occurrence (quartz, feldspar and ægirine). Elpidite and epididymite are often partly embedded in the neptunite. Associations with narsarsukite are also present.

In *San Benito County, California* neptunite occurs in natrolite-rich veins in serpentine together with benitoite, natrolite, joaquinite, perovskite, albite, ægirine, amphibole and calcite (LOUDERBACK (*27*) and PABST (*29*)).

In the *Khibina Tundra* manganiferous neptunite is found in the endocontact zone; in the *Lovozero Tundra* it is more common. It occurs in acicular masses of second generation ægirine and analcime and more rarely with natrolite. It is further associated with nepheline, microcline, mica, eucolite, hackmannite and ramsayite. It is a low temperature mineral crystallized probably at the same time as the analcime (BOHNSTEDT, *1*, FERSMAN, *13*, p. 131 and KRACVHENKO (*26*)).

NOCKOLDS (*28*) has described the occurrence of neptunite and eudialyte in quartz-bearing syenites from *Barnavave, Carlingford, Ireland*. The syenite occurs as veins in limestone and is formed by the desilication of granite by limestone. Neptunite is present as small interstitial flakes and partly replacing sphene. In another syenite there are small spots of eudialyte.

"White Mineral".

As mentioned on p. 21 a white mineral has been found in association with the neptunite at Igdlúnguaq.

It is present in a number of recrystallized inclusions of naujaite in the lujavrite. It is generally associated with neptunite, but also forms small independent masses, approximately a centimeter wide. Normally it is present in narrow bands built up of numerous small grains. The bands are radiating, in part parallel and where associated with neptunite they are parallel to that mineral. The bands are white or pale yellow in the handspecimens.

Under the microscope it is seen that the bands are made up of numerous small equidimensional grains. They are most often opaque but may, where the grains are very thin, be transparent with a reddish-brown colour. The grains are isotropic, but their central portions are often anisotropic. The mineral is white in reflected light and its refraction index is very high (plate 1, fig. 3).

The white mineral is partly enclosed in, partly surrounding the neptunite and it is then embedded in analcime and intergrown with epistolite and more rarely with sphalerite. Very thin dark strings and needles radiating out from the surface of the white mineral are very probably epistolite.

A mineral resembling the white mineral has also been found in thin sections of naujaite and lujavrite.

In two veins in the naujaite of Kangerdluarssuk singular grains of such a mineral occur (cf. p. 18 and p. 27). In no. 18467 b the mineral is present as a few grains in a rock in which wavy stripes of very fine-grained arfvedsonite and ægirine

with steenstrupine occur in a matrix of analcime. There are strongly altered grains of eudialyte with neptunite, and sphalerite is a scarce constituent. In no. 18468 b the mineral occurs in a fine-grained albitic vein with microcline (partly transformed to ussingite), steenstrupine, ægirine, lovozerite, sodalite, analcime, mica, sphalerite, and britholite. In both rocks the white mineral is birefringent being composed of anisotropic fields.

In an altered lujavrite, no. 18492 d from Tugtup agtakôrfia there are a few fairly large grains of the white mineral. They are composed of small anisotropic portions of different optical orientations. The axial angle is large. The grains are enclosed in analcime, microcline, and lithium-mica. The rock has altered eudialyte, but no neptunite.

Finally the mineral has been found in naujaite (no. 18508) from Igdlúnguaq. It is associated with strongly altered eudialyte.

The white mineral is interpreted as a secondary mineral formed together with neptunite and epistolite at the expense of the material set free during the alteration of the eudialyte and other primary minerals of the nepheline syenites.

The white mineral has been examined by means of X-rays. The diffraction pattern was of the same type as that of perovskite, i.e. the pattern which is produced by a cubic crystal with a primitive unit cell. The a-axis is a little larger than that of perovskite, namely 3.89 Å.

There is however a striking difference between the intensity distributions among the reflections of the white mineral and those of perovskite. This fact can to a certain extent be explained by different chemical compositions of the two minerals. Spectrochemical determinations on the white mineral carried out by Mr. K. ELLITSGAARD RASMUSSEN showed it to be rich in Ti, Nb, Na, Al, Ca, and with traces of Sr and Ba. Rare earths have not been searched for. The decisive factor in the present case is the distribution of light and heavy atoms between the sites of Ca and Ti in the perovskite structure. Varieties of perovskite such as loparite, knopite, and dysanalyte are examples of replacement of Ca by Ce and Na, and Ti by Nb. The X-ray powder patterns of these minerals are, however, much more like the perovskite pattern than that of the white mineral. A rough estimate of the intensity distributions among the reflexes sensitive to the substitutions mentioned above gave as a result that Ca must be replaced by Na, and Ti by Nb to a very large extent—if the mineral is to have the perovskite structure. When discussing this problem with Dr. H. NEUMANN it turned out that the X-ray powder diagram of the white mineral was almost identical with the powder diagram of $NaNbO_3$ synthesized by Mrs. BORGHILD NILSSEN, in Mineralogisk-Geologisk Museum, Oslo. The synthetic $NaNbO_3$ was heated to 775° C at which temperature the compound is reported to have the perovskite structure, see for instance WOOD (36).

Sufficiant quantities for a quantitative chemical analysis of the white mineral have been separated. The results of the analysis will be published shortly together with quantitative intensity determinations made on an X-ray spectrometer. We then hope to prove that the white mineral is a new member of the perovskite family with a composition close to $NaNbO_3$. To our knowledge this compound has not yet been found in nature and would then be a new mineral. If this be the case we suggest that this mineral should be named Igdloite after the locality Igdlúnguaq where it so far has been found in the largest quantities.

Ussingite.

Ussingite was first described by O. B. Bøggild (7). His description was based on three boulders found in Kangerdluarssuk in 1888 and 1908. In 1955 ussingite was found *in situ* at the head of the Kangerdluarssuk Fjord to the north of Lilleelv, about 300 m from the coast in an altitude of 30 m. The locality is marked on the map as 18468 (fig. 1 and fig. 3).

The ussingite occurs in a 0.2 m thick vein in crumbling naujaite. The vein is composed of brown and green rocks. The brown rock is rich in steenstrupine and ægirine, the green rock is mainly made up of tiny needles of ægirine. The vein is interpreted as a recrystallized zone of crushing in the naujaite.

The ussingite, which is white with a faint purple tinge, is especially found in irregular veins in the green rock. It is of much paler colour than the ussingite described by Bøggild. The identity of the new and the old samples was controlled by means of X-ray powder diagrams.

In thin sections (nos. 18468 a, b, c, d) the vein is seen to have alternating coarse- and fine-grained portions. The coarse-grained rock is made up of large plates of microcline, prisms of ægirine, crystals of steenstrupine, and "lovozerite". The fine-grained rock is composed of fine-needles of ægirine (parallel and partly bent), small laths of microcline and albite, steenstrupine and "lovozerite". Schizolite, sphalerite, lithium-mica, "perovskite" and britholite are minor constituents of these rocks. Analcime and sodalite are very rare.

There are small "drops" of albite on and around fractures in the microcline, probably formed as a result of exsolution of albite from the microcline.

Ussingite is present as scaly aggregates in the microcline and is especially conspicuous around the grains of steenstrupine, ægirine, and "lovozerite". Several small scales may be found in subparallel arrangement in a glomeroblastic way so that there is a tendency towards the formation of larger grains. The irregular veins of ussingite in the green rock consist of fairly large grains of ussingite composed of individuals having almost the same optical orientation. These grains are formed through the coalescence of several small scales and they have inclusions of ægirine needles, microcline, albite, and "lovozerite". The grains may show twinning and they are often crowded with dark pigmentory material.

Fig. 3. The locality in which ussingite and lovozerite? were found *in situ*. The two minerals occur in the ridge in centre, which is a recrystallized zone of deformation in crumbling naujaite.

The optical properties of the ussingite from the new occurrence correspond to those reported by BØGGILD. The birefringence is strong, the refraction is low ($n\alpha = 1.508 \pm 0.001$ and $n\beta = 1.512 \pm 0.002$, $(+)\, 2V = $ ca. $60°$, the extinction is oblique).

The thin sections made by BØGGILD for his original description of the mineral were also studied. He distinguishes between three types:

Type I. Ussingite is associated first of all with sodalite, which may be poikilitically enclosed in the ussingite. Large tabular crystals of microcline are also penetrated by ussingite. Albite is a rare constituent. Further associates are: ægirine, eudialyte (altered), schizolite, neptunite, and small brown octaedra of an unknown mineral.

Type II. This specimen has large prisms of ægirine and large crystals of steenstrupine (with inclusions of ægirine and "lovozerite") in a matrix of ussingite with inclusions of microcline and sodalite. Sphalerite, schizolite and analcime are rare.

Type III. The rock has large prisms of ægirine and arfvedsonite, steenstrupine and "lovozerite" in a matrix of ussingite with inclusions of microcline and sodalite. The "lovozerite" was not mentioned by BØGGILD in any of the types. The steenstrupine is partly present as crystals and partly as an "impregnation" of the rock with inclusions of ægirine and "lovozerite". There are radiating fractures around most

of the steenstrupine crystals. The microcline may be very deformed. Epistolite, schizolite, and sphalerite are present in minor quantities. Analcime plays an important rôle in some parts of the rock and replaces both feldspar and ussingite. It has small corroded inclusions of these two minerals. It should finally be mentioned that this type has ussingite in large grains as well as in scaly aggregates.

In all cases examined ussingite is a secondary mineral formed at the expense of microcline and sodalite. Albitic, steenstrupine-carrying veins are quite common in this area, but in the ussingite-bearing rocks albite is of minor importance and it is not replaced by the ussingite.

The ussingite in its turn is replaced by analcime.

The concentration of ussingite around the crystals of steenstrupine may point towards a genetical connection between these two minerals.

The occurrence of ussingite as a secondary mineral in a crushed and much altered vein in naujaite corresponds—as far as can be judged from the available literature—to the field relations of ussingite in the *Lovozero Tundra* of the *Kola Peninsula* (BOHNSTEDT,, *2 and* FERSMAN, *13*, p. 87). At Punkaruaiv, ussingite forms lenses up to 1.5 m in foyaite pegmatite with sodalite, schizolite, steenstrupine, erikite, natrolite, murmanite etc. In the Chinglusuai valley ussingite occurs in a sodalite syenite pegmatite with feldspar, nepheline, sodalite, ægirine, arfvedsonite, eudialyte, lamprophyllite, murmanite, ramsayite etc. Ussingite is—as in Greenland—a secondary mineral after sodalite and it crystallized at the end of the supercritical phase and at the beginning of the hydro-thermal (FERSMAN, *12*, p. 43).

In conclusion: ussingite is a secondary mineral formed at the expense of sodalite and microcline as a result of soda-metasomatism during the pegmatitic replacement of a zone of crushing in naujaite. It precedes the zeolitic stage of the replacement processes, a stage that is characterized by the formation of analcime.

Finally it should be mentioned that small grains of ussingite have been found in lujavrite from Tuperssuatsiaq. They replace lath-shaped crystals of microcline. The latter may be entirely replaced by a fine-scaled aggregate of ussingite.

Lovozerite.

In thin sections of the rocks from the ussingite locality at the bottom of the Kangerdluarssuk Fjord (see p. 27) there are always small equi-mensional and often strongly altered grains that recall the lovozerite of the Lovozero Tundra, the Kola Peninsula (GERASIMOVSKY, *17*).

These grains occur as inclusions in the steenstrupine, occasionally in ægirine, arfvedsonite, sodalite and microcline. They are also present in the ussingite, most often along the borders of the steenstrupine crystals.

In the sections nos. 18468 a, b, c, and d the lovozerite is transformed to a fibrous alteration product (apparently a colourless mica) and to a brown pigmentory material. The least altered of the grains are of a faint red colour and they are uni-axial negative (plate 2, fig. 3).

In some of BØGGILD's sections of the ussingite types II and III fairly fresh grains of lovozerite occur in the same way as in 18468, that is most often as inclusions in the steenstrupine.

The lovozerite is, when fresh, pale red, non pleochroic in thin section, uniaxial negative, the refractive indices are higher than those of ussingite and lower than those of the steenstrupine. The birefringence is rather low. The mineral shows a complicated polysynthetic twinning, and there may be a faintly developed zoning.

The alteration of the mineral to a colourless mica and a brown pigmentation is seen to proceed along the twin lamellae.

The steenstrupine may have small areas of pigmentation showing the outlines of the grains of lovozerite, thus the last-named appears to be digested by the steen-strupine.

Some parts of the sections 18468 have concentrations of small equidimensional brown areas of pigmentation and small needles of ægirine. They are believed to be altered lovozerite (plate 2, fig. 4).

So far it has been impossible to isolate the mineral. We hope to be able to do so at a later date, when more material has been collected. The optical data corresponds however quite well with those of the lovozerite from Kola.

In two samples of lujavrite from Lilleelv, grains identical with the lovozerite of 18468 have been found.

No. 325 is an ægirine lujavrite composed of nepheline, microcline, albite, arf-vedsonite in big prisms, ægirine in tiny needles, and sodalite. There are crystals of eudialyte with spots of lovozerite (plate 2, fig. 2). Britholite, sphalerite, steen-strupine, and iron ore are accessories; analcime and natrolite are secondary minerals. The rock is strongly deformed, the ægirine may occur in felt-like masses that wrap around the crystals of eudialyte, the albite is present in bent laths, and the micro-cline shows a peculiar spotted twin structure which according to our experience is an indication of the first stages of the deformation of this mineral.

Some of the grains of eudialyte are fairly fresh, they are most often optically positive, but may be negative in restricted parts (eucolite). The grains are often isotropic along irregular fractures. Katapleite and lovozerite are alteration products of the eudialyte. Where the crystals of eudialyte have disappeared, their place may be taken by aggregates of lovozerite which show the outlines of the original grains. The steenstrupine is associated with the altered grains of eudialyte.

The lovozerite of this rock is faintly red, uniaxial negative, with interference colours of first and second orders and it shows polysynthetical twinning. Its refrac-tion is lower than that of the eudialyte.

No. 313 is a greenish arfvedsonite lujavrite with lovozerite as a secondary mineral in eudialyte. Its refractive indices are a little lower than those of the eudia-

lyte. The rock is made up of sodalite, nepheline, arfvedsonite, microcline, bent laths of albite, layers of tiny needles of ægirine, sphalerite and a mineral resembling britholite.

The lovozerite in the two samples of lujavrite is clearly a secondary mineral formed at the expense of the eudialyte. The lovozerite associated with ussingite and steenstrupine in no. 18468 shows the crystal form of eudialyte and is most probably formed at the expense of this mineral although no traces of unaltered eudialyte have been found in the sections of the rock in question.

Small equidimensional areas of pigmentation in altered lujavrites from many parts of the Ilímaussaq batholith resemble the altered lovozerite found in 18468. They may represent grains of eudialyte transformed into secondary minerals via a lovozeritic stage.

The mineral described as lovozerite in this paper recalls the orthorhombic katapleite described by GORDON (*20*, p. 258) from Narssârssuk, where it is found in vugs in augite syenite. This katapleite is however biaxial with a large 2 E.

In the collections of the Mineralogical Museum of Copenhagen there is a small sample labelled lujavrite, *Lujaur Urt* (= *Lovozero*), *the Kola Peninsula*. In a thin section it was found to contain small grains of the same appearance as the mineral called lovozerite in this paper.

The rock is black and fine-grained and is made up of arfvedsonite (blue in the central parts of the grains, green along the margins), microcline with spotted twin structure, sodalite, nepheline, analcime and a great multitude of small needles of ægirine. There are small grains of eudialyte (with zonal structure, weak birefringence and often concentrated in clusters) and poikilitic flakes of murmanite.

The lovozerite is partly associated with the eudialyte, partly found as independent grains of the same outlines as the eudialyte. The mineral is pale red, uniaxial negative with lower refraction than the eudialyte. It shows twinning and is often altered into a colourless mica and brown pigmentation. Larger grains, brown in thin section, may also be lovozerite.

The lovozerite described by GERASIMOVSKY (*17*) is found in a porphyritic lujavrite together with eudialyte and it is partly a primary constituent of the rock partly a secondary mineral. It may be present as phenocrysts together with murmanite, lamprophyllite, and nepheline.

Epistolite.

When the murmanite-bearing sample of lujavrite from Kola, mentioned in the chapter on lovozerite, was examined, we had no samples of murmanite in the Mineralogical Museum. Through the kindness of professor H. STRUNZ in Berlin we obtained a small flake of murmanite from Kola and our identification was verified.

In the hand specimen murmanite resembles epistolite to some extent and X-ray powder diagrams of the two minerals were therefore compared. They were almost identical. X-ray powder diagrams of the epistolite and murmanite kept in the Mineralogical Museum in Oslo were placed at our disposal by Dr. H. Neumann and they were identical with our powder diagrams. The positions of the reflections in the two diagrams show that the unit cell of murmanite is slightly smaller than that of epistolite.

In the available literature the writers have found no information on the similarity between these two minerals and therefore this short note is written. A more conclusive discussion is not possible while the structures of epistolite and murmanite are unknown.

Epistolite was described by Bøggild (4), murmanite by Gutkova (23). Both minerals are colourless or pink with one perfect cleavage parallel to the "flattening" of the crystals. Bøggild gave the indices 001 to the cleavage of epistolite, Gutkova called the cleavage of murmanite 100. In both minerals Bx_α is almost perpendicular on the cleavage.

Table 5. Chemical analyses of epistolite, murmanite and lomonosovite.

	Epistolite Nunarssuatsiaq Bøggild (4)	Murmanite Punkaruaiv Fersman (13)	Murmanite Chinglusuai Fersman (13)	Lomonosovite Gerasimovsky (18)
SiO_2..........	27.59	30.93	30.06	24.07
ZrO_2	—	1.40	2.08	2.10
TiO_2..........	7.22	29.51	} 38.24	24.43
Nb_2O_5	33.56	7.71		} 3.00
Ta_2O_5	—	0.50		
Fe_2O_3.........	—	3.34	2.33	2.39
FeO	0.20	—	0.30	—
MnO	0.30	2.42	2.30	3.17
MgO	0.13	0.27	0.35	0.58
CaO..........	0.77	2.74	2.56	0.80
Na_2O	17.59	7.44	10.38	26.09
K_2O..........	—	0.56	0.83	0.26
$H_2O +$	} 11.01	6.46	4.17	—
$H_2O -$		6.06	6.03	—
F	1.98	0.19	—	—
P_2O_5	—	—	—	12.84
	100.35	99.53	99.63	99.73
O = F.........	0.83			
	99.52			
sp. gravity	2.885	2.763—2.769	2.84	

The physical constants of the two minerals as given in the literature are:

	$2V\alpha$	$n\alpha$	$n\beta$	$n\gamma$	$n\gamma-n\alpha$	density	hardness
epistolite	ca.80°	1.610	1.650	1.682	0.072	2.885	$1-1^1/_2$
murmanite ...	64°	1.735	1.765	1.839	0.104	2.76–2.84	2–3

The axial angle of epistolite was measured on the universal stage. Epistolite from Nunarssuatsiaq had (—) $2V = 83° \pm 5°$, epistolite from Tugtup agtakôrfia had (+) $2V = 84° \pm 2°$.

The chemical compositions of epistolite and murmanite are given in table 5. The main diferences in the chemical composition of the two minerals are that epistolite is rich in niobium and poor in titanium while the opposite relationship is found in murmanite, and that epistolite is rich in sodium and poor in the divalent cations, while murmanite has a higher proportion of Ca, Mn and Fe.

The similar powder patterns of the two minerals may then be explained by assuming that epistolite and murmanite are members of an isomorphous series with the Nb- and Na-rich epistolite at the one end and the Ti- and Ca, Mn, and Fe-rich murmanite at the other end. These substitutions are of the same kind as those mentioned on p. 26 in the case of the white mineral and perovskite.

Finally it should be pointed out that murmanite also forms an isomorphous series with lomonosovite (GERASIMOVSKY, 18).

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Plate 1.

Plate 1, fig. 1. 83 ×, 1 nic. Two small clusters of monazite in lujavrite composed of arfvedsonite, acmite, albite and analcime. Kangerdluarssuk. (CHR. HALKIER phot.).

Plate 1, fig. 2. 83 ×, 1 nic. no. 18467 b. Crystals of britholite, prismatic as well as hexagonal cross sections. The ground mass consists of analcime with remnants of nepheline and with small clusters of pigmentory material. Lilleelv.
(CHR. HALKIER phot.).

Plate 1, fig. 3. 26 ×, 1 nic. no. 18510. Large grains of neptunite (grey) intergrown with white mineral (black on photo because of the high index of refraction), flakes of epistolite (in border between neptunite and white mineral top left), and analcime (white). Igdlúnguaq. (CHR. HALKIER phot).

Plate 1, fig. 4. 26 ×, 1 nic. no. 18462. Neptunite and opaque mineral (both black) in fracture in rinkite. Top left a grain of the britholite-looking mineral (see p. 18).
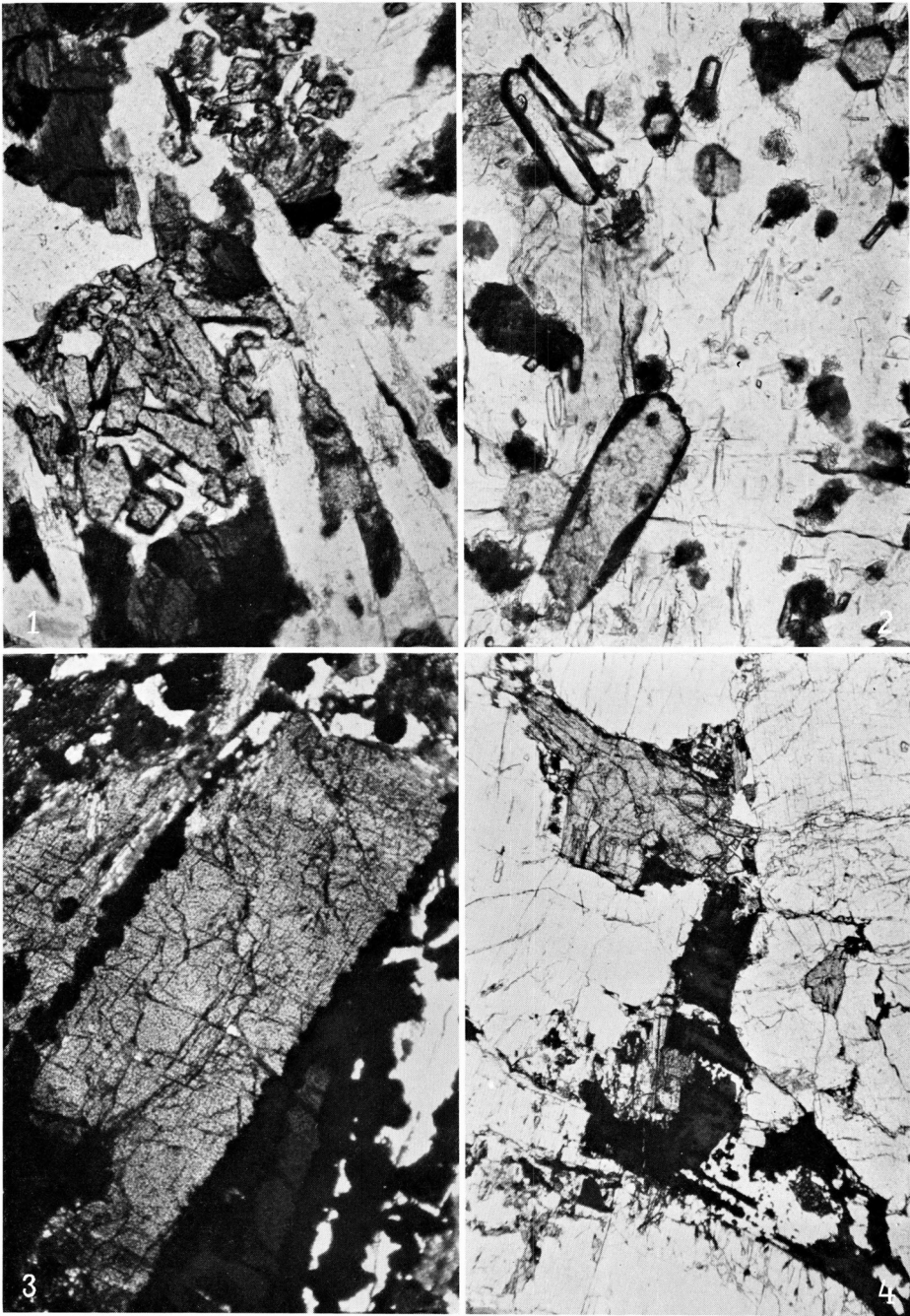Qeqertaussaq. (CHR. HALKIER phot).

Plate 2.

Plate 2, fig. 1. 26 ×, 1 nic. no. 18512 c. Crystals of eudialyte in groundmass of sodalite and natrolite. The eudialyte has strongly altered portions with neptunite and pigmentation (both black in the photo), katapleite, schizolite, analcime, etc. Naujaite from Igdlúnguaq. (CHR. HALKIER phot).

Plate 2, fig. 2. 26 ×, 1 nic. no. 325. Lujavrite with nepheline, albite, eudialyte, and needles of ægirine. Top centre: crystal of eudialyte (e) with a crystal of lovozerite ((l, above e). The dark portion (l) to the left of the eudialyte is an aggregate of small grains of lovozerite in strongly altered eudialyte. Lilleelv. (CHR. HALKIER phot).

Plate 2, fig. 3. 26 ×, 1 nic. no. 18468 b. Crystals of steenstrupine with inclusions of lovozerite. The dark grains between the steenstrupine crystals are also lovozerite, but strongly altered. Albite and ussingite are white. The locality shown in fig. 3. (CHR. HALKIER phot).

Plate 2, fig. 4. 26 ×, 1 nic. no. 18468 b. Crystals of steenstrupine with inclusions of lovozerite. The numerous small dark grains are altered lovozerite in a groundmass of albite and ægirine. Same locality as plate 2, fig. 3. (CHR. HALLKIER phot).