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ON THE OCCURRENCE OF STEENSTRUPINE IN THE ILÍMAUSSAQ MASSIF, SOUTHWEST GREENLAND

BY

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WITH 32 FIGURES IN THE TEXT
AND 16 PLATES

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Denne afhandling er i forbindelse med de 2 nedennævnte tidligere offentliggjorte arbejder:

1. The Ilímaussaq Batholith – a review and discussion
   (Meddelelser om Grønland bd. 162, nr. 3, 1958)
2. On the agpaitic rocks
   (Report of the International Geological Congress, XXI Session, Norden, 1960, part XIII)

af det matematisk-naturvidenskabelige fakultet ved Københavns Universitet antaget til offentlig at forsvares for den filosofiske doktorgrad.

København, den 26. april, 1962.

T. W. Böcher
h. a. dec.

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Abstract.

The rare mineral steenstrupine was first described from pegmatoid veins in the Ilímaussaq alkaline massif, South Greenland. It is now known to be of widespread occurrence in this massif, being present in agpaitic rocks (naujaite, sodalite foyaite and lujavrite) and in late veins of hydrothermal affinity.

In the present paper three small areas within the Ilímaussaq massif have been selected for a rather detailed study of the mode of occurrence of the steenstrupine, namely the small island of Qeqertaussaq made up of naujaite which is cut by very thin veins of a black, lujavrite-like rock, felted ægirine and albite-analcime-natrolite rocks; the head of Kangerdluarssuk with thicker veins of black lujavrite and green ægirine felt cutting the naujaite; and the north coast of Tunugdliarfik which represents a deeper level in the intrusion, being composed of lujavrite with numerous inclusions of naujaite. The naujaite of the last-named area is cut by thin veins of ægirine felt, acmite, albite and analcime-natrolite. The lujavrite here has apparently assimilated naujaitic material.

Steenstrupine occurs in these three areas in lujavrite, late veins and in the naujaite adjacent to these rocks. It is also present in albite-analcime-natrolite-bearing replacement bodies in some zoned naujaite pegmatites.

Some features favour a metasomatic origin of the lujavrite, but it is concluded that the combined observations are best explained by a magmatic interpretation.

The lujavrite is clearly later than the naujaite, its intrusion being guided by the joints of the naujaite. Considerable tilting and rotation of the naujaite inclusions in lujavrite is seen in places. In some lujavrite veins it is seen that the *mise en place* of the lujavrite was preceded by the formation of ægirine felt along the naujaite joints. The intrusion of the lujavrite was accompanied and succeeded by the formation of thin veins containing one or more of the minerals acmite, arfvedsonite, albite, analcime and natrolite.

In the lujavrite a very pure maximum microcline and a pure low albite have been formed in equilibrium indicating a low temperature of formation, probably of the order of 400° C. The albite and in cases also the microcline, nepheline and sodalite of the lujavrite, may be replaced, to varying extent, by analcime, and, more rarely, by natrolite. This also favours a low temperature of formation of the lujavrite. At these low temperatures and in this very sodium-rich environment liquid immiscibility may have played a role as is mentioned in the discussion of peculiar spheroidal structures in the lujavrite.

Some of the analcime of the lujavrite may be a primary precipitate of the lujavrite magma, but most analcime is probably secondary after the primary alkali-aluminium silicates. This analcitization is considered to be late magmatic.

The sodium-water-rich rest liquid of the lujavrite may be squeezed out and has effected analcitization of the naujaite inclusions. These late fluids are also responsible for the formation of the late veins made up of albite, analcime, natrolite and a number of rare minerals containing rare earths, Nb, Th, Mn, Li, P, F, Zn and S.

These elements are partly expelled from the lujavrite magma, partly leached out of the naujaite adjacent to the fractures by the percolating late fluids. The fact that the rare minerals (e. g. steenstrupine, britholite, monazite, lepidolite, schizolite, igdloite and sphalerite) of the late veins also occur in the analcitized lujavrite indicates that the formation of these minerals was closely connected with the later stages of crystallization of the lujavrite.

The lujavrite and naujaite are rich in eudialyte; this mineral is rare in the steenstrupine-bearing rocks. It is therefore concluded that the eudialyte is stable at a higher temperature than the steenstrupine, monazite, etc.

The steenstrupine-bearing replacement bodies of the naujaite pegmatites were formed simultaneously with the late veins and are thus considerably later than the naujaite and clearly formed from fluids of external origin, with respect to the primary pegmatite system. This feature is compared with the well-known replacement bodies in granite pegmatites.

The chemical and physical properties of the late fluids and the mechanisms of transport and precipitation of the rare elements are discussed.

New chemical analyses of ægirine, acmite, beryllium sodalite, chkalovite and igdloite and a number of partial chemical analyses of albite, analcime, microcline, monazite, natrolite, nepheline and sodalite are reported. Point countings have been made on the finer grained, more homogeneous rocks. The minerals of the rocks are briefly described and a number of rare rock types are described and discussed.

Preface.

The rare mineral steenstrupine was discovered by K. J. V. Steenstrup in the Ilímaussaq Complex, Southwest Greenland in 1876 and it was described by Lorenzen in 1881. Its mode of occurrence has later been dealt with by Flink (1898), Bøggild (1899) and Ussing (1911). In addition, mineralogical studies have been carried out by a number of authors. The mineral also occurs in the Lovozero alkaline complex of the Kola peninsula.

In 1955 the writer visited the Ilímaussaq complex in connection with a prospecting project carried out by the Danish Atomic Energy Commission. A number of steenstrupine-bearing specimens were collected and were studied in the laboratory and compared with the extensive collections of steenstrupine in the Mineralogical Museum of the University of Copenhagen. The preliminary results of this examination were so promising that it was decided to undertake more detailed field studies in a few selected localities. This work was carried out in 1957.

A series of publications was planned and the first part, a review and discussion of the Ilímaussaq batholith, appeared in 1958 (Sørensen, 1958). This paper was intended to serve as an introduction to the subsequent papers dealing with the steenstrupine occurrences and their mineralogy. A few mineralogical studies have been published (Danø and Sørensen, 1959, Sørensen, 1960 b, Buchwald and Sørensen, 1961, Bondam and Ferguson, in press, and Oen Ing Soen and Sørensen, in press), but the research program was seriously delayed because of other duties. Therefore, the description and discussion of the steenstrupine occurrences, which was planned to come in 1959, has only now been prepared for publication. The mineralogical study of the steenstrupine and a few other minerals will be continued, only the preliminary results are published here.

The steenstrupine occurs in strongly altered rocks and in thin veins of a very heterogeneous make up. Bulk chemical analyses and modal analyses are therefore of little use. Instead detailed petrographical descriptions of the steenstrupine occurrences have been made. It has been attempted to make these descriptions as objective as possible, interpretations being restricted to the final chapters of the paper, but it is of course realized that entirely non-genetic descriptions cannot be made.

The steenstrupine occurrences in Ilímaussaq are in this paper compared with related occurrences in other regions and the conditions of formation of the steenstrupine and its associated minerals are estimated from experimental data. Based on these combined studies, the origin of the steenstrupine is discussed.

The mineralogical and petrographical chapters are regarded by the author as appendices to the paper and they can be omitted by the reader who is interested only in the conclusions, since the relevant data is summarized in the chapters in which the field relations are described and the observations discussed.

The samples described in this paper are kept in the Mineralogical Museum of the University of Copenhagen.

Acknowledgements.

The field work of the present examination has been carried out in connection with the activities of the Geological Survey of Greenland in South Greenland and the laboratory examinations were carried out in the Mineralogical Museum of the University of Copenhagen. I am most grateful for the kind help I have received from my colleagues in these Institutions. Professor A. NOE-NYGAARD is especially acknowledged for the support and interest he has always shown my work.

I have learnt much from discussions with professor A. NOE-NYGAARD, Copenhagen, professor A. BERTHELSEN, Aarhus, professor T. F. W. BARTH, Oslo, professor V. I. GERASSIMOVSKY, Moscow, and my colleagues J. BONDAM, J. FERGUSON and H. MICHEELSEN. I wish to express my sincere thanks for this valuable co-operation.

The material collected at Ilímaussaq has been compared with material from the Kola peninsula, the Oslo region, Pilansberg and a few other regions. I have received material and information from professor T. F. W. BARTH and Dr. H. NEUMANN, Oslo, professors G. P. BARSANOV and V. I. GERASSIMOVSKY, Moscow, professors F. E. WICKMAN and S. GAVELIN, Stockholm, professor M. SAKSELA, Helsingfors, dr. S. O. AGRELL, Cambridge, Dr. L. VAN WAMBEKE, Euratom, Dr. A. SAFIANNIKOFF, Goma, Dr. T. DEANS, London, dr. L. R. PAGE, Boston and Mr. J. FERGUSON, Copenhagen. This kind and invaluable help is gratefully acknowledged.

The X-ray determination of the minerals has been undertaken by Mrs. M. DANØ, the chemical analyses and partial chemical analyses by

Miss ME MOURITZEN, a partial analysis of a monazite sample by Mr. E. SØRENSEN, and the spectrographic analyses by Mr. I. SØRENSEN. The microphotographs were taken by Mr. C. HALKIER, the aerial photographs by Mr. P. POVELSEN, and the field photographs were prepared for publication by Messrs. C. HALKIER and P. NIELSEN. Miss E. BREVAL and Mr. F. L. JACOBSEN assisted in the field, and Mr. K. BOESEN surveyed the point of Igdlúnguaq. The maps and sketches were drawn by Mrs. R. LARSEN and by the drawing office of the Geological Survey of Greenland under the direction of Mr. F. H. RØHLING. The thin sections have been made by Messrs. G. RITNAGEL and H. VALENTIN. Russian translations have been undertaken by Miss E. EREMEEVA, laboratory assistance rendered by Miss E. BØGGILD, and the manuscript was typed by Miss G. HANSEN. The text was critically read by Mr. J. FERGUSON, who also corrected the English. I extend my sincere thanks for all this kind assistance and help.

The Mineralogical Museum of the University
Copenhagen, February 1962

HENNING SØRENSEN

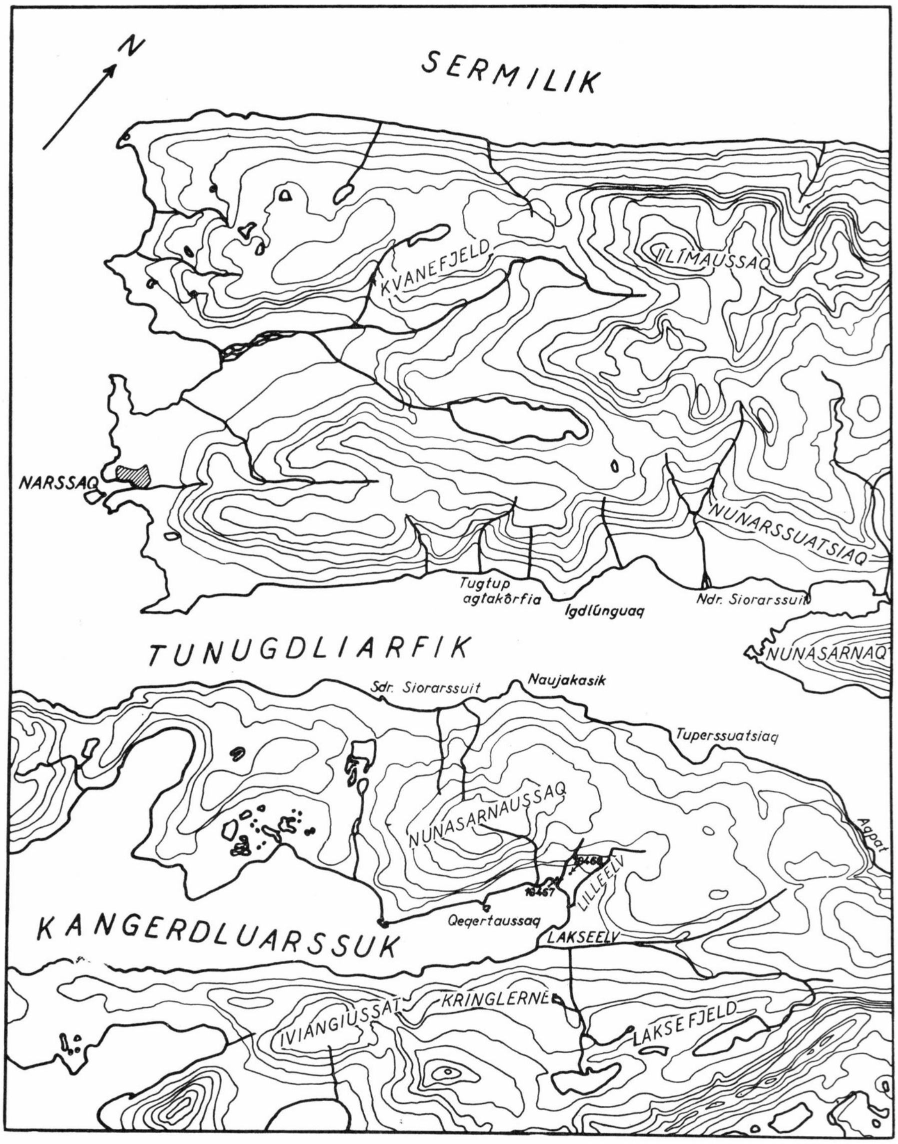

Fig. 1. Map showing the localities mentioned in the text. Scale: 1:143,000; equidistances 100 m. The map is based on a preliminary 1:50,000 map kindly supplied by the GEODETIC INSTITUTE, Copenhagen (Copyright the GEODETIC INSTITUTE). Geological maps are to be found in USSING (1911), SØRENSEN (1958) and FERGUSON (1962b).

I. INTRODUCTION

South Greenland is rich in plutonic bodies of alkaline affinity. The most famous of these intrusions is the Ilímaussaq complex which is situated at the Tunugdliarfik Fjord a few kilometres to the east of Narssaq (fig. 1).

The geology of the Ilímaussaq complex was first described by Ussing (1911). A brief review and discussion was published by the author in 1958. The reader is referred to these papers for further reference on the geology of the complex. It should, however, be mentioned that the whole Ilímaussaq region has been re-mapped by the Geological Survey of Greenland during the last few years. This work has been directed by J. Bondam and a preliminary account of the results has been published by J. Ferguson (1962 a). A new map will be published by Ferguson this year (1962 b).

As described in the above-mentioned papers, the Ilímaussaq complex has been divided into an unstratified and a stratified division. The former part is composed of augite syenite, essexite, nordmarkite and alkali granite; the latter part comprises the agpaitic rocks sodalite foyaite, naujaite, kakortokite and lujavrite. The agpaitic rocks are believed to be developed from an augite syenitic magma enriched in volatiles (Sørensen (op. cit.) and Ferguson (op. cit.)). At this place it should be pointed out, as it has often been done in the colloqui held by professor A. Noe-Nygaard, that assimilation of rock salt may have contributed to this evolution.

The agpaitic rock group has been reviewed in a paper presented at the XXI International Geological Congress in 1960 (Sørensen, 1960 a). It is concluded in that paper that the agpaitic rocks may be best defined as per-alkaline nepheline syenites containing soda pyroxenes and soda amphiboles instead of augite, hornblende and biotite. The rocks contain complex Zr- and Ti-silicates instead of zircon and sphene and they are rich in F, Cl and H_2O occurring in minerals such as eudialyte and rinkite. Details of the geochemistry and mineralogy of the agpaites are given by Gerassimovsky (1956).

According to Sørensen and Ferguson, naujaite occurs in the upper part of the stratified agpaitic sequence, whereas karkortokite occurs in the lower part. These rocks are believed to be formed in the main stage of crystallization of the agpaitic magma. Somewhat later is the lujavrite which, according to FERGUSON, occupies an intermediate position between the naujaite and the kakortokite. Only the naujaites and lujavrites will be further discussed in the present paper.

Steenstrupine has been described from sodalite foyaite, naujaite, lujavrite and late veins. It occurs sparingly in the first-named rock type (USSING, 1911, p. 139), the discussion of the present paper will therefore be confined to the latter rocks.

The steenstrupine is especially associated with the lujavrite and with the late veins. A few areas have been selected for a closer study of these types of occurrence, namely: the small island of *Qeqertaussaq*, which is composed of naujaite cut by very thin veins of lujavrite; *the head of Kangerdluarssuk to the north of Lilleelv*, where the naujaite is cut by thicker veins; and *the north coast of Tunugdliarfik*, where lenses of naujaite are enclosed in lujavrite. These localities are indicated in fig. 1.

The three small areas mentioned above will be described separately, but their rocks will be treated according to rock type in the petrographical chapter.

II. QEQERTAUSSAQ

The small island of Qeqertaussaq in Kangerdluarssuk (fig. 2) consists of naujaite with eudialyte-rich pegmatites and a few younger very thin green and black veins. The naujaite is friable, the surface of the island being partially covered by gravel of decomposed naujaite. Topographically the naujaite forms low rounded mounds (fig. 3).

The naujaite is coarse-grained and of massive appearance, however, locally a well-developed banding occurs (fig. 4) showing eudialyte-rich and eudialyte-poor layers in unbanded naujaite. There are no black layers as in the kakortokite on the southern shore of Kangerdluarssuk. The layers are thin, rarely attaining a thickness of one metre. The light coloured layers are commoner, but thinner than the red, a gradual transition being present between the layers. The banding is horizontal or with a slight westerly dip. The naujaite, apart from the mechanical disintegration, is very fresh.

Pegmatites are common in the naujaite. Most of them are small and of rather irregular shape, but there are a few larger sill-like pegmatites which are parallel to the banding and to a horizontal set of joints in the naujaite. Common to all the pegmatites is a high content of eudialyte, large plates of white microcline and large black prisms of arfvedsonite. The pegmatites lack the poikilitic texture of the naujaite. The small irregular bodies of pegmatites have the appearance of segregations in the naujaite and will not be further discussed in this paper. The two sill-like pegmatites in the southern and eastern parts of the island display a pronounced zoning which will be described in some detail below.

The pegmatite on the south coast of the island: This pegmatite has attracted all geologists working in the area. K. J. V. Steenstrup in 1888 excavated a considerable amount of eudialyte from this place. Later Ussing (1911, p. 35) gave a rather detailed description of this pegmatite.

The pegmatite is lens-shaped with a maximum thickness of about 80 centimetres and it is exposed for a few metres in the low "coast cliff" of the island (Danø and Sørensen, 1959, fig. 2).

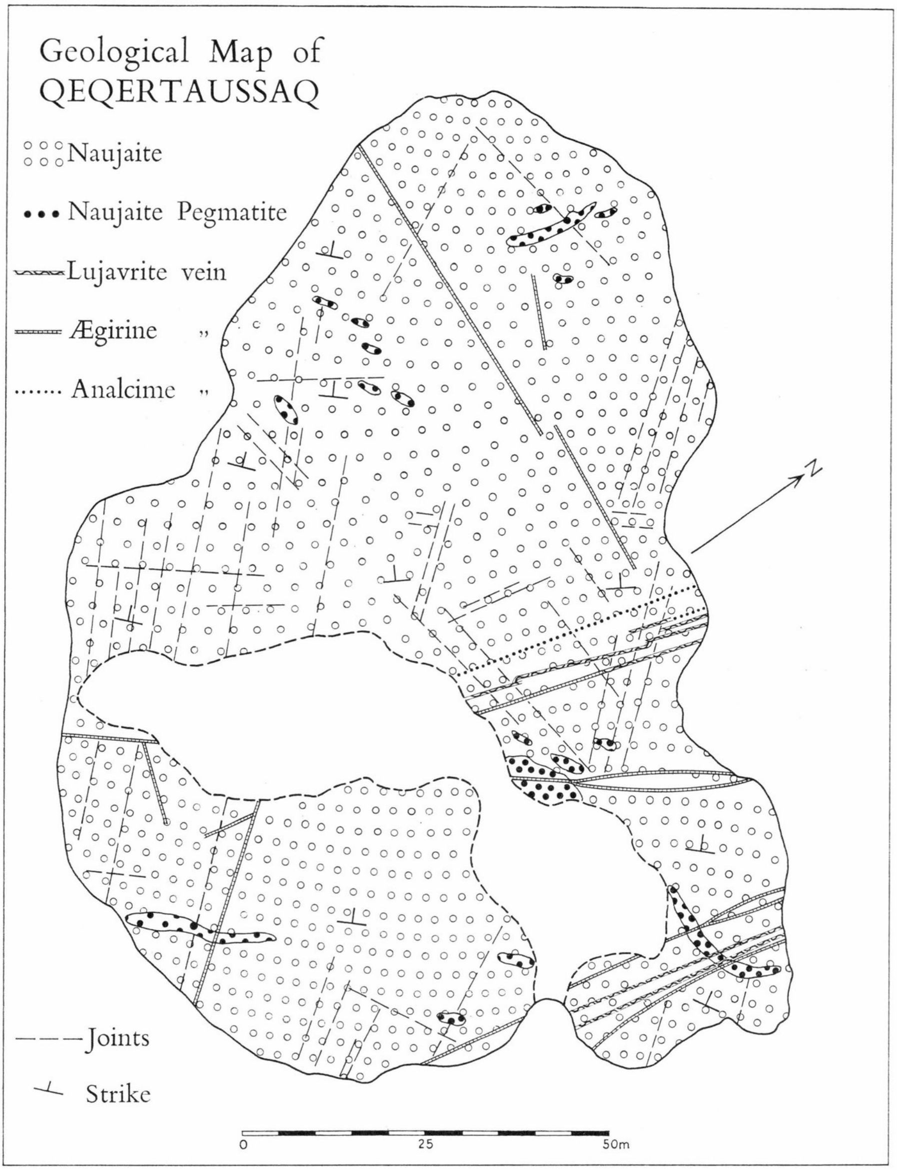

Fig. 2. Geological map of Qeqertaussaq. The thickness of the thin veins is exaggerated, the true thicknesses are a few centimetres. The multiple veins mentioned in the text are not distinguished from the black veins on the map, both vein types are indicated here by the lujavrite symbol. The trend of the naujaite banding is indicated by the strike symbols and schematically by the arrangement of the small open circles.

Fig. 3. Aerial photograph of Qeqertaussaq (Copyright the GEOLOGICAL SURVEY of GREENLAND).

At the wedge-shaped ends of the exposed part of the pegmatite there are two very conspicuous zones which are apparently conformable to the external shape of the pegmatite body, that is, almost horizontal (fig. 5). The upper zone, which may attain a thickness of 30 centimetres, is composed of large crystals of white microcline, arfvedsonite, ægirine, eudialyte, nepheline, sodalite and lepidolite. The lower zone, up to 50 centimetres thick, is very rich in eudialyte which makes up 80 $^0/_0$ or more of the rock. The eudialyte of the lower zone forms crystals up to a few centimetres across. The intercrystal areas of the eudialyte are occupied by arfvedsonite, ægirine, ænigmatite, nepheline, sodalite, microcline, albite and sphalerite. Locally there are in this zone dark patches rich in prismatic crystals of ægirine. These patches may also be developed as a network in the eudialyte zone and they are then associated with green felt-like ægirine. The eudialyte has developed crystal faces towards the ægirine rock.

The upper zone is, in places, separated from the overlying naujaite by a thin horizontal parting. The eudialyte zone may have sharp borders

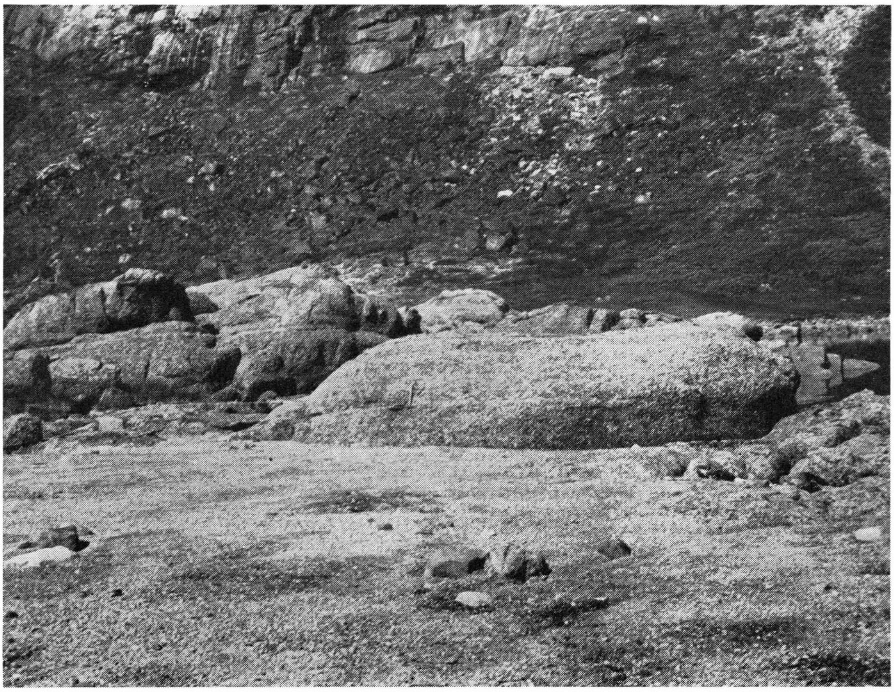

Fig. 4. Banding in naujaite, Qeqertaussaq.

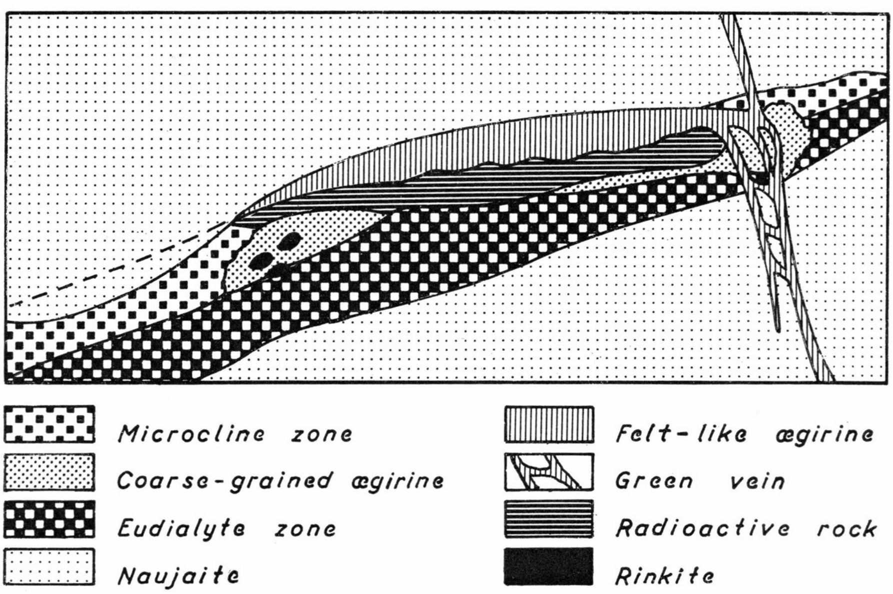

Fig. 5. Sketch of the central part of the pegmatite on the south coast of Qeqertaussaq. Compare fig. 6, USSING (1911, fig. 3), and DANØ and SØRENSEN (1959, fig. 2).

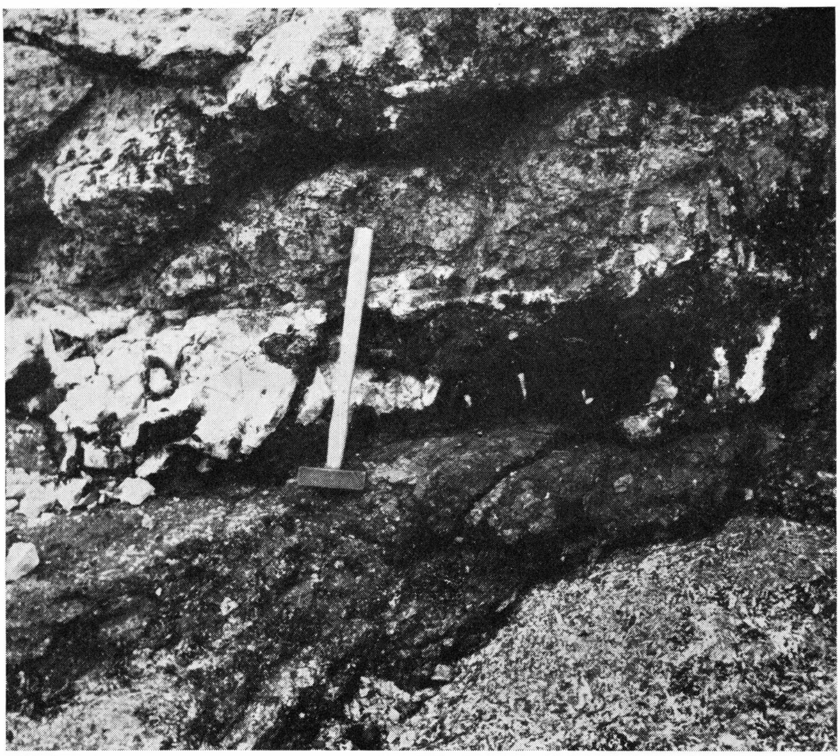

Fig. 6. Detail of fig. 5. The coarse-grained microcline rock occurs to the left of the hammer, the coarse-grained ægirine with rinkite to the right. The eudialyte zone is the dark rock below the head of the hammer. Bottom left: a gradual transition from the eudialyte zone into the underlying naujaite; top right: ægirine felt and the radioactive rock.

or gradual transitions into the underlying naujaite which is very rich in eudialyte (fig. 6).

The lower zone is developed all along the lower border of the pegmatite. The upper zone is best developed at the ends of the pegmatite; the central part of the latter only containing a few small patches of the coarse-grained rock along the upper border.

The upper microcline-rich zone is separated from the central and thickest part of the pegmatite by a black rock composed of prisms of ægirine, several centimetres long, intergrown in an irregular way. This rock has scattered large white plates of microcline and also large grains of arfvedsonite. In the interstices between the prisms of ægirine are sodalite, nepheline, albite, analcime and lepidolite. Eudialyte and sphalerite are present in subordinate amounts. There are groups of radiating ægirine needles, patches of felt-like ægirine and fine-grained zones recalling the radioactive rock to be mentioned below.

In a restricted area the ægirine rock contains groups of brownish-yellow prisms of rinkite which may attain a length of two centimetres (fig. 6). Rinkite also occurs in the eudialyte zone adjacent to the ægirine rock and is here confined mainly to the network containing large prisms of ægirine. Associated with the rinkite are sphalerite, pyrochlore, igdloite, neptunite, molybdenite, galena and natrolite. The latter mineral is especially present as crystals and fine-grained crusts in small cavities.

Between the two masses of coarse-grained ægirine rocks and above the lower eudialyte zone there are, in the central part of the pegmatite, two zones which wedge out to both sides in the exposure. The upper zone, which attains a thickness of 30 centimetres, is composed of green, felt-like ægirine with a few larger prisms of ægirine, which may be broken, and white spots of microcline, analcime and natrolite. In cavities there are small stout prisms of natrolite (BØGGILD, 1953, p. 399) and brown to black crusts of manganese oxide. The green zone is separated from the overlying naujaite by a fracture and it wedges out towards the southwest into a fracture in the naujaite immediately above the upper part of the pegmatite. Towards the northeast the zone wedges out in the coarse-grained ægirine rock. The lower border of the green zone is slightly folded (cf. figs. 5 and 6) and the rock shows a lineation normal to the almost horizontal border.

Below the green rock there is a 10–20 centimetres thick zone of a white to brown strongly radioactive rock. Natrolite makes up a large part of the rock and forms the crystals in miarolitic cavities. There are crusts of very fine-grained and layered natrolite in some of the cavities. Further major constituents are analcime, large white plates of microcline, white patches of dense albite, a good deal of slender prisms of ægirine (often arranged in stellate groups), large flakes of lepidolite and crystals of steenstrupine, up to half a centimetre across. Minor constituents are sodalite, sphalerite, neptunite, igdloite and monazite.

There are inclusions of felt-like ægirine in the upper part of the radioactive rock and of eudialyte in the lowermost part. Thus, the radioactive rock appears to replace the overlying green rock and the underlying eudialyte rock.

The radioactive rock borders on both sides of the exposure on the coarse-grained ægirine pegmatite mentioned above and it is often separated from the underlying eudialyte rock by a thin zone of coarse-grained ægirine pegmatite with microcline (in large tabular grains), eudialyte, ægirine (in radiating groups of slender prisms or in larger prismatic crystals), steenstrupine and fine- to medium-grained patches of natrolite.

The lower zone of eudialyte, in the central part of the pegmatite, is rich in thin, usually horizontal veins of felt-like ægirine with small grains of steenstrupine, pyrochlore, igdloite, neptunite and katapleite. Barren fissures are also present. There are many cavities with crusts of natrolite and small crystals of ægirine and lepidolite. The eudialyte zone contains, in this place, a network of large prisms of ægirine with minor amounts of natrolite, sphalerite and steenstrupine.

The coarse-grained ægirine rock in the northeastern part of the pegmatite is cut by thin irregular veins of felt-like ægirine which are connected with the felt-like ægirine in the top part of the pegmatite and also with a more regular vertical vein, a few centimetres thick, which cut the pegmatite as well as the adjoining naujaite. The coarse-grained rock is very rich in steenstrupine around the green veins, while this mineral is rare to absent away from the veins. The crystals of steenstrupine are half a centimetre or more across. This steenstrupine-bearing rock further contains large grains of sphalerite (up to one centimetre across), lepidolite, analcime, natrolite and small grains of galena. Steenstrupine also occurs in the green veins, but only as minute brown spots.

The vertical green vein is composed of felt-like ægirine which is often arranged in sinuous streaks perpendicular to the borders of the vein. Natrolite is also a macroscopic constituent, partly in the groundmass and partly as crystals in cavities.

The pegmatite on the east coast of the island: This pegmatite is, as the one just mentioned, lens-shaped and conformable to the banding of the naujaite (see Sørensen, 1958, fig. 14). It is composed of an upper very coarse-grained zone of large white tabular grains of microcline, etc., an intermediate incomplete zone rich in large prisms of ægirine and a lower zone rich in eudialyte, but contrary to the above-mentioned pegmatite there is no development of zones of ægirine felt and of the radioactive rock.

The upper zone consists, in addition to the microcline, of large prisms of arfvedsonite, large grains of green sodalite, ægirine, nepheline, eudialyte and scarce grains of rinkite. The prisms of arfvedsonite have inclusions of eudialyte and rinkite.

The prismatic grains of ægirine in the central part of the pegmatite are several centimetres long and do not show preferred orientation. The rock contains a considerable amount of crystals of rinkite, up to two centimetres long, and a few grains of eudialyte. Natrolite occurs in larger brown, dense masses with inclusions of eudialyte and rinkite, and in groups of tiny fibrous crystals in cavities.

The eudialyte of the lower zone has interstitial grains of nepheline, analcime, ægirine and microcline. Natrolite occurs as dense masses and as small crystals in cavities.

The thin veins: The naujaite and its pegmatites are cut by a number of thin veins which are from a few millimetres to a few centimetres thick. There are white veins of natrolite and analcime (which will not be described from this locality since they are very thin and inconspicuous), green veins of felt-like ægirine, black veins, and a type of "multiple" veining with green and black components. The veins are almost rectilinear, but can bend and branch. One *en echelon* structure has been observed (SØRENSEN, 1958, fig. 15). The naujaite adjacent to these veins is often of a bleached appearance.

The green veins are often almost entirely composed of felt-like ægirine. There are, however, patches containing considerable amounts of light coloured minerals which, in cases, are seen to be remnants of deformed naujaite minerals.

The fibres and needles of ægirine are either arranged in an irregular felt-like fashion or they show a more or less perfect parallel arrangement. The latter mostly parallels the strike of the veins, but curving lines almost normal to the strike of the veins can also occur. The green rock is sometimes schistose with wavy and silky-glistening surfaces.

In parts of the veins the green felt-like rock is only present as discontinuous stringers in rocks which are either dense and dark, or composed of lath-shaped areas of natrolite in a matrix of ægirine felt. Areas of analcime and natrolite appear to replace the green rock.

Some veins have small flakes of lepidolite. Small crystals of natrolite occur in the cavities.

Very thin green zones branch out from the veins and cut the minerals of the adjacent naujaite.

Several varieties of **black veins** are present. The main types are: dense, black rocks without macroscopic light coloured minerals and without parallel structures; fine-grained arfvedsonite lujavrites with small laths of feldspar attaining a length of about one millimetre and either arranged parallel to the strike of the veins, or randomly; black rocks with lath-shaped areas of natrolite, up to one centimetre long, showing no preferred orientation. Finally, in some veins composed mainly of light coloured minerals there are thin and discontinuous zones of very fine-grained dark rocks. The light coloured parts of these veins are rich in flakes of astrophyllite and also contain small pink areas of beryllium sodalite.

The black veins contain a few small blue grains of sodalite with white rims of natrolite and there are locally considerable amounts of analcime and natrolite which appear to replace the black rocks. Steenstrupine occurs as small scattered crystals and there are a few grains of eudialyte where the veins cut naujaite and pegmatites rich in that mineral.

The "**multiple**" **veins** are composed of black, green and light coloured rocks and also contain patches of deformed naujaite. The different rock types alternate along and across the veins. The black rocks contain inclusions of the green components of the veins in the form of *boudin-* or *pinch-and-swell*-like masses. These inclusions appear to wedge out into the black rock. The black rocks generally occupy the marginal parts of the veins, although they may be lacking for shorter or longer distances. Where they are absent there is often a coarse-grained rock with large prisms of arfvedsonite normal to the borders of the veins.

The black rocks have small laths of feldspar, up to one millimetre in size, and often orientated parallel to the strike of the veins.

The green components are dense and felt-like, but varieties with a considerable quantity of light coloured minerals also occur.

Where the black rock is lacking in the borders of the veins its place may be taken by green rocks with black spots of arfvedsonite.

The light coloured rocks are composed of albite, analcime and natrolite and they contain a considerable amount of astrophyllite in grains up to one centimetre across.

Structure: The naujaite of Qeqertaussaq is highly jointed. The joints show branching and *en echelon* arrangement and can only be followed for short distances.

There is a very pronounced set of joints parallel to the almost horizontal banding of the naujaite. The conformable pegmatites are parallel to this set.

Second in importance is a joint set striking N 120–150° and with steep southwesterly dips. A third joint set strikes N 70–95° and dips steeply south. Finally, there are a few joints striking N–S having steep easterly dips.

All the black veins, all the "multiple" veins and most of the green veins have strikes between N–S and N 30° with steep east and south-easterly dips. A few green veins are directed E–W with steep southerly dips and one green vein strikes N 150° having a steep northeasterly dip.

It is thus seen that there are a few pegmatites in the horizontal joint set, one green vein in the NW–SE set and a few green veins in the E–W set. There are very few joints parallel to the majority of the veins, which are diagonal to the two steep joint sets (fig. 2). It should however be noted that the bleached naujaite adjacent to the veins is cut by closely spaced fractures parallel to the latter.

Radioactivity: The radioactivity of the rocks were measured in the field with a Philips portable ratemeter. The background readings over the water of the fiord gave approximately 25 counts/min.

The naujaite is weakly radioactive with 40–60 counts/min., the highest radioactivity occurring in the eudialyte-enriched bands.

The eudialyte zones of the pegmatites are slightly more radioactive with 1–3 counts/sec.

The radioactive rock of the pegmatite of the south coast is the most radioactive rock of the island with 40 counts/sec.

The radioactivity of the thin veins (2–15 counts/sec.), is higher than that of the naujaite and the eudialyte zones of the pegmatites. In two veins, namely the green vein cutting the pegmatite of the south coast and the westernmost vein cutting the pegmatite of the east coast, there is a pronounced increase in radioactivity where the veins cut the eudialyte zone of the pegmatites. The two veins give 2–5 counts/sec. in naujaite and 7–30 counts/sec. in the eudialyte zone, the highest value being found in the steenstrupine-bearing rock around the vein in the pegmatite of the south coast.

No laboratory measurements and no chemical analyses have been carried out on samples of these rocks. However, an autoradiographic examination of thin green veins in eudialyte crystals from the pegmatite of the south coast displayed a higher radioactivity than those veins occurring in other minerals of the rock (BUCHWALD and SØRENSEN, 1961, p. 12).

III. THE HEAD OF KANGERDLUARSSUK

At the head of Kangerdluarssuk, to the north of Lilleelv, a pegmatite and a few veins of more fine-grained rocks occur in the naujaite. The exposures are rather incomplete due to the crumbling nature of the naujaite.

The pegmatite occurs in the shore cliffs a little to the north of Lilleelv (Ussing, 1911, p. 36). It is up to half a metre thick and has a slight northerly dip. It is composed of a lower zone rich in eudialyte and an upper zone rich in large crystals of microcline, arfvedsonite and ægirine. Further constituents in both zones are: nepheline, sodalite, lepidolite, sphalerite, schizolite, albite and molybdenite. The pegmatite wedges out southwestwards into the naujaite, the northern end is covered by scree. In the upper part of the pegmatite there are light coloured areas rich in albite and/or analcime and with large prisms of ægirine, patches of felt-like ægirine and flat crystals of steenstrupine (up to three centimetres across). In the central part of the pegmatite, just above the eudialyte zone, there is a concentration of steenstrupine in a dark rock rich in large prisms of ægirine. This rock also contains large grains of eudialyte penetrated by the ægirine. The groundmass of the dark rock is composed of analcime, natrolite, small black needles of ægirine and green ægirine felt. There are rust coloured pseudomorphs after eudialyte which, according to the X-ray examination, are composed mainly of monazite. The pseudomorphs are associated with steenstrupine. The rock has large grains of sphalerite.

The light coloured rocks in the upper part of the pegmatite are of several types. Some rocks rich in albite are sugary-grained and contain long prisms of ægirine, up to ten centimetres in length, and locally a large number of small black needles of ægirine a few millimetres long. Eudialyte occurs as large rounded grains or as tiny spots less than one millimetre across. Yellowish brown pseudomorphs after eudialyte are generally of a size intermediate between those of the two types of eudialyte just mentioned. Further constituents are large flakes of lepidolite, patches of ægirine felt and small brown crystals of steenstrupine, a few millimetres across.

In the sugary-grained rock there are patches and streaks of a more coarse-grained rock composed of bladed crystals of albite, a few millimetres across. The interstices between the blades of albite are empty. Enclosed in this rock are large prisms and small needles of ægirine, large grains of eudialyte, brown pseudomorphs after eudialyte, flakes of lepidolite and large crystals of steenstrupine. The last-named mineral is, in a few places, seen to form rims around grains of eudialyte and around pseudomorphs after that mineral. The bladed rock has patches of ægirine felt which may be folded and even S-shaped. The rock composed of felt-like ægirine thus appears to have been deformed and subsequently replaced by albite. The ægirine felt is rich in small brown crystals of steenstrupine, a few millimetres across, and it also contains sphalerite, molybdenite and small pseudomorphs after eudialyte. Unaltered eudialyte has not been observed although it occurs in the adjacent albite rock.

Parts of the white rock are rich in analcime which contains inclusions of nepheline and microcline. Further components are large prisms of ægirine, large grains of eudialyte, pseudomorphs after that mineral, steenstrupine crystals, sphalerite and black ore. Some of the ægirine occurs in radiating groups of slender prisms. Fine-grained masses of white natrolite are prominent.

The thin veins nos. 1 and 2: The pegmatite and the enclosing naujaite are cut by two green veins. The most southern of these is 15 centimetres thick and strikes N 75° having a steep northerly dip. The vein is composed of ægirine felt with patches of analcime and albite. There are small inclusions of naujaite and the latter rock is, adjacent to the vein, rich in small fissures filled with ægirine felt. The vein cuts the eudialyte zone of the pegmatite, but does not contain any visible steenstrupine.

Two metres to the north of this vein there is a second vein with the same strike and dip, but 30 centimetres thick. It is green and schistose with natrolite-filled cavities, small dense masses of steenstrupine and small grains of eudialyte and sphalerite. In the lower part of the exposure the vein is composed of a black lujavritic rock which is very fine-grained and with small laths of feldspar. There are small inclusions of felt-like ægirine and the rock is blackest adjacent to these. The lamination of the black rock is mainly parallel to the strike of the vein, but it is very irregularly developed because of the green inclusions.

Vein no. 3: Just to the north of the pegmatite there is a third vein which can be followed, with interruptions, over a distance of about

250 metres (no. 18467 in fig. 1). It is up to one metre thick and strikes N 85° with a northerly dip of 75°. The vein is best studied in the small brook to the north of Lilleelv. About 50 metres to the east of the vein there are true lujavrite veins in the naujaite.

The vein is of a rather complex nature and may be termed multiple or composite. Along the contacts there are generally coarse-grained rocks and the central part of the vein is composed of dense, green or black lujavritic rocks with inclusions of the coarse-grained rocks and also of altered naujaite. Similar dense rocks may occur locally along the contacts of the vein and then enclose patches of the coarse-grained rocks.

The predominant coarse-grained rock has large prisms of arfvedsonite, several centimetres long, in a groundmass of analcime and microcline with small spots of yellow eudialyte and radiating groups of arfvedsonite needles. The prisms of arfvedsonite are often orientated normal to the contacts of the vein. This rock type is often separated from the central fine-grained components of the vein by thin green zones of ægirine felt which display surfaces of movement.

Associated with this arfvedsonite-rich rock are a few other types of coarse-grained rocks. One type has numerous crystals of eudialyte, up to half a centimetre across, and a large amount of more or less altered nepheline in a groundmass of analcime and natrolite. Arfvedsonite is rare. There are strong concentrations of eudialyte at the contacts with the other rocks.

Another type of coarse-grained rock has small unorientated prisms of ægirine in an albitic groundmass with small spots of eudialyte.

The fine-grained, lujavritic rocks of the central part of the vein are also of a rather varied appearance. They may be green and laminated with small brown crystals and larger brown masses of steenstrupine. The latter may be several centimetres long and a few centimetres thick. Eudialyte occurs in some rocks, but not in all. There are inclusions of the coarse-grained rocks and of deformed naujaite, the inclusions may show folding. The lamination of the green rocks is conformable to the inclusions and it may be developed as a peculiar "fluxion" banding. Slickensided surfaces also occur. The inclusions of coarse-grained rocks are cut by slickensides and by thin lujavritic zones with small brown crystals of steenstrupine. The latter zones are most coarse-grained in contact with the inclusions.

The black fine-grained rocks in the central part of the vein, appear to replace the green rock.

Aggregates of small prisms of schizolite occur in the fine-grained rocks.

Where the fine-grained rocks extend to the borders of the vein they can be separated from the adjoining naujaite by a thin zone of analcime with slickensides. In contact with the latter the fine-grained rock has a dark millimetre-thick steenstrupine-bearing zone.

The naujaite adjacent to the vein is rich in eudialyte. It is strongly bleached and is cut by several thin veins of felt-like ægirine. The largest of these veins, which may attain a thickness of 15 centimetres, are rich in eudialyte and resemble a crushed type of the coarse-grained rocks from the vein. They may represent crushed apophyses from the large vein.

Vein no. 4: In the northeast corner of Kangerdluarssuk there is, at a short distance to the north of Lilleelv and about 300 metres from the coast, a fourth green vein in the naujaite (no. 18468 in fig. 1). It is up to one metre thick and only exposed for ten metres, the surface of the ground being covered by boulders and gravel of naujaite. The strike varies from N 73° in the eastern end of the exposure to N 100° in the western end, the dip being very steep. The vein forms a short ridge in the crumbling naujaite as shown in fig. 3 in DANØ and SØRENSEN (1959).

The adjacent eudialyte-bearing naujaite is rather crushed with fractures parallel to the strike of the vein. There are also cross-cutting thin green veins rich in felt-like ægirine.

The main part of the vein is composed of a green, very fine-grained rock with scattered black needles of ægirine, up to two millimetres long, and small grains of steenstrupine about one millimetre across. There is a poor lamination parallel to the strike of the vein. Irregular fractures in the green rock are covered by black powder.

Parts of the green rock, especially in the marginal zones, have closely spaced spheroidal nodules, up to one centimetre in diameter. They are grey in the cores and have thin white rims. The matrix between these nodules is composed of the fine-grained green rock with thin black prisms of ægirine and small brown crystals of steenstrupine. The needles of ægirine wrap the nodules.

The western end of the vein is developed as a black lujavrite-like rock which is composed of rather indistinct light coloured nodules, of the type mentioned above, enclosed in a darker matrix with small crystals of steenstrupine. The black rock is strongly sheared.

Scattered over the green and black rocks are brown patches with large prisms of ægirine, several centimetres long, and crystals and aggregates of crystals of steenstrupine in a more dense brown matrix. The patches vary in size from very small areas to masses ten centimetres or more long and several centimetres thick. The patches have small areas of purple ussingite with cavities formed through the weathering of grains of sphalerite. The brown rocks have flakes of lepidolite and small grains of sphalerite and galena.

Along the margins of the vein there are several small light coloured areas with grains of eucolite, prisms of ægirine, and in addition ussingite, chkalovite, albite and sphalerite. Steenstrupine is not seen in the hand specimen in contact with the eucolite, but the eucolite-bearing areas are generally separated from the green rock by brown zones rich in steenstrupine and prisms of ægirine.

IV. THE NORTH COAST OF TUNUGDLIARFIK

Two small areas on the north coast of Tunugdliarfik were selected for detailed studies, namely the two small points of *Igdlúnguaq* and *Tugtup agtakôrfia*. Also, a few horizons of steenstrupine-bearing lujavrite were studied in some detail.

The part of the coast in question is made up of rocks belonging to the so-called "breccia zone" (Ussing, 1911, p. 36). This zone is very well exposed on some of the small points of the coast section (to be treated here) and also in the steep mountain slopes facing the fiord (figs. 7 and 8). Rather large parts of the slopes and of the coast are, however, covered by scree and moraines.

The breccia zone is composed of lujavrites with inclusions of naujaite. The lujavrites are mainly black, but green and brown varieties also occur. The lamination is well pronounced and may grade into a well-developed schistosity. The lamination is horizontal or nearly so.

The inclusions of naujaite are conformably enclosed in the lujavrite and occur as *boudin*-like bodies in restricted horizons of the latter rock (fig. 26). It appears as if large layers of naujaite have been intruded by the lujavrite. Some rotation and deformation of the inclusions has taken place during this process and the enclosing lujavrite may be folded adjacent to the inclusions.

In the westernmost part of the coast section in question there are a great number of inclusions of coarse-grained syenite in the lujavrite. They are composed of microcline with numerous small needles of pectolite and of aggregates of small needles of soda amphibole. The latter may be pseudomorphs after pyroxene and the inclusions may therefore be strongly altered augite syenite of the type found in the marginal zone of the Ilímaussaq complex. The inclusions vary in size from few centimetres to many tens of metres. They can be situated adjacent to inclusions of naujaite and are apparently in a stage of dissolution in the lujavrite.

The breccia zone is overlain by naujaite in the upper part of the mountain wall and in the bay to the east of Igdlúnguaq (cf. Ussing, 1911, pl. 6).

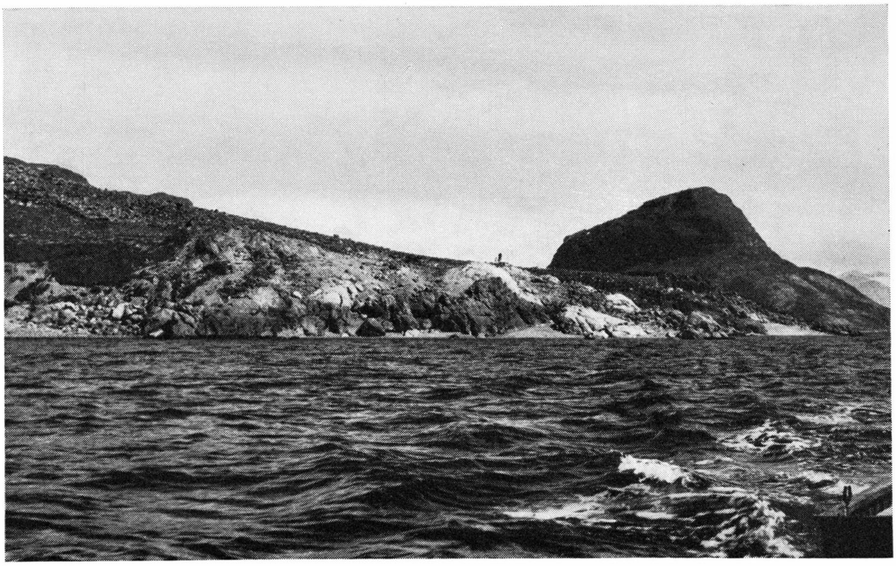

Fig. 7. The southwest point of Igdlúnguaq, as seen from the west. The Nunasarnaq mountain in background is in its lower part composed of lujavrite with inclusions of naujaite, the upper part is composed of lavas.

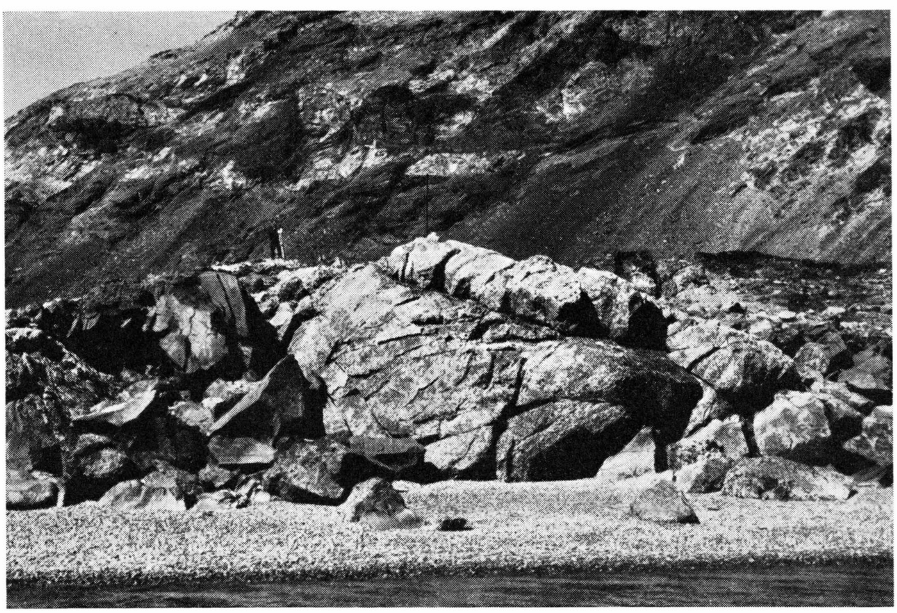

Fig. 8. The southwest point of Igdlúnguaq as seen from the east. The distinct slightly inclined fracture in the centre of the photo is a brown vein in a naujaite lens (cf. plate 1). In the mountain wall behind Igdlúnguaq naujaite inclusions in lujavrite can be seen.

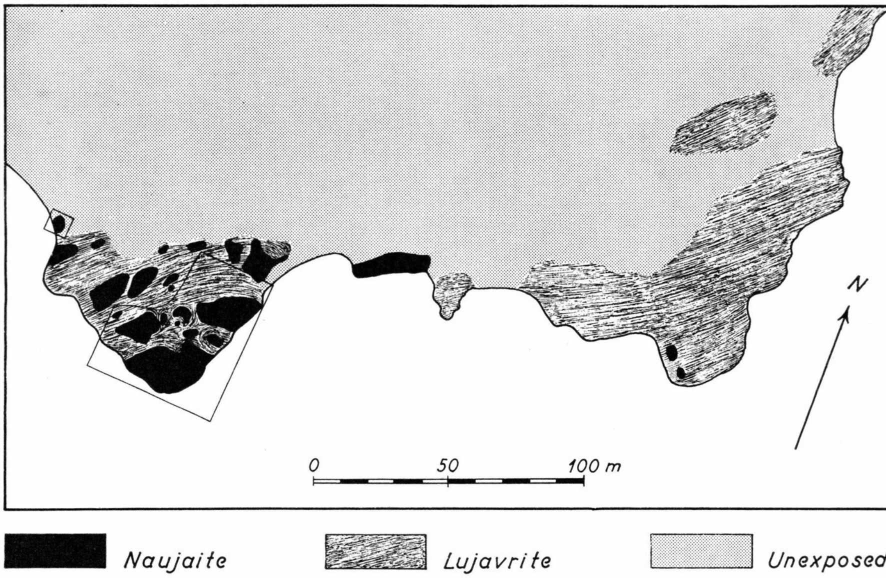

Fig. 9. Sketch map of Igdlúnguaq. The areas represented in the maps of fig. 23 and plate 1 are indicated by the two frames.

Igdlúnguaq.

Igdlúnguaq is a small "peninsula" on the north coast of Tunugdliarfik. It is covered by gravel, scree, etc. except for a rather thin zone along the shore. There are, as shown in fig. 10, two small points, an eastern made up of lujavrite with very few inclusions of naujaite and a western composed of naujaite veined by lujavrite. Two small areas were selected for detailed work, namely the western point (or rather southwestern), which was mapped in a scale of 1:100 (plate 1), and a small area on the west coast of Igdlúnguaq, which was mapped in the scale of 1:50 (fig. 23). The location of these two areas is indicated in fig. 9.

The description of Igdlúnguaq will be divided into three sections:

1. The southwestern point.
2. The small area on the west coast.
3. The easternmost part of Igdlúnguaq.

1. The Southwestern Point of Igdlúnguaq.

The geology of this area is shown in the map of plate 1. The major part of the area is occupied by naujaite which is enclosed in and veined by black lujavrite.

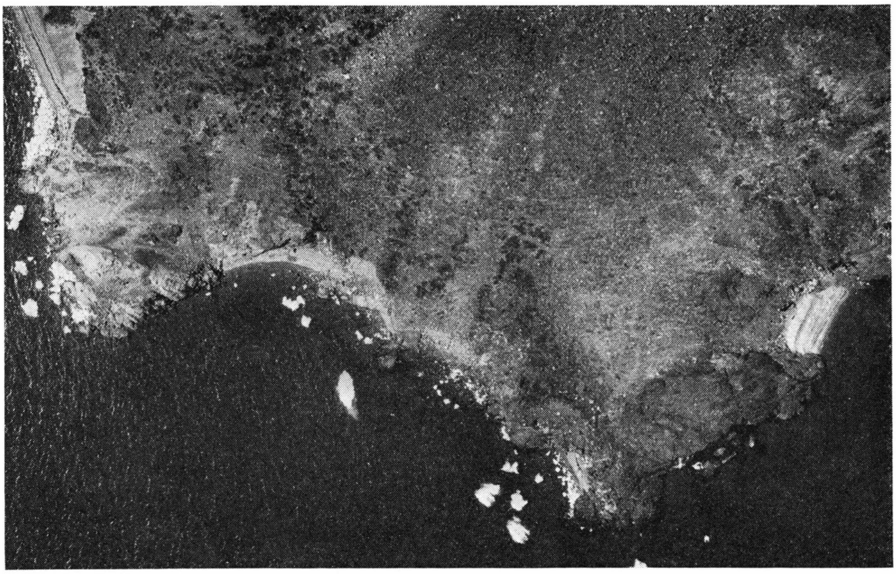

Fig. 10. Aerial photograph of Igdlúnguaq (Copyright the Geological Survey of Greenland).

The naujaite in this locality is very light coloured and of a bleached appearance. The naujaitic texture with the many small crystals of green sodalite enclosed in larger grains of microcline, ægirine and eudialyte is very pronounced. The small grains of sodalite are 0.2 to one centimetre across. The sodalite of this rock type is green, but there are also rocks extremely rich in grey sodalite, so rich that they may be termed sodalitites. Some rocks have large, non-poikilitic grains of grey nepheline. The light colour of the naujaite is caused by a large content of analcime and natrolite and the naujaite is generally most "bleached" adjacent to the lujavrite.

Banding in the naujaite has been observed in a few places (see fig. 20 and Sørensen, 1958, fig. 4). The bands are black, red or white according to the proportion of ægirine, eudialyte and microcline. All bands have the characteristic poikilitic texture with numerous small grains of sodalite enclosed in the above-mentioned minerals. There are gradual transitions between the bands which wedge out into unbanded naujaite. They can only be followed over distances of a few metres. In a few cases a banding succession from black to red to white has been observed (as in the kakortokites), but banding is generally less regular with alternating dark and light coloured bands. The dark bands are then richer in eudialyte than the light coloured ones.

The white bands from a banded sequence in the eastern part of the area in question continue towards the south into unbanded naujaite where they have the appearance of veins, since they cut small pegmatites in the naujaite (fig. 18). The white "veins" are in turn cut by lujavrite. The white rock is mainly composed of microcline with poikilitic inclusions of sodalite.

The pegmatites in the naujaite are small and rare. They form small lens-shaped patches and are mainly composed of large grains of microcline and arfvedsonite (fig. 18).

There are all transitions from thin veins of lujavrite to larger masses enclosing the naujaite.

The lujavrite is black, fine-grained and with a more or less pronounced lamination parallel to the borders on the inclusions of naujaite or parallel to the strike of the veins. The lamination is generally steep. At the ends of the inclusions of naujaite the lamination of the lujavrite may be normal to the border between the two rocks. Large areas of the lujavrite are without lamination. Lineation is rare.

The lujavrite in contact with the naujaite generally has developed a thin black zone up to a few centimetres thick. The black zone is rich in arfvedsonite which may form prisms normal to the border. Patches of acmite and scattered small grains of steenstrupine, green sodalite and blue apatite are common in the black rock (fig. 11 and SØRENSEN, 1958, fig. 13).

The lujavrite is of a rather homogeneous and fine-grained variety, the grain size varying from a fraction of a millimetre to a few millimetres. Banding is rare, but white streaks and peculiar "spheroids" surrounded by white rims occur in places (cf. USSING, 1911, p. 82). The white streaks are rich in nepheline, the spheroids are often more dark coloured than the surrounding lujavrite and the white rims are rich in analcime. The spheroids are flattened parallel to the lamination of the lujavrite and are up to 20 centimetres in diameter (fig. 12).

The lujavrite is locally rich in miarolitic cavities.

The banding of the naujaite in the north-eastern part of the area is cut by the lujavrite (SØRENSEN, 1958, p. 19, fig. 10). The lujavrite here has white stringers in continuation of the banding and also contains recrystallized inclusions of naujaite (fig. 12).

A special border type between naujaite and lujavrite occurs in the northeastern part of the area just outside the map of plate 1. The lujavrite is underlain here by naujaite and is separated from the latter by an almost flat-lying zone with a northerly dip of 20°. This border zone consists of a light coloured rock which has structural relics of naujaite. The overlying lujavrite encloses "drop-like" areas of the light coloured rock.

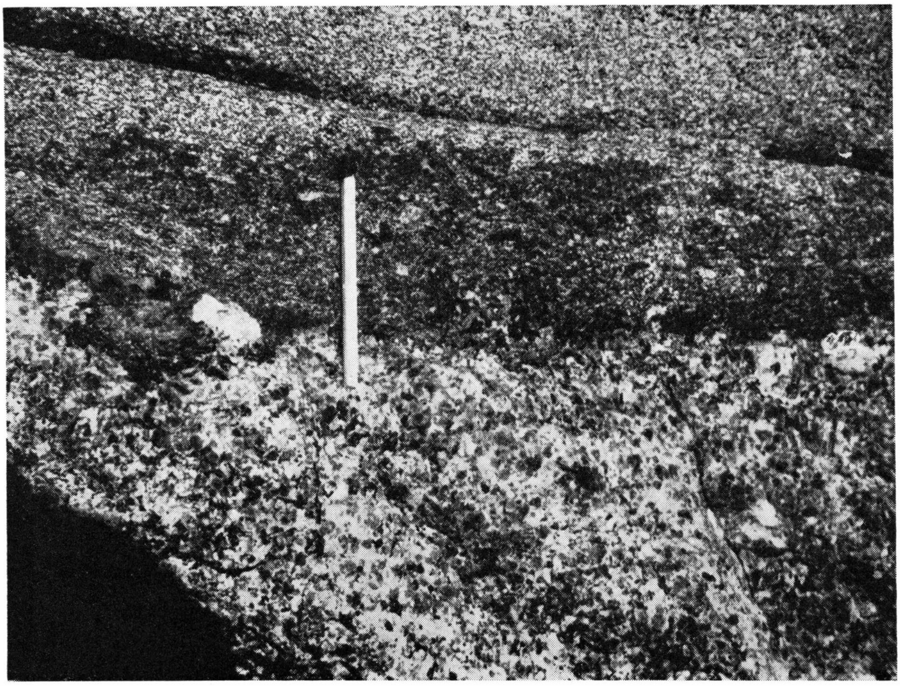

Fig. 11. Border between lujavrite and naujaite at I.5 of plate 1. Note the dark colouration of the lujavrite adjacent to the naujaite, and the small sodalite crystals (grey) in the naujaite. The match is 4.5 cm. long.

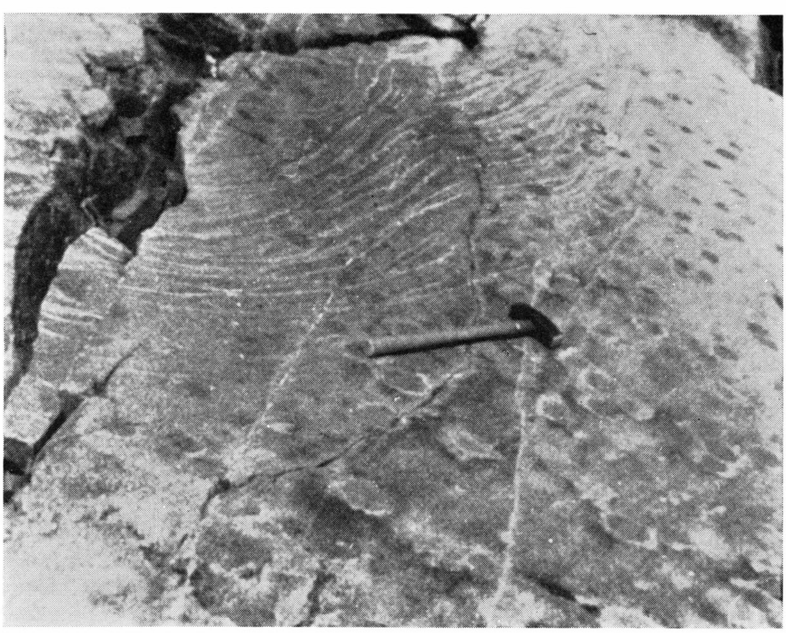

Fig. 12. White stringers and spheroids in the lujavrite to the north of the map area indicated by plate 1. These stringers are contiguous with the adjacent naujaite bands (see Sørensen, 1958, fig. 10).

The veins of lujavrite cutting the naujaite vary in thickness from a few centimetres to several metres as is seen in plate 1 (fig. 13). They often contain small grains of sodalite of the type found in the naujaite. The veins have coarse-grained patches with gradual transitions into the normal fine-grained lujavrite. The patches have large prisms of arfvedsonite and in places closely spaced rounded grains of nepheline up to one centimetre across. These grains recall, as to shape and distribution, the sodalite of the naujaite. The coarse-grained patches and the surrounding lujavrite can have scattered flat crystals of steenstrupine which are most often arranged parallel to the lamination of the lujavrite, but there are cases of orientation normal to the lamination. The crystals of steenstrupine are up to two centimetres across. The coarse-grained patches contain small grains of igdloite.

At **F. 6** of plate 1 it is seen that the lamination of branching veins of lujavrite in a small area is perpendicular to the border of the vein. But the lamination here is contiguous with the lamination of the lujavrite at the opposite side of the naujaite. In the naujaite there are small areas of lujavrite (too small to be indicated in the map) showing the same orientation of the lamination.

Coarse-grained patches in the lujavrite: The lujavrite often contains patches of dark coloured, coarse-grained rocks which are especially abundant around the inclusions of naujaite. They have been indicated as coarse-grained lujavrite in the map of plate 1.

These coarse-grained rocks are composed of arfvedsonite, microcline, nepheline, sodalite, analcime and sometimes eudialyte, steenstrupine and blue apatite. The large prisms of arfvedsonite are often orientated at right angle to the borders of the patches and may reach a length of about three centimetres. The small needles of arfvedsonite (less than half a centimetre long) can be arranged in star-like groups.

Some of the coarse-grained rocks are almost exclusively composed of arfvedsonite and nepheline. The latter mineral has a similar distribution as the sodalite in the naujaite. These rocks should most properly be termed ijolites.

The coarse-grained rocks can have inclusions and patches of naujaite which are penetrated by lujavrite. Some of the coarse-grained rocks have scattered remnants of naujaite minerals as sodalite, ægirine, nepheline, microcline, eudialyte and acmitized arfvedsonite. The enclosed naujaite is generally strongly recrystallized.

The lujavrite adjacent to the coarse-grained rocks is very dark coloured because of a high content of arfvedsonite and it can develop black border zones adjacent to these rocks as in the case of the naujaite inclusions. The lamination of the dark coloured lujavrites is very irregu-

Fig. 13. Thin lujavrite vein in naujaite at H. 7 of plate 1.

lar, but there are well-laminated zones with lamination parallel to the borders of the patches. Close to the coarse-grained rocks there are poikilitic grains of steenstrupine in the lujavrite, further away black nodules occur (up to one centimetre across). Steenstrupine and nodules may, however, occur in the same rock. The nodules are more resistant to weathering than the lujavrite and therefore appear as small balls on the weathered surfaces. In the lujavrite adjacent to the coarse-grained rocks there are, in cases, round areas made up of schizolite. These areas are up to one centimetre across.

Coarse-grained inclusions in the lujavrite: In addition to the abovementioned coarse-grained patches there are a great number of inclusions in the lujavrite. They are of two main types: naujaite and light coloured, coarse-grained rocks. The light coloured rocks are intimately associated with the above-mentioned coarse-grained rocks and they often form the marginal parts of the inclusions of naujaite in lujavrite.

The inclusions of naujaite are recrystallized to varying extent and their marginal zones are generally rich in analcime and/or natrolite. Eudialyte is lacking and steenstrupine is often present. The enclosing lujavrite has, as mentioned on p. 34, black border zones towards the inclusions and it can be penetrated by an intricate network of analcime veins branching out from the marginal zones of the inclusions of naujaite (fig. 15).

The light coloured rocks are composed of grey or green analcime, large prisms of light blue natrolite, yellow sodalite, steenstrupine, etc. and they can contain small scattered grains of green sodalite of naujaitic type. As an example of such a rock the analcime rock at **G-H. 4** in plate 1 will be described. It consists of large grains of greyish-green analcime up to five centimetres across and with a pronounced cubic cleavage, grains of yellow sodalite of the same size, prisms of bluish green natrolite several centimetres long and dense masses of pink natrolite. There are in places fairly high concentrations of steenstrupine and white stripes composed of numerous small grains of igdloite intergrown with neptunite, epistolite, yellow pyrochlore and sphalerite. Igdloite was first found in this place (DANØ and SØRENSEN, 1959). The pyrochlore forms a network between the grains of analcime. There are scattered remnants of naujaite minerals such as green sodalite, ægirine, acmite, pseudomorphs after eudialyte (often associated with steenstrupine), and there are small patches of felt-like ægirine. Parts of the rock are brown and rich in acmite.

The lujavrite adjacent to this rock is very dark coloured in the border zone and contains some acmite and patches of analcime with prisms of arfvedsonite, up to one centimetre long, and grains of steenstrupine half a centimetre across.

Parts of the coarse-grained rock in question are cut by veins of arfvedsonite-acmite up to five centimetres thick which branch out from the enclosing lujavrite. These veins are dark and dense, but with patches of fairly normal lujavrite. The veins are most coarse-grained in their central parts and have border zones rich in steenstrupine, prisms of arfvedsonite and pseudomorphs after eudialyte. The veins wedge out in an analcime-rich rock with concentrations of steenstrupine and arfvedsonite which are continuations of the borders of the veins.

Associated with the coarse-grained rock at **G-H. 4** are light coloured banded rocks of the type described on p. 42. These rocks also occur as inclusions in a coarse-grained rock with streaks of pyrochlore and bands of "out-rolled" pseudomorphs after eudialyte associated with igdloite, steenstrupine and biotite.

The largest occurrence of steenstrupine in Igdlúnguaq is situated at **J. 6** of plate 1. The steenstrupine occurs in a zone, up to 50 centimetres thick, parallel to the lower border of an inclusion of naujaite in lujavrite (fig. 14). The inclusion is about five metres across and composed of eudialyte-rich naujaite which is fairly unaltered in the central part. The marginal parts are "bleached" and rich in analcime and natrolite but with a good deal of the original sodalite preserved. Eudialyte and ægirine are generally lacking in the bleached rock but are locally found in contact with lujavrite. Thin zones of deformation rich in analcime cut the naujaite. They contain scattered grains of steenstrupine.

The enclosing lujavrite is rather massive and only shows lamination along the borders on the naujaite. The lamination is generally conformable to the borders of the inclusion of naujaite, but locally it is normal to the border. In these places the lamination is contiguous with the strike of the steenstrupine zone, as it is indicated in plate 1. The lujavrite is darkest coloured adjacent to the inclusion from which it is separated by a thin black zone. Apophyses, up to a few centimetres thick, branch out from the black rim and into the naujaite. The lujavrite contains coarse-grained patches rich in analcime and arfvedsonite, the latter in long prisms which are often arranged perpendicular to the elongation of the patches. The lujavrite adjacent to the naujaite is rich in poikilitic crystals of steenstrupine, black nodules and white spots of schizolite, all attaining sizes of about one centimetre.

The steenstrupine zone along the lower border of the naujaite inclusion only carries steenstrupine in thin zones which are up to a few centimetres thick.

Steenstrupine occurs in the largest quantity in the coarse-grained analcime rock along the border of the naujaite. The analcime rock contains remnants of naujaite minerals such as sodalite, eudialyte and large grains of nepheline, the latter often with thin rims of yellowish green sodalite.

The steenstrupine occurs in clusters of flat brown to black crystals; the aggregates are several centimetres long and the individual crystals up to one centimetre across. Associated with the steenstrupine are pseudomorphs after eudialyte, large grains of arfvedsonite, large grains of nepheline, green sodalite of naujaitic type, strongly green sodalite (which only occurs in this zone), neptunite, igdloite, pyrochlore, galena and natrolite (in small crystals and in dense pink masses of extremely fine grain size).

The steenstrupine can be separated from the naujaite by arfvedsonite and acmite, but there are cases of steenstrupine impregnating the adjacent naujaite which is then very poor in eudialyte.

Fig. 14. The naujaite inclusion, now occupied by the cave, is underlain by a steenstrupine-bearing zone from which analcime veins penetrate into the adjacent lujavrite (lower left corner). Top right and left: lujavrite. (J.6 of plate 1).

Below the analcime-steenstrupine rock there is a peculiar suite of banded rocks, the banding being parallel to the border of the naujaite. There are white, very fine-grained bands rich in nepheline and red bands which are dense or more coarse-grained. The latter have small crystals of orange yellow eudialyte, about one millimetre in diameter, in a matrix of analcime which may contain larger grains of nepheline, up to one centimetre across. The white bands also have small scattered crystals of eudialyte. The banded sequence has inclusions of naujaitic sodalite and also contains ægirine/acmite and steenstrupine in small amounts. In the banded zone there are diffuse streaks of darker rocks with small needles of arfvedsonite arranged in the plane of banding. These streaks penetrate the zone in an irregular way and sometimes come in direct

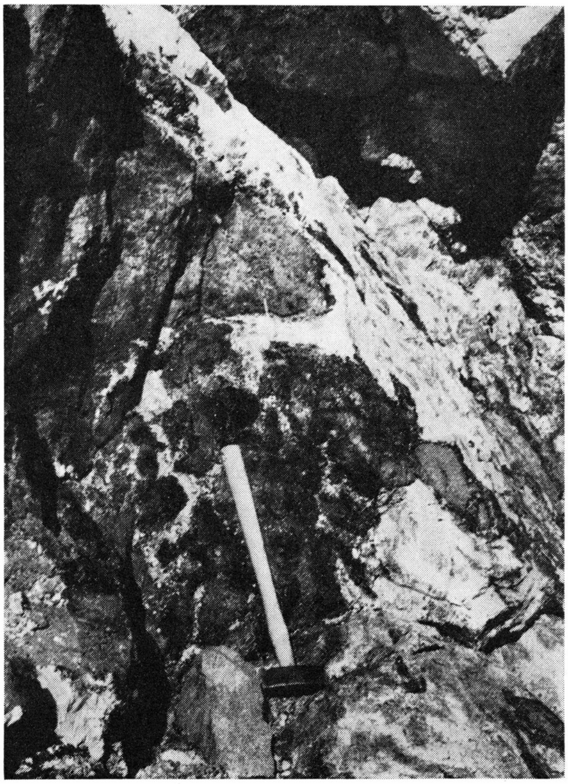

Fig. 15. Detail of fig. 14 showing veins of analcime branching out into the very dark lujavrite. These veins are too small to be indicated on the map of plate 1.

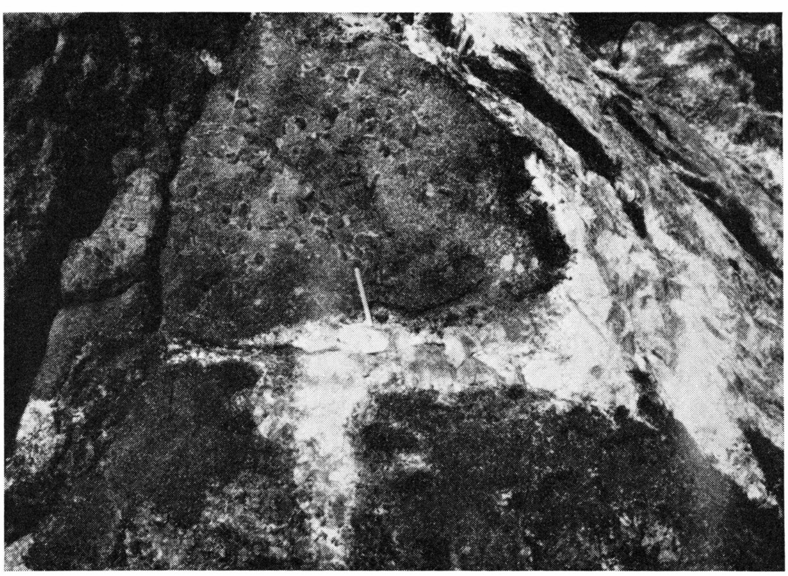

Fig. 16. Detail of fig. 15. Analcime vein with a concentration of steenstrupine and eudialyte pseudomorphs along the borders. The lujavrite is rich in poikilitic grains of steenstrupine (black).

contact with the above-mentioned steenstrupine-analcime rock. The arfvedsonite-bearing rocks contain small crystals of eudialyte, but besides there are larger pseudomorphs after eudialyte. Crystals of steenstrupine, up to one centimetre across, and grains of yellow sodalite also occur. The dark rocks show transitional stages into lujavrite and the banded zone is underlain by lujavrite with very coarse-grained patches.

The eudialyte of the banded zone is generally separated from the steenstrupine by a light coloured, eudialyte-free zone. Where these two minerals are associated the eudialyte changes colour from orange yellow to brown. The steenstrupine-bearing parts of the zone contain pseudomorphs after eudialyte.

The banded zone contains patches of naujaite with steenstrupine, analcime and natrolite between the grains of sodalite.

In places a rock composed of white analcime, yellow sodalite and steenstrupine replaces the banded zone which may then contain small grains of galena.

The above-mentioned steenstrupine zone wedges out towards the south into a lujavrite rich in altered naujaite and coarse-grained dark rocks. The lujavrite, which forms the northern continuation of the steenstrupine zone, is rich in poikilitic grains of steenstrupine and in black nodules.

Thin veins of analcime branch out from the marginal parts of the inclusion of naujaite and penetrate the lujavrite up to 50 centimetres from the border (figs. 15 and 16). The veins usually cut the lamination of the lujavrite but can be parallel to the latter for short distances. The lujavrite has developed black border zones on these veins and the latter wedge out into such black rocks with large prisms of arfvedsonite. Acmite can also occur in the border zone. The veins are mainly composed of analcime and there are often concentrations of yellow sodalite along the margins. Some veins are rich in microcline, and green sodalite may be present in the veins close to the naujaite. There are scattered grains of steenstrupine and pseudomorphs after eudialyte and these constituents form larger concentrations along the margins of the veins where they are associated with sphalerite and galena. The central parts of some veins have "out-rolled" pseudomorphs after eudialyte associated with steenstrupine. Some veins have prisms of arfvedsonite and small pink masses of dense natrolite.

The lujavrite adjacent to these veins contains large poikilitic grains of steenstrupine (fig. 16), a centimetre or more across, and further away from the veins there are black nodules.

"Dense" analcime rocks: At **G. 2** and **G. 4** of plate 1 there are banded rocks of the type described from the steenstrupine zone. At the first-

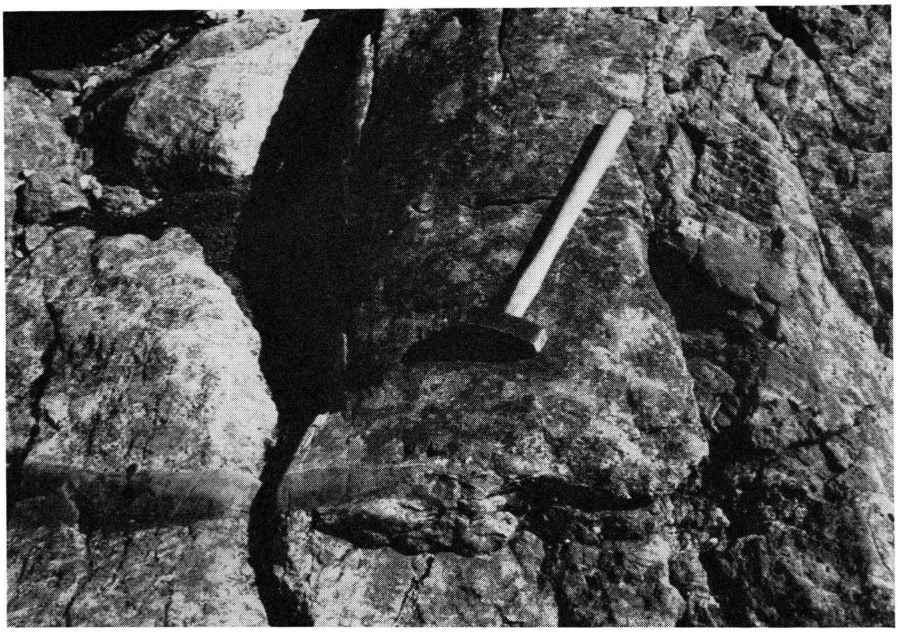

Fig. 17. In the bottom left part of the photograph a small lujavrite vein is seen (G.2, plate 1). Just below the head of the hammer this vein is connected with the east-west zone of "dense" analcime rock. The internal folding of that rock may be faintly seen to the right of the hammer handle.

named place these rocks form a vein in naujaite. The vein has alternating red and white bands, the former up to four centimetres thick, the latter mostly less than one centimetre thick. The red bands are composed of tiny crystals of eudialyte, scattered grains of nepheline (up to one centimetre across) and acmite. The white bands are more dense and are mainly composed of nepheline. The grain size of the banded rock is generally from 0.2 to 2.0 millimetres. The bands are strongly folded in parts of the vein, the folding being restricted to the interior of the vein, whilst the borders of the vein are straight and undeformed (fig. 17). In places there are small needles of arfvedsonite, a few millimetres long, in the red and white rocks. These darker rocks are laminated and sometimes show a weak lineation. The dark rocks have pure white bands which may have thin zones of eudialyte along the borders. The vein passes towards the north into a thin vein of black lujavrite (fig. 17).

At **G. 4** a similar banded rock occurs as a zone in a bleached naujaite with scattered grains of steenstrupine. There are red and white bands of the type described above, but they contain prisms of arfvedsonite arranged in the plane of the banding. The red bands often form the borders on the naujaite. There are inclusions of altered naujaite and the banded rock is associated with a lujavrite with inclusions of naujaite and coarse-grained patches. The inclusions of naujaite in the lujavrite are intergrown by the latter in such a way that single grains of eudialyte, sodalite and ægirine are enclosed in the lujavrite. The lujavrite contains star-shaped groups of needles of arfvedsonite. The lamination of the lujavrite is rather irregular.

Thin veins: The naujaite is cut by a number of thin veins which are often steenstrupine-bearing. The following main types may be distinguished: green veins of felt-like ægirine, brown veins of acmite-arfvedsonite and light coloured veins rich in analcime and natrolite.

There are only a few veins of felt-like ægirine. The most conspicuous of these runs from **I. 1** to **G. 3** in the map of plate 1. This vein is up to 10 centimetres thick and occupies a zone of deformation in the naujaite. Thus the white band mentioned on p. 33 is displaced a few centimetres along the vein (see fig. 18 and plate 1 at **G-H. 3**). The naujaite adjacent to the vein and enclosed fragments of naujaite have closely spaced fractures parallel to the strike of the vein. These fractures can have coatings of white natrolite.

The naujaite adjacent to the vein is generally very rich in natrolite and poor in eudialyte. In places, however, almost unaltered naujaite is in contact with the vein, but the eudialyte is then more brown than is usually the case in the naujaite.

There are thin stripes of green ægirine felt in the naujaite adjacent to the vein. The stripes have small brown grains of steenstrupine and are mainly restricted to the interstices between the grains of the naujaite, especially between large plates of white microcline.

The central parts of the vein are made up of a rather homogeneous rock of felt-like ægirine with white spots. There are also small fragments of naujaite with preserved eudialyte, sodalite, ægirine, etc. The fibres of ægirine are in large parts of the vein almost at right angle to the strike, but in places parallel that direction. They then "wrap" the inclusions of naujaite.

There are dense, pink masses of natrolite up to two centimetres across and also larger grains of green natrolite.

In thin zones in the central part of the vein there are rather large concentrations of steenstrupine in crystals up to one centimetre across. They are associated with yellow or grey pseudomorphs after eudialyte. There is also a slight amount of steenstrupine in the adjoining naujaite.

Some parts of the green vein resemble green lujavrite.

The vein cuts thin brown zones with acmite and steenstrupine. The

Fig. 18. Zone of felt-like ægirine cutting a white band in the naujaite (G-H.3 plate 1). Around the hammer, small patches of pegmatite occur on adjacent sides of the white band.

thin zones penetrate a short distance into the vein and may be traced across the latter as a row of small crystals of steenstrupine.

The green vein wedges out towards the north into recrystallized naujaite.

At **E. 6** and **F. 3** two other green veins occur in the border between naujaite and lujavrite. The last-named rock has developed black border zones along the naujaite and vein contacts.

In the last-mentioned of the two localities the green vein, which contains scattered crystals of steenstrupine, is situated inside the naujaite, but in a few places inclusions of naujaite and green vein rock are found in the lujavrite. The green rock is then broken into fragments, a few centimetres across, and the enclosing lujavrite is very dark coloured around these inclusions (fig. 19) (as well as around inclusions of naujaite). Thin veins of lujavrite cut the inclusions. The enclosing dark lujavrite contains small green grains of sodalite of naujaitic type, black nodules and small patches of steenstrupine-bearing analcime pegmatites with igdloite, neptunite, pyrochlore and blue apatite as minor components. The lujavrite adjacent to these patches contains scattered grains of blue apatite. The fibres of ægirine of the green rock are normal to the strike of the vein. Analcime replaces the green rock and there are transitions between the green rock and the analcime pegmatites mentioned above.

The green vein of **F. 3** pinches out towards the south where there is a bending of the border zone between naujaite and lujavrite. Towards the north the vein wedges out in a coarse-grained rock containing analcime, large prisms of arfvedsonite, blue apatite, igdloite, neptunite and small yellow pseudomorphs. In the continuation of this vein to the west, after interruption by a small area covered by gravel, there is a 3–15 centimetres thick black zone between naujaite and lujavrite. The zone has patches of green ægirine felt, but is mainly composed of prisms of arfvedsonite arranged normal to the strike of the zone (see SØRENSEN, 1958, fig. 13).

There is a considerable number of thin brown veins in the naujaite (figs. 20 and 21). They are up to a few centimetres thick and can only be followed for short distances, wedging out in naujaite which may have concentrations of steenstrupine. The large thickness of some of these veins in the map of plate 1 is produced by a topographic effect since the veins are locally parallel to the surface of the rocks. The dip of the brown veins varies from steep to rather flat (see further p. 51).

Some of the veins are clearly situated in zones of deformation since the bands of the naujaite may be displaced along the veins. There are also slickensides in some borders between vein and adjoining naujaite.

The naujaite adjacent to the veins is generally light coloured and rich in natrolite and analcime, but entirely unaltered naujaite is also seen in contact with the veins.

The veins are mainly composed of acmite and arfvedsonite. The acmite is brown or greenish brown and occurs in fine-grained aggregates which may be felt-like or with some preferred orientation parallel to the strike of the veins. The arfvedsonite occurs in large prisms, a few centimetres long, which are arranged parallel to the strike of the veins. Small grains of arfvedsonite also occur and are predominant in some veins. They are often arranged in streaks of many small grains, the streaks being normal to the strike of the veins. In some veins there are large prisms of a greenish-brown colour. They are seen in thin section to have cores of ægirine and rims of acmite. The proportion of acmite to arfvedsonite varies from vein to vein and even within one and the same vein. Acmite generally forms the border zones of the veins.

Fig. 19. Inclusions of felt-like ægirine in lujavrite (F.3 plate 1). The lujavrite is darkest around the inclusions. Naujaite occurs in the foreground.

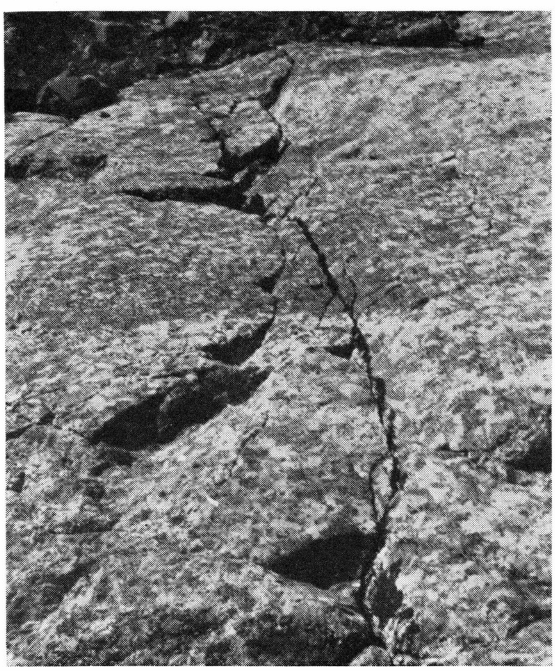

Fig. 20. Acmite vein cutting banded naujaite (northeast of plate 1).

Thin white fracture fillings of fine-grained natrolite form systems of fractures parallel to the strike of the veins. More conspicuous are light coloured coarse-grained patches, which are mainly composed of white or grey analcime with distinct cubic cleavage. Prisms of bluish green natrolite are prominent and yellow sodalite also occurs, especially in the marginal parts of the patches. Large grains of chkalovite have been found in one case and there are white patches of fine-grained natrolite and small prisms of arfvedsonite. The coarse-grained patches also contain pseudomorphs after eudialyte, areas of yellow pyrochlore, fine-grained igdloite and neptunite in irregular fractures, lepidolite, schizolite, sphalerite, galena and steenstrupine.

The steenstrupine occurs as aggregates, up to one centimetre across, composed of small crystals in the dark vein rock, especially where it is rich in acmite. The largest concentrations of steenstrupine are found in the borders of the above-mentioned coarse-grained patches where the steenstrupine is associated with yellow pyrochlore which can form a thin incomplete rim between the white rock and the steenstrupine. In places the dark vein rock is reduced to a very thin margin between the coarse-grained patches and the naujaite. Steenstrupine may then form the border of the vein, but is generally separated from the naujaite by a thin rim of acmite.

Some veins have a streaky arrangement of the minerals, an arrangement which is most probably due to deformation. There are black patches of lujavritic appearance in some of the veins.

In addition to the natrolite and analcime mentioned above there may also be concentrations of steenstrupine, yellow sodalite, acmite and lepidolite in the naujaite adjacent to the veins. In one case small streaks and nests of nickel arsenides have been found in the natrolite adjacent to a brown vein (OEN ING SOEN and SØRENSEN, in press).

The radioactivity of one brown vein cutting a eudialyte-rich band in the naujaite was measured in the field. The vein gave 10–20 counts/sec. where it cuts the eudialyte band, 5–6 counts/sec. where it cuts eudialyte-poor naujaite and the radiaoctivity of the naujaite is less than 3 counts/sec.

A special case of an acmitic vein is found just to the northeast of the map of plate 1. It is the only occurrence of an albite-bearing vein observed so far in Igdlúnguaq.

The vein is seen in a small exposure in gravel-covered naujaite and forms a flat-lying zone in the latter, the zone is up to one metre thick. In this zone there is an upper, almost horizontal vein of lujavrite, half a metre thick, with a diffuse border on the overlying naujaite and a distinct lower black border which may be weakly folded. This lower

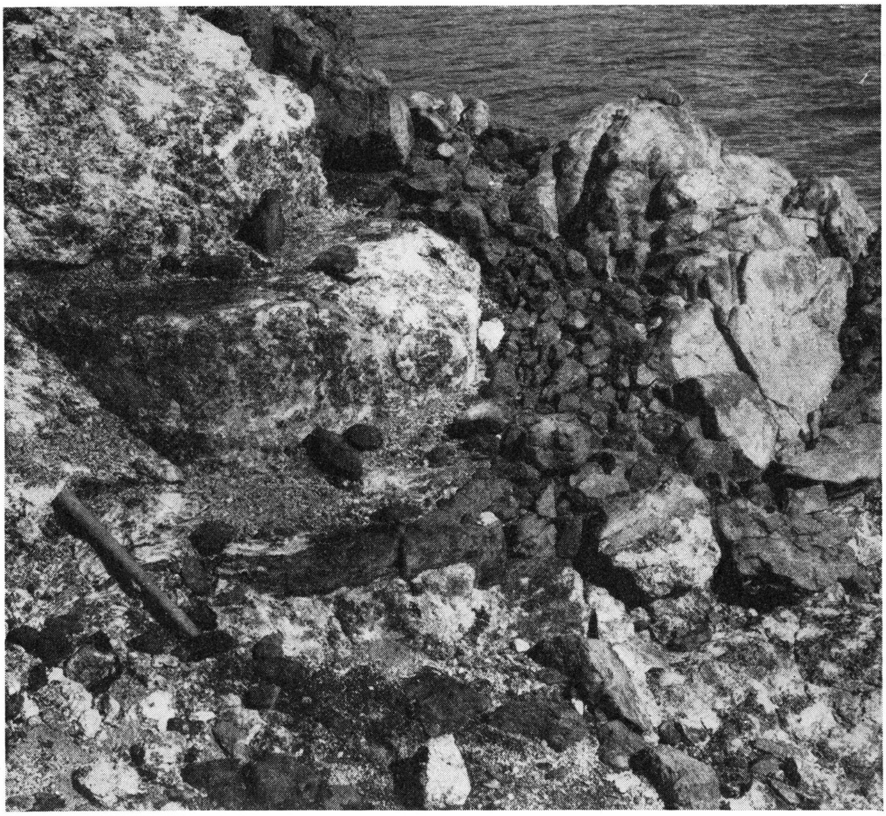

Fig. 21. Lujavrite wedging out in naujaite (H.5–6 plate 1). Towards the left, this vein is continued as a brown acmitic vein containing steenstrupine. The brown vein is not seen in the photograph.

border zone is 10 centimetres thick and rich in acmite. It has white patches with prisms of arfvedsonite, a few centimetres long, arranged normal to the border. There are also patches showing relic naujaite texture with small grains of green sodalite in a matrix of analcime and natrolite.

The lujavritic vein in question is connected with a few underlying thin, lujavritic zones. In the west end of the exposure there is, in the junction of the upper and lower veins, a white, albite-rich rock with black folded streaks. The lowermost lujavritic veins are very thin and have light coloured rocks with black borders of arfvedsonite and acmite. The veins wedge out into a bleached naujaite containing steenstrupine, green and yellow sodalite, natrolite and pseudomorphs after eudialyte. The naujaite between the lujavritic veins is light-coloured with scattered small white laths of albite and some steenstrupine, arfvedsonite and acmite.

The analcime-natrolite veins are coarse-grained and up to five centimetres thick (fig. 22). They are rather rare in this locality, the only prominent example being the vein from **I. 1** to **G. 3** in plate 1. Petrographically and mineralogically these rocks recall the recrystallized inclusions of naujaite mentioned above and the coarse-grained patches of the brown veins.

The veins are composed of large grains of analcime, natrolite and yellow sodalite. The analcime is grey to brown in colour and has a distinct cubic cleavage. The natrolite occurs in prismatic grains of bluish green colour. There are dense white masses of analcime and natrolite. Further components are yellow pseudomorphs after eudialyte, scarce poikilitic grains of ægirine, small needles of arfvedsonite, scattered small crystals of steenstrupine and small amounts of pyrochlore and igdloite. The latter two minerals are especially present in cracks as thin fracture fillings. Black crusts of manganese oxides are probably formed at the expense of schizolite. The steenstrupine-bearing parts of the veins recall the radioactive rock of the pegmatite of the south coast of Qeqertaussaq. There are veins which may be regarded as transitional between the acmite veins and the analcime-natrolite veins; they have, for instance, acmitic borders.

Where the most prominent of the veins in question cuts the banded zone described on p. 43 there is a high concentration of crystals of steenstrupine (fig. 22). The vein in question wedges out towards the north into a border between lujavrite and naujaite.

Most of the analcime-natrolite veins are very thin and are to be regarded as fracture fillings in the naujaite.

None of the thin veins described above cut the lujavrite of Igdlúnguaq. On the contrary inclusions of green felt-like rocks have been observed in the lujavrite as mentioned on p. 45. But there are cases of contiguous arrangement of veins of lujavrite and of analcime-acmite-steenstrupine. Thus at **I. 5-6** a thin vein of black lujavrite wedges out in the naujaite, its place being taken by a steenstrupine-bearing analcime-acmite vein (fig. 21).

The structure: The banding of the naujaite, in the eastern part of the map of plate 1, strikes N 170° with a westerly dip of 70°. Immediately to the north of the map the bands strike N 30°, dipping about 25° to the northwest.

The most prominent joint set of the naujaite is directed N 60–80° with a southerly dip of 60–70°, that is, very nearly normal to the average banding of the naujaite. A less prominent joint set strikes N 135–160° with westerly dips of 60° to almost vertical. There are minor joints with the following orientations: N 60–100° with northerly dips of 30–40°,

Fig. 22. Analcime-natrolite vein in naujaite (H.2–3 plate 1). There are concentrations of steenstrupine along the borders of the vein (see the text p. 50).

N 80–100° with steep northerly and southerly dips, and N 10° dipping 60° W.

The white bands in the naujaite of the southern part of the map are approximately parallel to the major joint set of the naujaite.

The brown veins may be divided into two main groups, a predominant set striking N 100–120° (to N 80°) and with northerly dips of 20–60°, and a minor group striking N 135–175° with easterly dips of 20–75°. A few veins strike N 168° and dip 50° towards the west and N 2–20° with vertical dips. That is, the two main groups of veins have directions parallel to those of the two major joint sets, but with different dip attitudes (see further p. 144).

The green veins and the predominant analcime-natrolite vein are orientated N 132–167° with steep to vertical dips.

The orientations of the borders between naujaite and lujavrite, and of the lamination of the lujavrite, may be arranged in two main groups, one group striking around N–S with dips from 40° W to 85° E, and another group striking around E–W with dips from 40° N to 75° S. There is thus a rather close agreement between the orientation of the naujaite joints and the orientation of the lujavrite.

The lujavrite has, in places, developed cross joints and is cut by green crush zones which also cut through the naujaite.

2. The Small Area on the West Coast of Igdlúnguaq.

This small area is, as shown in the map of fig. 23, made up of naujaite with a few small patches of pegmatite. The naujaite is cut by a number of veins.

The naujaite is rich in eudialyte and of a rather "bleached" appearance due to the presence of analcime and natrolite. The two last-mentioned minerals are especially abundant adjacent to the veins, where acmite with inclusions of arfvedsonite also occurs. The naujaite pegmatites contain eudialyte, arfvedsonite, microcline, etc.

The veins of lujavrite are black and laminated to some extent, the lamination, when present, being steeply inclined and parallel to the margins of the veins. The lujavrite contains monazite in white areas and in yellow star-shaped groups which may be as much as half a centimetre across. There are also greenish patches rich in acmite. In places, small streaks of felted ægirine occur along the borders of the veins.

The lujavrite differs from the lujavrites of the other parts of Ilímaussaq studied by the writer in having folded "veins" of coarse-grained rocks which recall the coarse-grained inclusions in the lujavrite of the southwest point of Igdlúnguaq (fig. 24). These "veins" have had some influence on the lamination of the lujavrite which can be conformable to the "veins", but there are also cases of "veins" cutting the lamination of the lujavrite. The lujavrite is blackest in contact with the "veins" and may have prisms of arfvedsonite normal to the borders on the latter. The "veins" are composed of analcime, natrolite, large prisms of arfvedsonite (often normal to the margins of the "veins"), nepheline, microcline and green sodalite of naujaitic type. There are also patches recalling the recrystallized naujaite and the analcime-natrolite veins of the southwest point of Igdlúnguaq. These patches have analcime, natrolite, arfvedsonite, yellow sodalite, pseudomorphs after eudialyte, steenstrupine, galena, sphalerite, neptunite, pyrochlore and igdloite. The two last-named minerals are especially found as crusts on irregular fractures. Steenstrupine is confined to the borders of these patches. Patches of the dense analcime rocks mentioned on p. 42 also occur (fig. 25).

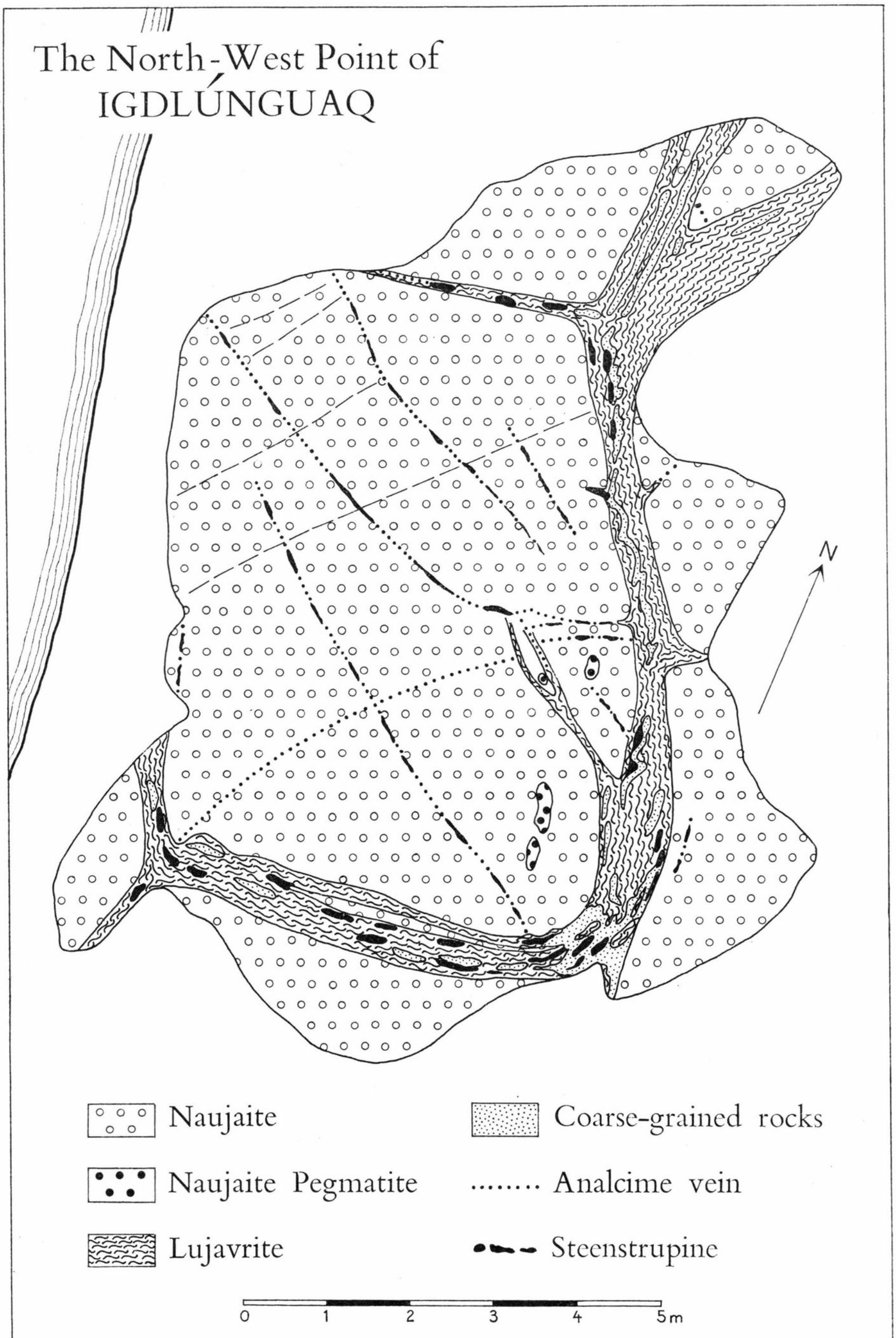

Fig. 23. Map of the small area on the west coast of Igdlúnguaq (cf. fig. 9). The analcime vein symbol also includes natrolite-bearing veins; the symbol indicating the coarse-grained rocks comprises the recrystallized inclusions of naujaite in lujavrite and the "dense" analcime rock. The white areas are covered by scree.

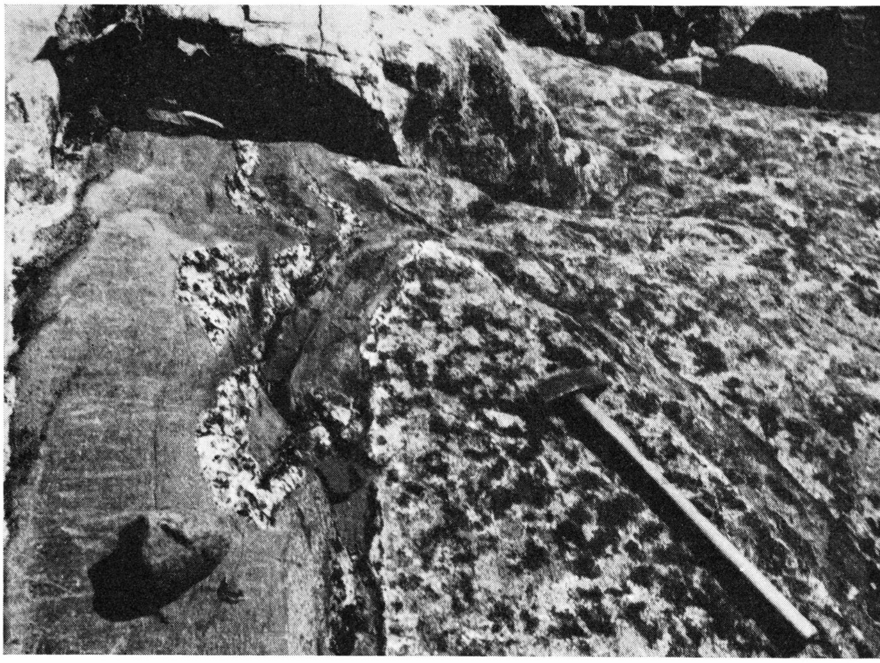

Fig. 24. Detail of the eastern lujavrite vein of fig. 23. Note the folded coarse-grained inclusions and the lujavrite apophysis parallel to the hammer handle.

The veins of lujavrite are, as is the lujavrite of the southwest point, orientated around a N–S and an E–W direction.

There is a number of thin veins of analcime-natrolite occurring in fractures which are diagonal to the vein directions of the lujavrite. The thin veins orientated NW–SE contain a good deal of steenstrupine. The veins do not cut the lujavrite, but in a few of the diagonal fractures, thin veins of lujavrite are contiguous with analcime-natrolite veins (cf. SØRENSEN, 1958, fig. 16). The analcime-natrolite part of the veins may have selvages of lujavrite.

In the central part of the exposure, between the bifurcating vein, a small patch of pegmatite in the naujaite is cut by an analcime-natrolite vein. The large prisms of arfvedsonite of the pegmatite are bent adjacent to the vein which is therefore most probably formed in a zone of deformation. The pegmatite and the naujaite contain eudialyte, but this mineral is not present in the vein.

The veins are composed of large grains of analcime, natrolite, nepheline, and yellow sodalite. There are white fracture fillings of fine-grained natrolite. Parts of the veins are rich in steenstrupine and contain igdloite and pyrochlore in fractures. There are also small yellow patches of pyrochlore. The igdloite is associated with neptunite. The veins may have

Fig. 25. The southeast corner of fig. 23. The "dense" analcime rock occurs where the lujavrite bends. Enclosed in the lujavrite are analcime-rich rocks.

patches of arfvedsonite and acmite with small grains of green sodalite of naujaitic type.

There may be scattered grains of steenstrupine in the naujaite adjacent to the veins.

A single NW–SE striking thin brown vein with acmite and steenstrupine is present.

3. The Easternmost Part of Igdlúnguaq.

The southeast point of Igdlúnguaq is almost exclusively made up of arfvedsonite lujavrite of a rather light coloured type, but with black bands. The lamination is very pronounced with the small needles of arfvedsonite, up to three millimetres long, arranged at random in the planes of lamination. The lamination and banding are near horizontal or have a slight southerly dip.

Parts of the lujavrite have spheroids flattened parallel to the lamination and with gradual transition into the surrounding lujavrite. The cores of the spheroids are dark coloured, the margins are white.

There are in some horizons of the lujavrite lens-like inclusions of green lujavrite and there are also coarse-grained patches of the type described from the southwestern point.

The few inclusions of naujaite in the lujavrite have steenstrupine-bearing fractures striking N 90°–120° and having steep dips.

The lujavrite adjacent to the largest inclusion of naujaite contains coarse-grained patches of the type described on p. 36, and numerous veins of analcime branch out from the naujaite into the lujavrite. The veins can have small streaks of felt-like ægirine along the borders and in their central parts. There are also small needles of ægirine in the adjacent lujavrite. The lujavrite has developed a thin black border zone on the veins. The analcime veins have large prisms of arfvedsonite, large brown grains (microscopically seen to be composed of aggregates of monazite), yellow pseudomorphs after eudialyte, igdloite, neptunite, sphalerite, large plates of microcline and nepheline in a groundmass of analcime and natrolite.

The lujavrite of the southeast point is cut by green mylonite zones striking N 30° and with vertical or steep southeasterly dips.

Between the bay of Nordre Siorarssuit and the southeast point of Igdlúnguaq there is a complex suite of rocks which show evidence of strong deformation. These rocks are well exposed along the coast between Igdlúnguaq and Nordre Siorarssuit.

There are in this zone a number of lenses of naujaite enclosed in black lujavrite and injected by flat-lying, sill-like masses of lujavrite.

The naujaite of the smallest inclusions is strongly recrystallized and even mobilized, sending thin veins into the enclosing lujavrite. The large lenses of naujaite are cut by thin veins of acmite.

The lujavrites are very rich in patches of coarse-grained rocks of the type described on p. 37. The coarse-grained rocks are of several types. Prominent among these are ijolitic rocks made up of small crystals of nepheline in a matrix of arfvedsonite. In the sill-like lujavrites there are rocks composed of large plates of white microcline, several centimetres across, and large prisms and star-shaped groups of small needles of arfvedsonite in a matrix of analcime. Associated with these coarse-grained rocks of the sills are pegmatoids composed of large grains of green analcime, white nepheline intergrown with natrolite and analcime, schizolite, blue apatite, pyrochlore, and dark radioactive grains. The radioactive minerals are especially concentrated in arfvedsonite-rich fracture fillings in the coarse-grained rocks. In vugs in the coarse-grained rocks are well-developed small icositetrahedrons of analcime and radiating needles of natrolite.

Small grains of blue apatite are common in the lujavrites of this area.

All rocks are cut by steep zones of deformation striking N 40–50°.

The naujaite overlying this complex zone has conformable pegmatites and is cut by veins of green ægirine felt striking N 150°. The green zones are again cut by mylonites striking N 105°.

Tuĝtup aĝtakôrfia.

The coastal cliffs of Tugtup agtakôrfia, a short distance to the west of Igdlúnguaq, are made up of black lujavrite with inclusions of naujaite (fig. 26).

The lujavrites have a distinct lamination which is often so strongly developed that the rocks might be termed schistose (fig. 28 and Sørensen, 1958, fig. 11). The lamination is horizontal to slightly northerly dipping.

Banding is developed in some horizons of the lujavrite, the bands being parallel to the lamination. The major parts of the banded horizons are made up of a black lujavrite identical to the unbanded sequences. In this black rock there are white bands, up to a few centimetres thick, and thin arfvedsonite-rich bands up to one centimetre thick. The common dark lujavrite and the white bands are rich in equidimensional grains of nepheline about one millimetre across. The arfvedsonite-rich bands are poor in nepheline. The white bands wedge out into unbanded lujavrite which may, however, enclose small remnants of the white rock.

The white bands are so rich in nepheline and so poor in feldspars that they could be termed urtites. The normal dark rock contains nepheline, feldspars and arfvedsonite and the arfvedsonite-rich bands mainly arfvedsonite and feldspars.

The lujavrite of the easternmost part of the cliff has spheroids of the type mentioned on p. 34. The cores of the spheroids are apparently darker than the enclosing lujavrite, the rims are white with a greenish tinge because of a large content of acmite. The spheroids are up to a few centimetres in diameter and are flattened parallel to the lamination of the enclosing lujavrite. In places they may show a cross-cutting relationship to the laminae of the lujavrite. The needles of arfvedsonite and the laths of feldspar in these spheroids are, according to the available observations, in parallel arrangement with those of the enclosing lujavrite.

Fig. 26. View of Tugtup agtakôrfia from the fiord. The inclusion of naujaite studied in this paper is seen on the shore in the left part of the photograph. Note the horizons of naujaite inclusions in lujavrite in the mountain wall.

The lujavrites have in many horizons yellow star aggregates, a few millimetres across, made up of small grains of monazite.

Although boulders of steenstrupine-bearing lujavrites are common along the shore below the cliff of Tugtup agtakôrfia, steenstrupine has only been found *in situ* in a very restricted area in the easternmost end of the cliff. Steenstrupine is, in this locality, disseminated through the lujavrite, but only within a two to three metres thick zone is the amount of steenstrupine conspicuous. There are small conformable lenses of white nepheline-rich rocks in this zone with large amounts of steenstrupine crystals up to one centimetre across. This occurrence has been briefly mentioned by BUCHWALD and SØRENSEN, 1961, p. 20.

The *boudin*-shaped inclusions of naujaite are conformably enveloped by the lamination of the lujavrite. There are, however, as shown in

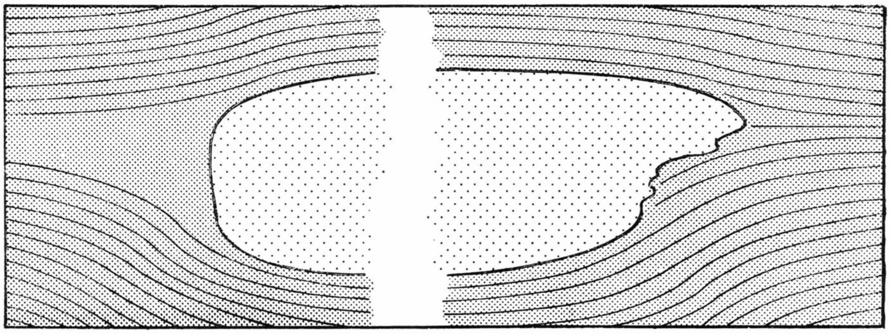

Fig. 27. Sketch to illustrate the form of an inclusion of naujaite (light dotting) enclosed in lujavrite (close dotting). Note the irregularities at the "ends" of the inclusion. Tugtup agtakôrfia.

fig. 27, small irregularities in this arrangement along the shortest sides of the inclusions, that is, the sides normal to the general lamination of the lujavrite. The latter rock frequently has a thin black zone developed at the naujaite contact. The naujaite of these inclusions may be of a rather "bleached" appearance due to a large content of analcime.

The albititic veins: The inclusion of naujaite in the westernmost part of Tugtup agtakôrfia is cut by thin veins of analcime, by zones of deformation filled with fine-grained, partly rusty-coloured natrolite, and by two parallel veins of albitite. The latter veins strike N 80° and are vertical (fig. 28).

The largest of these veins, the southernmost one, is 30–50 centimetres thick and is exposed over about seven metres. The easternmost end of the vein has been removed by erosion; towards the west the vein stops against the horizontal border between the naujaite and the overlying lujavrite. There is, however, a short horizontal continuation of the vein along this border zone (fig. 29). In the lower part of the fracture in the naujaite, the vein is in contact with a short apophysis from the underlying lujavrite. The vein does not cut the lujavrite and is thus confined to the naujaite.

Albite is the major component of the vertical part of the vein and large parts of the vein are almost pure albitite. The albite is either sugary with a grain size of one millimetre or less, or it is cleavelanditic with long thin laths in parallel orientation and up to four centimetres long. The laths of albite are gently bent and in such a way that the bending of all laths in a restricted zone is congruent. The laths are often arranged perpendicular to the borders of the vein. In miarolitic cavities the albite is developed as flat crystals a few millimetres long.

Fig. 28. Naujaite cut by two albititic veins and enclosed in schistose lujavrite (Tugtup agtakôrfia).

Scattered through the albite are grey patches of microcline and transparent crystals of analcime. The latter can be as much as two centimetres across. Further components are pink and brown prisms of schizolite, up to four centimetres long and sometimes arranged in star-like aggregates, small brown crystals of steenstrupine which are generally less than one centimetre across, large flakes of lepidolite and epistolite, brown crystals of sphalerite, and prisms or aggregates of prisms of acmite with patches of arfvedsonite. The microcline can have small spot inclusions of eudialyte. Epistolite is especially present as coatings on fractures.

Irregular grains of yellow sodalite, several centimetres across, are common in the vein. The adjacent albitite is then rich in analcime and sometimes also in microcline. There may, furthermore, be a good deal of prisms of acmite arranged in a way recalling the poikilitic texture of the naujaite. The rocks rich in sodalite can also be rich in steenstrupine and epistolite.

Parts of the vein are rich in analcime, vugs of the latter containing beautiful icositetrahedrons, a centimetre or more across, associated with sphalerite, epistolite, steenstrupine and sodalite. There appear to be all

Fig. 29. Close up of the albititic veins seen in fig. 28. Note the dark borders of the vein on the left and its horizontal continuation in the upper border between naujaite and lujavrite (top left).

transitions from such crystal cavities to masses of sugary-grained albite with scattered crystals of analcime. The analcime crystals of the cavities have white crusts of natrolite as well as grains of microcline and albite.

Analcime is especially developed in the uppermost horizontal part of the vein where large crystals of brown analcime, several centimetres across occur and display a perfect cubic cleavage. In vugs in these larger masses there are small crystals of analcime of the above-mentioned type. In this upper part of the vein, the two rare beryllium minerals, chkalovite and beryllium sodalite (which have been preliminarily described by Sørensen, 1960 b), occur in an albitite with scattered grains of analcime. This occurrence will be treated in detail elsewhere, but it should be mentioned here that fine-grained aggregates of beryllium sodalite penetrate the albitite. The thicker zones of these aggregates have large grains of chkalovite and there are also crystal cavities with small crystals of beryllium sodalite. The beryllium-rich part of the vein further contains epistolite, schizolite, sodalite, steenstrupine, acmite and sphalerite. The crystals of analcime can be enclosed in the beryllium sodalite.

The lujavrite overlying the naujaite has developed a thin black zone rich in arfvedsonite in contact with the horizontal part of the vein.

The albititic vein has dark border zones up to a few centimetres thick which are mainly composed of acmite and steenstrupine (fig. 29).

The acmite occurs in brownish green prismatic grains which can attain a length of a few centimetres. These grains are scattered over the white albitite in the outer parts of the vein but there are, in places, zones of a dense brown acmitic rock or patches of aggregates of acmite along the contact with the naujaite. The prisms of acmite in the dense zones can be perpendicular to the border of the naujaite. The brown rocks recall the acmitic veins described from Igdlúnguaq.

Analcime and microcline are prominent constituents of the border zones. The analcime occurs in round grains up to one and a half centimetre in diameter. Steenstrupine is present in crystals, up to one centimetre across, between the prisms of acmite. Further constituents of the border zones are sodalite, sphalerite, epistolite, schizolite and lepidolite. The epistolite occurs in fractures which are often normal to the border and it penetrates into the adjoining naujaite.

In some places there is a dense white rock rich in a fibrous natrolite-like mineral in the border zone between vein and naujaite. The fibrous mineral impregnates the naujaite a short distance from the margin of the vein. The white rock has, in addition to the accessory minerals mentioned above, ussingite and small pseudomorphs after eudialyte. A few large prisms of arfvedsonite are almost at right angle to the border.

The naujaite adjacent to the vein is often practically unaltered, but locally contains a good deal of the fibrous natrolite-like mineral mentioned above. The green grains of sodalite can be replaced by white masses composed of analcime, albite and microcline. Eudialyte is generally lacking, and grains of lepidolite, epistolite, schizolite and acmite occur in the naujaite adjacent to the vein.

At the base of the fracture containing the albititic vein, there is an apophysis from the underlying lujavrite. This lujavrite is black and laminated parallel to the walls of the fracture. There are also thin leuco- and melanocratic bands parallel to the lamination. In the border zone of the albitite, the lujavrite is brown because of a large content of acmite. The border between the vein and the lujavrite has an irregular course parallel to, as well as cutting, the lamination of the lujavrite. The part of the albitite in contact with the lujavrite is rich in large irregular grains of yellow sodalite, analcime, microcline, steenstrupine, arfvedsonite, acmite, epistolite and sphalerite. The grains of acmite are arranged in a way recalling the naujaitic texture.

A few small masses of lujavrite are enclosed in the albitite. They are massive and light coloured or brown because of a large content of analcime and acmite. Parts of the inclusions have a high concentration of small lepidolite flakes and there are large poikilitic grains of steenstrupine up to two centimetres across. In addition there occur: schizolite prisms, epistolite flakes and a great number of small pink, rounded grains of igdloite, about one millimetre across. The vein rock is rich in yellow sodalite and clear analcime around the inclusions and also contains acmite and steenstrupine. Areas rich in analcime and yellow sodalite also occur in the inclusions of lujavrite. These areas have prisms of acmite larger than those of the lujavrite and there may be concentrations of steenstrupine in the lujavrite adjoining these areas. The rock rich in analcime can have textural remnants of lujavrite.

The northernmost vein of albitite is only a few centimetres thick. It contains small grains of steenstrupine and large flakes of epistolite but has no acmitic border along the naujaite contact.

Steenstrupine-bearing Lujavrites of the North Coast of Tunugdliarfik.

Steenstrupine-bearing lujavrites have, as mentioned by BONDAM and SØRENSEN (1959) and by BUCHWALD and SØRENSEN (1961), been found in a number of places in Ilímaussaq. One of these areas, namely the occurrences on the north coast of Tunugdliarfik, which was briefly described in the last-named paper (op. cit. p. 20), will be treated in more detail in the present paper.

Boulders of steenstrupine-bearing lujavrites are quite common on the north coast of Tunugdliarfik between Igdlúnguaq and the small brook to the west of Tugtup agtakôrfia (see fig. 1). In places there are large quantities of such boulders, particularly in the small brook just mentioned.

In spite of the large number of boulders, steenstrupine is very scarce in the lujavrites of this coastal section, but concentrations have been found in a few horizons. The lowermost of these horizons was described in the section on Tugtup agtakôrfia. Another horizon occurs on either side of the small brook mentioned above. To the west of the brook, steenstrupine-bearing rocks are found *in situ* at altitudes between 130 and 150 metres; to the east, they occur between 80 and 150 metres. The lateral extension of this horizon could not be followed because of scree, but the zone is nearly horizontal in accordance with the common orientation of the lamination of the lujavrites of this coast. A third horizon occurs at an altitude of 190 to 200 metres, between the small brook and Tugtup agtakôrfia.

The steenstrupine in these horizons occurs in scattered grains from a few millimetres to about two centimetres across. They are distributed in an irregular way in the lujavrites and generally occur in subordinate amounts. However, there are a few thin horizons within these lujavrites with very high concentrations of steenstrupine (fig. 30). The grains of steenstrupine do not disturb the lamination of the lujavrite. This is in contrast to the small round grains of nepheline and sodalite which are about two millimetres (and more rarely five millimetres) across. These grains are conformably enclosed by the elongated lujavrite minerals (laths of feldspar and needles of arfvedsonite and/or ægirine), which by their arrangement, in planes, are the cause of the lamination.

The lujavrites can be faintly banded: coarse-grained, light coloured bands alternate with finer-grained, dark coloured bands.

Small shining flakes of epistolite, a few millimetres across, occur in some of the black lujavrites.

The well-laminated black lujavrites have inclusions of more massive green rocks. The latter occur as flat, lens-shaped bodies arranged parallel to the lamination of the lujavrite and are usually conformably enclosed. There are, however, small discordances in some places. The latter structures, for instance, are seen where inclusions of green rock wedge out in the black lujavrite. The green inclusions are restricted to horizons in the black rock and it appears as if green bands have been broken and enclosed by the latter.

The green lujavrites have, in the two horizons considered here, scattered small grains of steenstrupine, brown prisms of schizolite and small coarse-grained patches with arfvedsonite prisms.

At an altitude of 90 metres to the east of the brook, there are flat, pillow-shaped inclusions of green lujavrite in black lujavrite (cf. SØRENSEN, 1958, p. 43, fig. 18). These "pillows" are closely spaced, but separated by thin zones of the black lujavrite. The lamination of the latter is parallel to the borders of the inclusions. The "pillows" are at least 20 centimetres long and are elongated in a north-south direction having a southerly plunge. This horizon is a few metres thick. Upwards and downwards, the green inclusions become smaller and more scarce.

Often, there is a light coloured zone, a few millimetres thick, between the black and green rocks. From this development there are all transitions into light coloured patches in the black lujavrites. These patches may therefore be partly replaced inclusions of green lujavrite.

There are, in the horizons in question, lujavrites of a greenish black colour and more massive than the black lujavrites. They may be interpreted as intermediate types between green and black rocks. They have scattered grains of steenstrupine.

Fig. 30. Concentration of steenstrupine in lujavrite (see text p. 65).

In the steenstrupine-bearing lujavrites there are small lens-shaped areas of light coloured rocks with a high concentration of steenstrupine and also tiny grains of sulphides.

Some parts of the horizons in question are made up of brown, green and black lujavrites which are interbanded in an irregular way. The brown rocks are rich in acmite and contain a good deal of shiny flakes of a white mica, probably lithium-bearing. Steenstrupine occurs as scattered grains, but there is, at an altitude of 132 metres to the west of the brook, a two metre thick layer extremely rich in steenstrupine and containing 5500 ppm Th and 1200 ppm U (fig. 30). The steenstrupine of these rocks is often strongly altered into a yellowish-brown powdery substance. The rocks also have small cavities with a black powder (manganiferous) and small needles of acmite.

There are a few inclusions of naujaite in the steenstrupine-bearing green lujavrite to the west of the brook. The naujaite is conformably enclosed and almost unaltered, but there is some ægirine felt in the outer parts of the inclusions. In cavities and fractures there are white fillings of fine-grained natrolite. The green lujavrite in contact with the naujaite has developed a brown border zone rich in acmite.

V. PETROGRAPHY

The rock types mentioned in this paper will be described below. Each rock type will be treated separately.

The mineralogical composition of the steenstrupine-bearing veins, which form the main topic of the present paper, is so variable, even within one hand specimen, that no attempt at a quantitative treatment will be made.

With regard to the rock types naujaite and lujavrite, the occurrences described in the present paper are too small to allow a conclusive treatment of these rocks. The descriptions below will therefore be confined to the features which are of importance for the problems studied in this paper.

Naujaite.

The rock type naujaite was defined by Ussing (1911, p. 143) "as an extremely coarse-grained nepheline syenite, characterized by a very high content of sodalite and by a peculiar poikilitic structure".

Petrographically the naujaite varies a good deal from place to place in Ilímaussaq. These variations will not be considered here.

The most characteristic feature of the naujaite is the occurrence of inclusions of sodalite in large grains of microcline, eudialyte, ægirine and arfvedsonite. The grains of sodalite are from 0.2 to 1.0 centimetre across when in equidimensional grains, but there are also elongated, prismatic grains which may be up to two centimetres long. The poikilitic grains of microcline, etc. may be several centimetres across. The poikilitic intergrowth is so large that the use of the word structure instead of texture is justified.

Accessory minerals are: ænigmatite, albite, schizolite, lepidolite, britholite, rinkite, astrophyllite and pyrrhotite. Steenstrupine may be present adjacent to the steenstrupine-bearing veins.

Secondary minerals are: analcime and natrolite (replacing the light coloured minerals), acmite (replacing the ægirine and arfvedsonite) and katapleite (which is the most prominent secondary mineral after eudialyte).

The sodalite is generally rich in microlites of arfvedsonite and ægirine (see p. 228).

Nepheline occurs in dull, grey, prismatic crystals. The mineral may be perfectly unaltered but in most cases is partially replaced by fine-grained aggregates of natrolite (hydronepheline). It may also be partially replaced by sodalite free of dark microlites.

The large platy grains of microcline are generally crowded with inclusions of sodalite (with dark microlites) and may also be surrounded by sodalite (without microlites).

The major part of the large grains of eudialyte are occupied by the inclusions of sodalite and the eudialyte is often reduced to a thin network between the sodalite. The shape of the eudialyte grains is for this reason very irregular and crystal faces are only developed in restricted parts of the grains. The smallest grains of eudialyte without inclusions of sodalite may, however, be well-developed crystals.

Ægirine occurs in large poikilitic grains which are black in the hand specimen and strongly green in thin section. Parts of the large grains are composed of acmite which is homoaxial with the ægirine, only differing from the latter by its colour. Inclusions of arfvedsonite may be homoaxial with the ægirine. The large grains of ægirine can be deformed and their place may then be taken by aggregates of felt-like ægirine.

In some rocks there are large poikilitic areas composed of aggregates of small grains of acmite. The acmite is generally associated with small flakes of a brown mica.

Arfvedsonite is rather rare in the specimens examined during this study and may be totally lacking as independent grains, but small inclusions in other minerals are usually present. The larger grains of arfvedsonite appear to be partially replaced by acmite and brown mica.

Steenstrupine is present adjacent to the steenstrupine-bearing veins and occurs in independent crystals or associated with altered eudialyte. In cases the steenstrupine impregnates the naujaite and then forms the matrix between the small grains of sodalite. This recalls the mode of occurrence of the poikilitic eudialyte and the steenstrupine-bearing rocks are poor in or free from eudialyte. Inclusions are scarce in the steenstrupine, this mineral being confined to the interstices between microcline, sodalite, etc. The steenstrupine is generally colourless to brown and most often isotropic. The marginal parts of the grains are often dark and, together with the most fractured parts of the grains, are weakly anisotropic. The steenstrupine is surrounded by radiating fractures in the analcime and sodalite.

The areas rich in steenstrupine are also rich in analcime and contain small rounded grains of albite, up to 0.5 millimetre across, with few or no twin lamellae. Further components are lepidolite flakes, britholite and acmite. The albite penetrates the sodalite and can have a thin network of natrolite.

Analcime and natrolite have a patchy distribution and may occupy such large parts of the rock that the naujaite develops the "bleached" appearance referred to in the descriptions of Igdlúnguaq and Tugtup agtakôrfia. Cavities in the naujaite often contain small fibres of natrolite.

The light coloured bands: No. 21006 is an example of these rocks. It is white and coarse-grained with plates of microcline up to three centimetres long and of the type found in the naujaite, that is, with small inclusions of sodalite. There are also larger crystals of sodalite with microlites of ægirine and arfvedsonite. Further components are scattered small poikilitic grains of ægirine and arfvedsonite and small brown grains of steenstrupine with aggregate extinction and with patches of the red type of steenstrupine. The interstices between the above-mentioned minerals are occupied by analcime with small laths of albite (with few twin lamellae). There are also small patches of natrolite, especially in the microcline.

The Pegmatites in the Naujaite.

Only the sill-like pegmatites of Qeqertaussaq and the head of Kangerdluarssuk will be treated here.

The upper, very coarse-grained parts of these three pegmatites are composed of microcline, arfvedsonite, ægirine, nepheline, eudialyte, sodalite and lepidolite in large grains. The microcline contains inclusions of euhedral nepheline and small needles of ægirine. The independent grains of nepheline contain inclusions of sodalite. The larger grains of sodalite have microlites of ægirine and arfvedsonite. Minor components are small albite laths, steenstrupine, sphalerite, analcime and natrolite.

The bottom zone of eudialyte was examined in thin sections nos. 18458, 18460, 18464, 21119 and 21142 from the pegmatite of the south coast of Qeqertaussaq.

This rock is composed of crystals of eudialyte with interstitial grains of nepheline, sodalite, microcline, albite, ægirine, arfvedsonite and rare ænigmatite and sphalerite.

The eudialyte contains lines of liquid inclusions, except in the marginal parts of the grains and around inclusions of ægirine. There are thin coatings of arfvedsonite on irregular fractures.

The nepheline occurs in grains of rather irregular shape and up to a few centimetres across. They have small inclusions of ægirine, arfvedsonite and sodalite, and are surrounded by sodalite, analcime and natrolite which clearly replace the nepheline. The latter mineral is also cut by fine-grained zones of natrolite.

The grains of sodalite have sparse arfvedsonite and ægirine needles.

The large grains of ægirine have dark green cores and colourless margins. They have small grains of neptunite in cross fractures. Arfvedsonite may be enclosed in the ægirine, the latter often being bleached around the inclusions.

The network of ægirine prisms in the eudialyte zone is, in addition to ægirine, composed of microcline, albite, analcime, natrolite and eudialyte.

The ægirine prisms are partially crushed and may be substituted by glomeroblast-like aggregates in which the individuals have slightly different optical orientations. From these aggregates there are transitions into aggregates of felt-like ægirine which may be present along the prisms and in zones cutting the latter. Bent cleavages and twinning with (001) as composition plane are further evidence of deformation of the large prisms (cf. Ussing, 1894, p. 177).

The microcline displays the spotted type of twinning and is sometimes broken down into aggregates of very small grains which are intergrown with albite. The latter mineral is also present in large grains, up to half a centimetre across and with polysynthetic twinning, and in aggregates of small grains with few or no twin lamellae. The latter aggregates contain small grains of microcline.

Analcime, and in places natrolite, form the matrix of the network.

The eudialyte of the network is generally strongly altered into katapleite, schizolite, ægirine, analcime, dust, neptunite, sphalerite and steenstrupine, which form irregular patches and veins in the eudialyte. The steenstrupine here is cloudy, weakly anisotropic and practically free from inclusions.

In the ægirine network there are patches and zones of felt-like ægirine with steenstrupine (in grains of dark colour and 0.2 to 2.0 millimetre across), schizolite, neptunite, aggregates of crushed microcline (intergrown with albite with few and thick twin lamellae), analcime, natrolite, sphalerite, katapleite, monazite and pigmentary material (cf. Buchwald and Sørensen, 1961, p. 12). A few larger grains of deformed ægirine in these zones and prisms of ægirine adjacent to the zones show disintegration into felt-like ægirine.

Two types of natrolite-filled cavities occur in the eudialyte zone. The one forms small dense masses composed of fibrous natrolite in the interstitial areas between the eudialyte crystals, the other type occurs in the eudialyte which is bleached around the cavities. This second type contains crusts of natrolite with a central zone of very fine-grained and cloudy natrolite surrounded by zones of larger prisms of clear natrolite which may be arranged at right angle to the crusts. Small crystals of ægirine in these crusts are strongly corroded by the natrolite and sometimes have neptunite on irregular fractures.

The coarse-grained ægirine-rich parts of the pegmatites were examined in the samples nos. 18455 and 18457 from the south coast and the nos. 21126, 21127, 21128, 21130 and 21132 from the east coast of Qeqertaussaq.

Large prisms of ægirine of the type mentioned from the ægirine network in the eudialyte zone make up the major part of the ægirine rock of the pegmatite of the south coast of Qeqertaussaq. They are slightly deformed and show a weak development of felted ægirine. Between the ægirine prisms are: large grains of sodalite with sparse inclusions of arfvedsonite and ægirine and partly replaced by analcime; large grains of nepheline with inclusions of sodalite, arfvedsonite and ægirine and partly replaced by analcime and natrolite; laths of albite showing polysynthetic twinning; and small laths of microcline. The albite is separated from the nepheline by thin rims of analcime. The scattered eudialyte grains are cut by zones of katapleite, neptunite, schizolite, black pigmentation, ægirine needles, analcime and natrolite. The rock contains small patches of fibrous natrolite.

The rinkite-bearing part of this rock was examined in thin section no. 18462. The rinkite is associated with large prisms of ægirine and interstitial grains of eudialyte, sodalite, nepheline (with inclusions of sodalite and arfvedsonite), albite (in polysynthetically twinned grains which are somewhat deformed), lepidolite, rounded small grains of apatite, analcime and small areas of fibrous natrolite. The parts of the rock composed of analcime and natrolite have star-like groups of arfvedsonite needles. The rinkite, ægirine and eudialyte enclose small laths of albite (smaller than the interstitial grains) and there are inclusions of schizolite in the ægirine.

The prismatic grains of rinkite are slightly deformed and their marginal parts may be altered into ill-defined brown or yellow alteration products. In cross fractures the crystals contain small grains of neptunite, igdloite, "britholite" (DANØ and SØRENSEN, 1959, plate 1, fig. 4), schizolite, ægirine, albite and small brown steenstrupine-looking grains.

In the pegmatite of the east coast of Qeqertaussaq the coarse-grained ægirine rock is composed of large prisms of ægirine in a matrix of cloudy and fine-grained natrolite. Enclosed in this matrix are corroded grains of nepheline (with inclusions of sodalite, arfvedsonite and ægirine), microcline in large plates and small deformed laths, a few unaltered grains of eudialyte, rinkite and a few larger grains of arfvedsonite associated with a biotite-looking mineral. In cavities there are prisms of clear natrolite with rusty crusts. There are also thin veins of fine-grained natrolite.

Rinkite occurs in well-developed crystals. They have often isotropic patches which are normally of a stronger yellow colour than the anisotropic parts of the crystals. These isotropic patches occur in some grains in the central parts, in others along the margins, and they can also form small spots distributed throughout the grains.

As mentioned on p. 21 there is in the eastern end of the pegmatite of the south coast of Qeqertaussaq a concentration of steenstrupine in the coarse-grained ægirine rock where it is cut by veins of felted ægirine. This occurrence was studied in the thin sections nos. 18455, 18461 and 21119. The prisms of ægirine are bent and broken and are sometimes split up into aggregates of small needles. There is, thus, a transition into the felt-like rock. The groundmass between the prisms of ægirine is composed of analcime, natrolite, large grains of albite with polysynthetic twinning and deformed microcline. The rare grains of eudialyte are cut by zones of katapleite, black and brown pigmentation, and some small grains of brown steenstrupine. Associated with the analcime, albite and natrolite are large grains of steenstrupine of rather irregular shape, although crystal faces can be developed. The grains are brown with irregular colour distribution and they are practically free from inclusions. These large grains of steenstrupine, which may attain a size of half a centimetre or more, are restricted to the coarse-grained rock adjacent to the felt-like zones of ægirine which have small well-developed crystals of steenstrupine. The steenstrupine-bearing part of the coarse-grained rock contains, in addition to the above-mentioned minerals, sphalerite, lepidolite and galena. The green veins will be described in a later section.

The green felt-like rock in the upper part of the pegmatite of the south coast of Qeqertaussaq was examined in thin sections nos. 18453 and 18465. The rock is composed of a multitude of needles of ægirine, a few larger prisms of that mineral, platy crystals of microcline with cloudy central parts and clear marginal zones, pseudomorphs after microcline composed of analcime and natrolite and a groundmass of the two last-mentioned minerals. The microcline is free from inclusions of ægirine, but needles of that mineral are common as inclusions in the analcime and natrolite. The microcline sometimes forms aggregates of many small grains.

In the thin sections examined the ægirine is arranged in a haphazard way, but as mentioned on p. 20 there is in places a preferred orientation.

In the lower part of the green rock small grains of albite and steenstrupine occur. The border on the underlying radioactive rock is marked by considerable amounts of deformed microcline with spotted twinning, needles of ægirine, pigmentary material, small grains of steenstrupine and schizolite.

Thin fractures are filled with fine-grained natrolite.

The radioactive rock of the pegmatite of the south coast of Qeqertaussaq was examined in the thin sections 18465 and 21134. The greater part of this zone of the pegmatite is composed of small rather platy crystals of natrolite. The interstices between these crystals are often vacant which gives the rock its miarolitic appearance. Analcime is also an important constituent. Enclosed in the groundmass of these two minerals is a considerable number of small deformed laths of microcline with the spotted twinning, and with cloudy central parts and clear marginal zones. There are also a few large platy crystals of microcline which do not show evidence of deformation but are subject to corrosion by the analcime. Ægirine occurs as large bi-terminated prisms of the type found in the coarse-grained ægirine rock in this pegmatite. In addition there are small needles of ægirine in the parts of the rock rich in small grains of deformed microcline.

Further components of the radioactive rock are large albite grains with few twin lamellae, large grains of sphalerite associated with hemimorphite, large flakes of lepidolite, large grains of neptunite, eudialyte, steenstrupine and large grains of schizolite. The parts of the rock rich in albite are poor in needles of ægirine.

In the lower part of the radioactive zone there are a few large grains of eudialyte enclosed in the natrolite. They are almost unaltered but with some katapleite and pigmentation. Small pseudomorphs after eudialyte with scarce remnants of this mineral are, however, scattered throughout the rock. They are composed of katapleite, cloudy natrolite, pigmentary material, schizolite, a brown mica, neptunite and small spots of purple fluorite. In the upper part of the radioactive rock there are small areas of entirely altered eudialyte containing britholite, monazite, biotite and steenstrupine.

Steenstrupine is present as small brown grains of the same appearance as the steenstrupine of the green veins (which will be described later). These grains are found in the parts of the rock containing needles of ægirine. But steenstrupine also occurs as crystals up to half a centimetre across.

Although this steenstrupine forms perfect crystals, the interior parts of the grains show a most irregular development, not only because of the irregular distribution of the brown colour and the dark pigmentation, but also because of the irregular extinction, most of the grains being weakly anisotropic. The steenstrupine contains inclusions of ægirine and is cut by zones with a brown biotite-looking mineral and fluorite. Small areas of katapleite, pigmentation and neptunite are locally associated with the steenstrupine. The steenstrupine is interstitial but can be enclosed in analcime with scattered pigmentary material of the type found in the steenstrupine, indicating that the steenstrupine is partly replaced by analcime (plate 15, fig. 1).

The albititic rocks in the upper part of the pegmatite to the north of Lilleelv were examined in the specimens nos. 21155, 21156, 21157 and in some samples from the collections of the Mineralogical Museum in Copenhagen. These rocks are composed of varying amounts of albite, microcline, ægirine, eudialyte, steenstrupine, analcime, lepidolite and schizolite.

Albite occurs in fine-grained masses of rounded grains with few or no twin lamellae and a grain size of 0.2–2.0 millimetre; in bladed crystals, up to half a centimetre across, with two or three twin lamellae according to the albite and the complex albite-Karlsbad laws; and in large grains, polysynthetically twinned according to the albite law, which apparently enclose the fine-grained albite. The polysynthetically twinned grains have the same optical orientation in the different parts of the thin sections and are thus of considerable size. They are especially associated with large prisms of ægirine and are slightly deformed.

Large plates of microcline are enclosed in the sugary-grained albite and are penetrated by thin veins of that mineral. The microcline is clearly being replaced by albite and is deformed to varying extent with the development of the spotted type of twinning. This type of twinning is for instance seen along the veins of fine-grained albite in grains which otherwise do not show traces of deformation. In parts of the rocks there are masses composed of numerous small irregular and deformed laths of microcline (plate 5, fig. 2).

The large prisms of ægirine show an irregular colouration with strongly coloured cores and colourless margins. The prisms are often bent with a development of a fibrous ægirine in the zones of bending. In these places there may also be small grains of neptunite. In some prisms of ægirine there is a columnar type of extinction which is most probably caused by deformation. Thin grains of albite occur between the columns. The small black needles of ægirine mentioned on p. 25 are seen in thin section to be fine, acutely bi-terminated crystals which show the same type of irregular colouration as the larger prisms. These small grains are only slightly deformed. A few grains of acmitic ægirine with inclusions of albite and natrolite have been seen.

Eudialyte occurs as large rounded or irregular grains and as small crystals less than one millimetre in diameter. The latter are especially found in the sugary-grained albite. Both types of eudialyte are generally unaltered and are almost free from pigmentation. Some of the larger grains have a fine dendrite-like network of eudialyte with lower birefringence, but with the same optical orientation as the main parts of the grains. This network gives the grains a very "flamed" appearance under crossed nicols. The "flames" may be considered as transitional forms to mesodialyte. A few inclusions of small prisms of green ægirine in the eudialyte are surrounded by rusty grains of schizolite which are separated from the eudialyte by rust and radiating plates of katapleite. Some grains of eudialyte are penetrated by irregular thin fractures filled with a flaky or fibrous mineral with high birefringence. The fibres are length-slow and they are arranged at right or oblique angles to the borders of the fractures. The fibres have lower refractive indices than the eudialyte. They may show twinning.

Some grains of eudialyte are brown or black in a thin outer zone, but with apophyses of the dark material penetrating for a short distance into the interior parts of the grains. These rust coloured areas have a few plates of katapleite and are slightly more birefringent than the interior parts of the grains. All parts of the grains display the same optical orientation, that is, no eucolite is present. The grains with the dark rims are cut by irregular zones of the strongly birefringent mineral mentioned above and they can be surrounded by steenstrupine.

The latter mineral is deep brown and generally isotropic, but there is often a thin colourless (and isotropic) zone in contact with the dark border of the eudialyte. A few anisotropic patches have been observed in the steenstrupine, especially in the outer parts of the grains. These patches have almost the same extinction position as the adjacent eudialyte and show the same colour variation when the gypsum plate is inserted, that is, the optical axes of the two minerals are almost at right angles, since the eudialyte is optically positive and the steenstrupine is negative. The fibrous mineral mentioned above can occur between eudialyte and steenstrupine.

In addition to the steenstrupine associated with the eudialyte there are a few other types of steenstrupine. In the rocks rich in albite or rich in analcime and/or natrolite there are large crystals or more irregular grains which are clear, colourless and isotropic in the central parts and brown or reddish brown in the marginal zones. The latter can show a weak aggregate extinction. The grains have quite a few black spots and a few inclusions of ægirine and microcline. Some of the larger grains have only a few small areas of clear steenstrupine, these areas being cut and surrounded by a rusty-coloured material of very irregular structure and with spherical features recalling the consolidation products of colloidal substances. The strongest colours occur around black inclusions. The rust coloured substance is anisotropic and optically negative.

Small well-developed crystals of steenstrupine are more common than the larger grains. They are mostly coloured throughout with brown to black colours but may be colourless in the cores. The crystals are often zoned with black or very dark margins and sometimes with a very thin black zone a short distance from and parallel to the crystal faces (cf. BUCHWALD and SØRENSEN, 1961, p. 27). The grains can have red and anisotropic patches, or in cases, red marginal zones which may be surrounded by thin zones of clear isotropic steenstrupine. The central parts of the red grains are generally colourless and with a weak aggregate extinction, but some grains are red throughout. The red material recalls the red type of steenstrupine. The small crystals of steenstrupine occur especially in the patches of ægirine felt and in areas composed of small laths of microcline.

The ægirine felt in the pegmatite to the north of Lilleelv is composed of a multitude of small needles of acmitic ægirine in a groundmass of deformed microcline. Albite is not always present, but when it occurs it appears to replace the microcline. The albite can be crowded with small needles of ægirine, but the larger areas of albite are practically free from such inclusions. Analcime is sometimes present. There are a few large and deformed prisms of ægirine. The small reddish-brown crystals of steenstrupine mentioned above are enveloped by the needles of ægirine and they occur especially in the outer parts of the aggregates of felted ægirine. The steenstrupine is practically free from inclusions. There are a few small crystals of eudialyte which can be broken and corroded and associated with tiny plates of katapleite. Small areas of the size and shape of the eudialyte, but composed of a very fine-grained aggregate of monazite, recall "erikite". The ægirine felt contains small clusters of a pyrochlore-like mineral, poikilitic grains of neptunite with numerous small inclusions of ægirine, and bunches of a fibrous mineral, perhaps apatite.

The areas composed of deformed small laths of microcline contain, in addition to the microcline, small prismatic and bi-terminated crystals of ægirine, large deformed prisms of ægirine, neptunite, igdloite, small prisms of schizolite and a few large prisms of arfvedsonite (with inclusions of ægirine, neptunite and a rusty-red material recalling steenstrupine). There are in places small aggregates of needles of arfvedsonite between the laths of microcline and with inclusions of ægirine and microcline. In one thin section there are rounded grains of analcime, up to 0.5 centimetre across, with microlites of arfvedsonite and ægirine in the central parts. They are conformably enclosed in a network of laths of microcline, aggregates of arfvedsonite (with few inclusions of ægirine), small bi-terminated crystals of ægirine and patches of ægirine felt (partly intergrown by arfvedsonite). These rocks have small crystals of steenstrupine of the reddish brown type associated with ægirine felt and fine-grained arfvedsonite and occurring as small grains in and between the light coloured minerals. The crystals have a few small inclusions of arfvedsonite, also when enclosed in ægirine felt. These rocks, which recall some of the veins of Qeqertaussaq, occur especially in the central part of the pegmatite between the top part rich in steenstrupine and the bottom part rich in eudialyte. In this place there is no albite in the rock. Small remnants of similar rocks occur in the albite-rich and in the analcime-rich parts of the pegmatite.

The analcime-rich parts of the pegmatite to the north of Lilleelv are mainly composed of large grains of analcime and masses of fine-grained natrolite. They have large grains of nepheline with inclusions of albite, microcline and ægirine and surrounded by fine-grained natrolite. Also enclosed in the natrolite are large grains of sodalite. Further components are small laths of microcline (enclosed in the analcime), sphalerite, small crystals of ægirine, britholite, igdloite and crystals of steenstrupine (with black spots and aggregate extinction).

Lujavrite.

The term *luijaurite* was introduced by Brøgger (1890) as a name for some rocks from Lujavr-Urt (Lovozero) of the Kola Peninsula which were found and described by Ramsay (1890). The name was later spelt lujavrite by Ramsay and subsequent authors.

According to Vlasov, et al. (1959) lujavrites occur in Lovozero in an upper complex of eudialyte lujavrites and in a lower complex of differentiated rocks. The lujavrites are coarse- to fine-grained, massive or trachytoid and with hypidiomorphic texture. The eudialyte lujavrites are made up of alternating bands of leuco-, meso- and melanocratic rocks; the lujavrites of the differentiated complex are interlayered with bands of urtite and foyaite. Ægirine is the most prominent dark coloured mineral, but varieties rich in arfvedsonite also occur. Between the two complexes, mentioned above, there is a horizon of more dense, but porphyritic lujavrites.

The lujavrites of Ilímaussaq differ from those of the type locality in a finer grain size and in the more important role played by the arfvedsonite-bearing varieties. USSING (1911, pp. 39–41 and 156–176) distinguished two types of lujavrite, a green, ægirine-bearing one and a black, arfvedsonite-bearing one. In the areas described in the present paper, the black variety is predominant.

The following rock types will be considered in this chapter:

1. The normal arfvedsonite lujavrite.
2. Veins of arfvedsonite lujavrite in naujaite.
3. The black border zones between lujavrite and naujaite.
4. The coarse-grained rocks associated with the lujavrites in some areas.
5. The steenstrupine-bearing lujavrites.

1. The Normal Arfvedsonite Lujavrite.

These rocks are of a pronounced igneous habit with a well-developed lamination and also in places a trachytoid structure. The lamination is due to the planar orientation of the elongated minerals, namely the laths of feldspar, the needles of arfvedsonite and the platy crystals of eudialyte. These minerals are generally orientated at random in the planes of lamination, but there are examples of lineation. The laths of feldspar may reach a size of $6 \times 4 \times 2$ millimetres, but the average size is in this lujavrite type thin laths of a length of 1–3 millimetres. The needles of arfvedsonite may reach a size similar to that of the feldspar but are generally smaller than that mineral. The crystals of eudialyte can only rarely be seen with the naked eye and they are only a fraction of a millimetre across. Most lujavrites contain small equidimensional grains of nepheline and sodalite of an average diameter of 2–3 millimetres, but grains of sodalite up to one centimetre across have been seen. The grains of nepheline and sodalite are wrapped by the elongated minerals, so that a type of flow structure is produced (plate 11, fig. 1).

The texture of the lujavrite is hypidiomorphic, the feldspars, eudialyte, nepheline and sodalite being present in rather well-developed crystals.

Minor components and accessories are ægirine/acmite, schizolite, sphalerite, steenstrupine, monazite and britholite. Astrophyllite, biotite, ussingite, lovozerite, igdloite, pyrochlore, epistolite, the green mineral mentioned on p. 222 and an ænigmatite-looking mineral have also been observed. Analcime, and more rarely natrolite, substitute the light coloured minerals to varying extent.

Microcline is the predominant feldspar in most rocks and may be the only feldspar present. It occurs in laths which are generally undeformed, but some rocks contain strongly deformed microcline which then shows the spotted type of twinning. In some rocks there are large cloudy laths of microcline, a few millimetres long, in a matrix of finer-grained and clear microcline.

The albite laths are polysynthetically twinned according to the albite law. The laths are often deformed with bent and broken twin lamellae and undulatory extinction. The content of albite in the lujavrites varies a good deal, but this variation has not been studied in the field.

The laths of feldspar have slightly "lobed" borders and are generally replaced by analcime to varying extent. Where the replacement is complete, the original lath shape of the feldspars is often preserved.

Nepheline occurs in stout prisms with somewhat corroded outlines. The largest grains have enclosed small laths of microcline and needles of arfvedsonite. Small inclusions of sodalite have also been observed. The amount of nepheline varies within wide limits, some rocks being almost devoid of nepheline, whilst others contain up to 30 % or more. The lack of nepheline in some rocks is caused by the alteration of this mineral into fine-grained natrolite, analcime and/or sodalite. But there are also rocks poor in nepheline, analcime, natrolite and sodalite, and with a large content of feldspars.

There are independent small round grains of sodalite. The smallest grains are without microlites of arfvedsonite and ægirine, the larger ones have these microlites, as in the case of the sodalite of the naujaite. The sodalite is partially replaced by analcime and natrolite.

The small crystals of eudialyte are generally entirely unaltered. Zoning is rare, but irregular "flames" of mesodialyte are common. The crystals often have irregular cross fractures. In places the crystals are mechanically deformed. The crystals of eudialyte are often enclosed in the needles of arfvedsonite, but inclusions of arfvedsonite in eudialyte have also been observed. The altered grains of eudialyte contain katapleite, neptunite, analcime, pigmentary material, and in some cases britholite and monazite. Small clusters of tiny grains of monazite in some lujavrites may, as suggested by Danø and Sørensen (1959, p. 13 and 19), be interpreted as pseudomorphs after eudialyte.

Arfvedsonite occurs in needles, which may be twinned, or in elongated areas composed of many small grains. These areas are interstitial to the laths of feldspar. Arfvedsonite makes up from 30 to 50 % of the lujavrite. The arfvedsonite in contact with altered eudialyte often has homoaxial rims of acmite, but with many exceptions.

Some samples of black lujavrite are free from ægirine/acmite, but small grains of these minerals occur in many rocks. They can be enclosed, partly homoaxially, in the arfvedsonite.

Locally, small aggregates of acmite occur in the lujavrite. Arfvedsonite forms interstitial grains in these aggregates and incomplete rims on the acmite. The larger grains of arfvedsonite of these rocks may enclose small grains of acmite in their marginal parts. It should, however, be mentioned that small fibres of acmite have been observed in interstitial areas between grains of arfvedsonite in some rocks.

In some lujavrites analcime, and more rarely natrolite, have replaced the light-coloured minerals so that eudialyte, arfvedsonite and acmite are enclosed in a matrix of analcime and in some cases natrolite. The analcime is present in large grains which may occupy a whole thin section, natrolite occurs in large prisms, in aggregates of tiny fibres and in peculiar vermicular intergrowths with microcline and sodalite.

The white bands in the lujavrite at Tugtup agtakôrfia (see p. 57) have, in a groundmass of analcime, closely spaced crystals of nepheline which may be somewhat corroded and sometimes crushed.

The white bands (see the table p. 234) are rich in crystals of eudialyte which may be crowded with black pigmentary alteration products, in part lovozerite-like. The eudialyte may also be intergrown with aggregates of the erikite type of monazite. Feldspars are scarce in the thin sections examined, arfvedsonite and ægirine/acmite are present in rather subordinate amounts. The arfvedsonite in contact with altered eudialyte can have rims of acmite, but there are also examples of the opposite relationship with rims of arfvedsonite between acmite and eudialyte.

The white bands at Igdlúnguaq (see the table p. 234) are poor in eudialyte and rich in acmite with homoaxial inclusions of arfvedsonite and also with inclusions of eudialyte. Further components are laths of microcline and albite, nepheline, a few flakes of a white mica and a few small pseudomorphs after eudialyte composed of katapleite, neptunite and pigmentation.

Steenstrupine is a scarce constituent of the white bands.

In these localities the lujavrite adjacent to the white bands is poor in nepheline and rather rich in arfvedsonite and microcline (and sometimes also albite). The arfvedsonite encloses acmite. These rocks form bands which are more dense and dark than the average lujavrite of these areas.

The lujavrites containing the spheroids with white rims are composed of albite, arfvedsonite (often associated with acmite and brown pigmentation), corroded crystals of nepheline (which may be closely spaced and sometimes have developed irregular extinction), minor microcline, small crystals of eudialyte, microlite-free sodalite (which may surround the nepheline), clusters of monazite, small star-shaped groups of britholite crystals, a few flakes of a white mica and interstitial analcime and natrolite (see the table p. 234).

The white rims are richer in analcime and acmite than the surrounding lujavrite. They have deformed laths of microcline and albite, the former with the spotted type of twinning. The two feldspars are associated with analcime and in the Tugtup agtakôrfia occurrence also with fine-grained ussingite. Further components are sodalite, nepheline, small crystals of eudialyte, britholite, sphalerite and monazite. The nepheline may be enclosed in the sodalite. The larger grains of acmite have homoaxial inclusions of arfvedsonite, but arfvedsonite also forms rims on the acmite. In the ussingite-bearing rocks there are small grains of lovozerite and also steenstrupine of the skeleton-like crystal types. Thin zones of ussingite penetrate the lujavrite around the white rims.

The dark cores of the spheroids are, in the cases examined, extremely rich in analcime and practically free from nepheline, sodalite and feldspars. Enclosed in the analcime are arfvedsonite needles, a small amount of acmite and crystals of eudialyte.

The arfvedsonite needles and acmite grains of the cores and rims of the spheroids are parallel to those of the surrounding lujavrite and there are gradual transitions between these three rock types.

The spheroidal lujavrite contains scattered grains of the "green mineral".

2. Veins of Arfvedsonite Lujavrite in Naujaite.

These veins were especially studied at Igdlúnguaq. They are more fine-grained than the above-mentioned lujavrites, at least in the thinnest veins. The laths of feldspar rarely exceed two millimetres in length. The rocks are often of a rather dense appearance which is caused by a large amount of analcime replacing the light coloured primary minerals of the rock. The lamination is, when developed, parallel to the borders of the veins.

The matrix of the veins is composed of analcime either in large grains occupying a whole thin section, or also in aggregates of many small crystals. Enclosed in the analcime are grains of microcline, albite, nepheline, sodalite, arfvedsonite, acmite, eudialyte and steenstrupine. Accessories are britholite (in single grains and in clusters of crystals), monazite, schizolite and sphalerite. There are small areas of granular and fibrous natrolite (table IV, p. 235).

The laths of microcline and albite are deformed and partially replaced by the analcime. Some rocks have lath-shaped areas of analcime which are apparently pseudomorphs after feldspar.

The grains of nepheline are corroded by the analcime and may also be surrounded by fine-grained natrolite. They contain inclusions of microcline and in some parts of the veins, adjacent grains of nepheline have so similar optical orientations that it appears as if larger grains of nepheline have been crushed and partly replaced by the analcime.

Rounded grains of sodalite with microlites of arfvedsonite and ægirine are rather common in the veins. They have, in the hand specimen, the same appearance as the sodalite of the naujaite.

Arfvedsonite is the predominant dark-coloured mineral occurring in prisms up to half a centimetre long and in small needles which may be arranged in star-shaped groups. The larger grains of arfvedsonite have inclusions of acmite, especially in their marginal parts, the composition planes of the twinned grains sometimes bending around the inclusions.

There are aggregates of acmite with small inclusions of arfvedsonite and brown mica. The aggregates have interstitial grains and incomplete rims of arfvedsonite. In cases the aggregates appear to be out-rolled.

The small crystals of eudialyte of normal lujavritic type are often entirely unaltered, but altered grains with katapleite, neptunite, analcime and pigmentation also occur. In places there are large areas, up to half a centimetre across, composed of the above-mentioned alteration products of eudialyte. These areas, which are much larger than the eudialyte crystals of the lujavrite, may be altered grains of naujaitic eudialyte enclosed in the veins. The small crystals of eudialyte can be enclosed in the large prisms of arfvedsonite.

Some of the veins have zones rich in small crystals and larger, more irregular grains of steenstrupine. This mineral is clear, yellowish brown and isotropic, but with stronger coloured and anisotropic margins. The small crystals can have cleavages developed parallel to the basal face and are then weakly anisotropic. These small crystals have very few inclusions, arfvedsonite being most common. The large grains with more irregular outlines have numerous inclusions of arfvedsonite of the size and orientation of the surrounding rock. There are furthermore inclusions of microcline, altered eudialyte, acmite (partly enclosed in arfvedsonite), britholite and polygonal and lath-shaped areas of analcime.

Monazite forms, on the west coast of Igdlúnguaq, small clusters which are in intimate association with epistolite, eudialyte, arfvedsonite, katapleite and schizolite.

Some veins have patches of coarse-grained rocks which are apparently in a stage of dissolution in the lujavrite. These rocks will be described on p. 81 (table IV, p. 235).

3. The Black Border Zones between Lujavrite and Naujaite.

The lujavrites adjacent to the inclusions of naujaite are, at Igdlúnguaq and Tugtup agtakôrfia, rich in analcime and arfvedsonite. They often contain a large concentration of small crystals of eudialyte of lujavritic type adjacent to the border. These small crystals are partly enclosed in the arfvedsonite. The analcitic matrix encloses corroded grains of nepheline, microcline, sodalite and pseudomorphs after eudialyte composed of neptunite, katapleite, pigmentation, etc. These pseudomorphs may be larger than the small crystals of unaltered eudialyte in these rocks. Further constituents are schizolite, epistolite and natrolite (table IV, p. 235).

There is often a rather large amount of acmite in fine-grained aggregates and in single grains, the amount of acmite increases generally towards the contact. This acmite is often partly surrounded by arfvedsonite.

The lujavrite adjacent to the black border sometimes has poikilitic grains of steenstrupine, for instance in some of the veins. These grains occur in rocks in which analcime is the predominant groundmass mineral.

The steenstrupine grains may show crystal faces or are of rounded, but rather irregular, outlines. The clear, yellow to brown cores are isotropic, the stronger coloured marginal zones often anisotropic. There are inclusions of arfvedsonite, microcline, britholite, altered eudialyte and lath-shaped areas of analcime. In the thin sections examined of acmite-bearing rocks there are no inclusions of that mineral (plate 15, fig. 2).

The black border zones have prisms of arfvedsonite, up to one centimetre long, arranged either parallel to, or normal to the contact with the naujaite. There may also be inward radiating groups of needles of arfvedsonite which have their apexes in the naujaite side of the black zone. Acmite may make up as much as 50 per cent of these rocks. It occurs as small fibres in the interstitial areas between the arfvedsonite, as inclusions in the marginal parts of the large grains of arfvedsonite and as fine-grained aggregates. The latter have interstitial grains of arfvedsonite which appear to penetrate the acmite along cleavages and along grain boundaries. There are also incomplete rims of arfvedsonite on these aggregates. The aggregates can contain pseudomorphs after eudialyte, but in some cases there are rims of arfvedsonite between the pseudomorphs and the acmite.

The naujaite in contact with these black zones is generally rich in analcime and may also contain albite. The grains of arfvedsonite have small marginal aggregates of acmite and there are also large poikilitic areas of the latter. The grains of acmite may have green cores. Besides, small needles of ægirine and small crystals of eudialyte of the lujavritic type occur.

4. The Coarse-grained Rocks Associated with Lujavrite.

The coarse-grained rocks of the west coast, southwest point and east coast of Igdlúnguaq were studied in the specimens nos. 18496, 18499, 18512, 21024, 21036, 21055 and 21079.

These rocks have, in a groundmass of analcime, large prisms of arfvedsonite with inclusions of acmite and altered eudialyte. Further components are acmite, biotite, nepheline, microcline, sodalite, eudialyte pseudomorphs and steenstrupine. Accessories are schizolite, britholite, apatite and monazite. The arfvedsonite prisms may be several centimetres long, the nepheline grains up to two centimetres across and the microcline plates a few centimetres across. The average grain size of the rocks is 0.5 to 1.0 centimetre.

The arfvedsonite often occurs in groups of radiating prisms and needles. The elongated patches of coarse-grained rocks, for instance the folded inclusions in the lujavrite veins of the west coast, may have the prisms of arfvedsonite orientated at right angle to the elongation of the patches.

Fibrous acmite occurs in fractures and in zones of deformation in the arfvedsonite prisms and also along their margins. In the microcline-rich rocks of the east coast, the large prisms of arfvedsonite are associated with very fine-grained aggregates of a brown micaceous mineral. A few small flakes of a brown biotite of the same colour as the aggregates also occur and the aggregates are therefore most probably composed of biotite. These aggregates may be formed at the expense of arfvedsonite or perhaps at the expense of ænigmatite.

Some rocks have streaks of fine-grained acmite with partial rims of arfvedsonite.

Nepheline is a prominent constituent of the coarse-grained rocks and may comprise up to half of the rock. Ijolitic types are then formed. The nepheline displays generally at least traces of crystal shape, but most grains are corroded by the analcime or by sodalite and fine-grained natrolite. The grains have enclosed small laths of microcline and they are often cloudy. There are all transitions from large grains of a diameter of one centimetre or more to small grains of the size commonly found in the lujavrites. The larger grains of nepheline show evidence of crushing and are divided into areas of slightly different optical orientations. In the coarse-grained rocks of the east coast, which are rich in green analcime, there are large white grains of nepheline several centimetres across. They are intergrown with the analcime and with long prisms of natrolite in radiating groups. Fine needles of schizolite are scattered through this nepheline.

There are generally only traces of microcline in these rocks, but some occurrences on the east coast have large plates of microcline (corroded by the analcime and with inclusions of albite).

Pseudomorphs after eudialyte are composed of katapleite, neptunite, pigmentation and arfvedsonite (surrounded by acmite). The small pseudomorphs have the crystal shape of eudialyte, the larger ones have rather irregular shapes. Steenstrupine is often associated with the pseudomorphs and appears to replace the latter. It has inclusions of arfvedsonite, acmite (often surrounded by arfvedsonite) and lath-shaped and polygonal areas of analcime.

Some coarse-grained rocks of the east coast have a naujaitic structure with white grains of the size and shape of the naujaitic sodalite enclosed in arfvedsonite. These white grains consist of cloudy analcime with microlites of schizolite and ægirine. The enclosing arfvedsonite has columnar extinction and is partially altered into the brown micaceous aggregate.

The radioactive "fracture fillings" in the coarse-grained rocks of the east coast have a groundmass of analcime which may be in lath-shaped areas. The large grains of arfvedsonite are, to varying extent, penetrated and replaced by ægirine/acmite and a brown mica. Eudialyte is rare, but pseudomorphs after that mineral are abundant. Further components are neptunite, monazite, britholite, sphalerite, pyrochlore, igdloite, apatite and grains of sodalite. The latter have inclusions of microcline, arfvedsonite, ægirine and scales of a white mica. There are large poikilitic grains of a brown and black material which may be steenstrupine.

Green sodalite of naujaitic type is rather common in the coarse-grained rocks, but fragments of naujaite may also occur in these rocks and in the enclosing lujavrite. These inclusions vary in size from several centimetres down to single grains of eudialyte, ægirine, etc. They are most common adjacent to the larger inclusions of naujaite. No. 18512a is an example.

The fragments of naujaite contain large grains of ægirine and sodalite in a matrix of analcime and natrolite. Eudialyte occurs in the fragments and as single large grains which are heavily fractured and with a faint undulatory extinction. They do not show zoning or flames of mesodialyte. More common than these large grains are aggregates and streaks of small crystals which especially occur in the border zones between fragments and the enclosing lujavritic rocks. The small crystals have flames of mesodialyte and are associated with small needles of arfvedsonite. Scattered large grains of nepheline are somewhat corroded and may be surrounded by fine-grained natrolite.

The coarse-grained rocks are clearly in a stage of dissolution in the lujavrite and are penetrated by veins of that rock. The groundmass analcime of the coarse-grained rocks in the cases examined is optically continuous with the analcime of the groundmass of the adjacent lujavrite.

The lujavrite adjacent to the coarse-grained rocks is rich in analcime and arfvedsonite and also contains steenstrupine (see p. 80) and black nodules. The latter are composed of pigmentary material, altered eudialyte, neptunite, katapleite, arfvedsonite, natrolite, analcime, schizolite, white mica, astrophyllite and spindle-shaped grains of monazite. The neptunite often occurs in the marginal parts of the nodules, a feature which has also been described from altered naujaite eudialyte (Danø and Sørensen, 1959, p. 22). The nodules have lath-shaped areas of analcime and may be associated with steenstrupine. These grains of steenstrupine are clear, yellowish brown and isotropic. The most brown parts of the grains may show aggregate extinction. The small crystals of eudialyte in the lujavrites containing these nodules have small areas with neptunite, etc. The white round spots in these rocks are composed of aggregates of prisms and fibres of schizolite. There are also larger prisms of schizolite with numerous inclusions of arfvedsonite.

5. The Steenstrupine-bearing Lujavrites.

The steenstrupine-bearing lujavrites of the north coast of Tunugdliarfik have been briefly described by Buchwald and Sørensen (1961, p. 20). In the present chapter the steenstrupine-bearing rocks at the eastern end of Tugtup agtakôrfia will first be mentioned and the different rock types of the upper horizons of steenstrupine-bearing lujavrites (cf. p. 63) will be subsequently described.

The steenstrupine-bearing rocks of the east end of Tugtup agtakôrfia were examined in no. 21098. The lujavrite here is extremely rich in crystals of nepheline and eudialyte. The groundmass is made up of analcime. Arfvedsonite is the predominant dark coloured mineral, but there are large grains of ægirine/acmite with inclusions of arfvedsonite. Further components are microcline, murmanite, molybdenite and, in cavities, small fibres of natrolite.

The lujavrite is separated from the steenstrupine-rich white rock by a thin zone rich in arfvedsonite and with scarce acmite and eudialyte.

The white rock has large grains of nepheline, up to one centimetre across, enclosed in a groundmass of analcime and minor natrolite. The nepheline grains are strongly corroded, the adjacent grains having almost identical optical orientations. It appears as if larger grains of nepheline have been broken into smaller pieces. There are a few grains of sodalite and very small amounts of eudialyte, arfvedsonite, acmite and microcline. Steenstrupine occurs in poikilitic grains with numerous inclusions of nepheline.

In places, the steenstrupine is restricted to a thin network between the grains of nepheline. The steenstrupine can then attain a size of several centimetres. The enclosed nepheline is far less corroded than the nepheline of the adjacent white rock and it is also of interest to note that the steenstrupine contains inclusions of small crystals of eudialyte, lovozerite, analcitized laths of microcline, a few laths of albite, acmitized arfvedsonite and igdloite. It appears then as if the grains enclosed in the steenstrupine have been protected against the replacive activity of the analcime. The steenstrupine is isotropic, yellowish grey to strongly brown.

The upper horizons of steenstrupine-bearing lujavrites are as mentioned on p. 65 composed of black, green and brown rock types (see the table p. 235).

The general features of the black rocks have been described on p. 76. The steenstrupine-bearing samples nos. 21085, 21101, 21106, 21111, 21112 and 21115 were studied. The rocks are beautifully laminated and composed of microcline, albite, nepheline, sodalite, occasional ussingite, arfvedsonite, eudialyte and minor amounts of acmite and the "green mineral". Analcime and natrolite are absent in some samples, but generally occur in small to large amounts. Accessories are small flakes of epistolite (undergoing alteration into an unidentified aggregate mineral), astrophyllite, sphalerite and prisms of schizolite, the latter altering into a brown earthy substance.

The maximum lengths of the main minerals are: arfvedsonite one millimetre (rarely 3 mm), feldspar laths 2 mm, nepheline 1 mm, sodalite 2 mm, eudialyte 0.5 mm and the green mineral 1 mm.

Ussingite occurs in some rocks in association with microcline and sodalite. The areas of ussingite may be lath-shaped and are made up of scaly aggregates. In parts of the rocks ussingite is the predominant groundmass mineral. The ussingite-bearing rocks contain small crystals of cloudy lovozerite.

The steenstrupine is present in poikilitic grains with inclusions of arfvedsonite, ægirine, microcline, lath-shaped areas of analcime, nepheline (surrounded by natrolite), schizolite, ussingite, lovozerite and natrolite. The steenstrupine is associated with grains of altered eudialyte and is isotropic to weakly anisotropic with yellowish-grey to brown colours. There are transitions to poikilitic areas composed of a brown, ill-defined substance. The inclusions in the steenstrupine are of the same size and orientation as the minerals of the surrounding lujavrite.

The green lujavrites, which, as mentioned on p. 64, are enclosed in the black rocks, were studied in nos. 21070, 21072, 21106, 21107 and 21115. They are rich in small acicular grains of ægirine which are generally undeformed and homogeneously green. The needles are up to one millimetre long, in some samples up to two millimetres. The acicular ægirine often shows preferred orientation parallel to the lamination of the enclosing black lujavrite. The matrix of the rock is made up of small laths of microcline and varying amounts of nepheline, albite, eudialyte, schizolite, analcime and natrolite. There are a few grains of acmite which are larger than the needles of ægirine. They can have small inclusions of arfvedsonite and can be surrounded by needles of ægirine. Arfvedsonite is entirely lacking in some samples, but in others there are tiny grains which can occur as rims on the ægirine. Such grains are especially abundant in the marginal parts of the green inclusions in the black lujavrites. Small areas in the green rocks, rich in arfvedsonite, have small laths of microcline in parallel orientation. These laths are smaller than those of the surrounding green rock. Accessories are sphalerite, igdloite, britholite, astrophyllite and groups of flakes of a white mica. Fibrous natrolite occurs in cavities.

The laths of microcline in the green rock are either undeformed or with the spotted type of twinning. Albite occurs in deformed laths which are smaller than the microcline laths and it is sometimes enclosed in the latter. The feldspar laths are up to one millimetre long. Small corroded crystals of nepheline, up to 0.5 millimetre across, are abundant in some samples and practically lacking in others. The round grains of sodalite have inclusions of microcline and microlites of ægirine.

Eudialyte occurs in smaller crystals than in the black rocks. Unaltered eudialyte is lacking in some samples, but there are then small rust coloured pseudomorphs. The small crystals of eudialyte can form aggregates.

The poikilitic grains of steenstrupine are associated with areas of pigmentation and neptunite and they have inclusions of ægirine, eudialyte, eudialyte pseudomorphs, microcline, analcime, nepheline, white mica, arfvedsonite and sphalerite. The inclusions of ægirine and microcline are orientated in the same way as the grains of these minerals in the surrounding rock, but are much smaller than their latter occurrence. The inclusions of arfvedsonite are, on the other hand, of the same size as in the lujavrite. The steenstrupine is similar to the one mentioned from the black rocks and shows transitions into poikilitic brown areas.

Schizolite occurs in aggregates of small prisms and in large poikilitic prisms which are often orientated normal to the lamination of the lujavrite. The inclusions of microcline, ægirine and arfvedsonite occur in smaller grains than in the surrounding lujavrite.

Coarser grained patches in the green rocks are composed of microcline, sodalite, eudialyte and prisms of arfvedsonite.

The black lujavrites enclosing the green rocks appear to have replaced the latter since these are penetrated by microcline, arfvedsonite and analcime in their marginal parts. There are also small needles of ægirine in the parts of the black rocks adjacent to the green inclusions, but the needles are smaller than those of the green lujavrite. The grains of microcline and arfvedsonite of the black rock are arranged conformably around the green inclusions.

Lujavrites, which are intermediate between the green and black rocks, were studied in nos. 21087, 21102 and 21114.

As in the green lujavrites there are acicular grains of ægirine in a groundmass of microcline, scarce albite, sodalite, nepheline, analcime and fine-grained natrolite. Arfvedsonite occurs in larger quantities than in the green rocks as small grains which can form incomplete rims on the ægirine. Ægirine and arfvedsonite can also occur in independent grains which may have been formed in equilibrium. There are small crystals of eudialyte, small pseudomorphs after that mineral and occasional lovozerite. Large prisms of schizolite (with inclusions of arfvedsonite and ægirine) are normal to the lamination of the rocks.

The poikilitic grains of steenstrupine have clear, yellowish brown cores and brown margins; they are isotropic. The inclusions of arfvedsonite, microcline, nepheline and analcime occur in smaller grains than in the surrounding lujavrite and are orientated as in the latter. The ægirine enclosed in the central parts of the steenstrupine grains is in smaller grains than in the lujavrite, whilst the inclusions in the marginal parts of the grains are of the size of the grains in the surrounding rock. Some of the inclusions of ægirine have rims of arfvedsonite. The steenstrupine appears to have grown at the expense of the pre-existing minerals of the lujavrite. Some of the steenstrupine grains are of the red type and there are also brown poikilitic areas of ill-defined composition.

There are small flakes of epistolite, astrophyllite and white mica. Sphalerite, black ore and fracture fillings of fine-grained natrolite also occur.

The brown lujavrites were studied in nos. 21070, 21072, 21073 and 21105. They have conformable inclusions of naujaite which, adjacent to the lujavrite, contain streaks and aggregates of small needles of ægirine associated with analcime, natrolite and pigmentary material. Poikilitic grains of arfvedsonite have marginal patches of fine-grained acmite. Besides, there are small separate prisms of arfvedsonite and acmite, the first-named sometimes forming rims on the latter. Large grains of ægirine have patchy colour distribution and the grains in contact with lujavrite are deformed with the formation of small needles of ægirine which take part in the border zone of the lujavrite.

The border zone of the lujavrite is rich in acmite and further contains ægirine, analcime, microcline, sodalite (sometimes with microlites of arfvedsonite and ægirine), natrolite, rust coloured pseudomorphs, neptunite, schizolite (with inclusions of arfvedsonite) and white mica. The acmite and ægirine may be in homoaxial intergrowths. Arfvedsonite occurs as small grains interstitially in the aggregates of acmite and there are sometimes rims of arfvedsonite between acmite and the rust coloured pseudomorphs. There are poikilitic grains of steenstrupine with inclusions of acmite, arfvedsonite, sodalite and analcime.

The brown lujavrite inside the border zone is rich in acmite but also contains needles and prisms of ægirine. The matrix is composed of analcime, fine-grained natrolite, laths of microcline and some sodalite. Small rust coloured pseudomorphs after eudialyte are common. The acmite occurs in prismatic grains, up to two millimetres long, which show some preferred orientation parallel to the border of the naujaite. The grains have green patches of ægirine. Grains of arfvedsonite smaller than the acmite grains occur interstitially between the prisms of acmite and can also grow on the latter.

Poikilitic grains of steenstrupine have inclusions of ægirine and more rarely acmite, arfvedsonite and pseudomorphs after eudialyte. The steenstrupine is brown and cloudy, but with clear yellow patches.

Schizolite occurs in prisms and groups of small prismatic grains and parts of the rocks are rich in flakes of white mica, probably lithium-bearing. Accessories are neptunite and black ore.

The transition from brown to green lujavrite is rather gradational with small needles of ægirine in the outer parts of the brown lujavrite and acmite in the outer part of the green rock. This acmite occurs as larger grains than the ægirine needles and is of the size of the acmite of the brown rocks. The acmite can be wrapped by small needles of ægirine.

Some thin zones in the brown lujavrite are rich in ægirine. These zones can be followed continuously from the green into the brown rock as a type of veining. The green lujavrite in contact with the brown rock is without eudialyte but contains pseudomorphs after that mineral.

Inclusions of brown lujavrite in black lujavrite in the horizon at 220 metres have concentrations of small crystals of eudialyte along the border.

As mentioned on p. 65 there are in some horizons of the steenstrupine-bearing lujavrites small lenses of light coloured rocks extremely rich in steenstrupine. No. 21113 is an example of such a rock.

The adjacent lujavrite is bluish-green and composed of ægirine, arfvedsonite (sometimes occurring as rims on the ægirine), microcline laths, natrolite, sodalite and epistolite(?).

The poikilitic grains of steenstrupine are rich in inclusions of arfvedsonite, ægirine, natrolite and microcline in smaller grains than in the lujavrite but with the same orientation. The greater part of the grains of steenstrupine are made up of ill-defined brown material which is generally isotropic. But there are patches of colourless to brown, isotropic or weakly anisotropic steenstrupine.

The groundmass of the light coloured steenstrupine-rich rock is composed of fine-grained natrolite. Sodalite occurs in large grains which are often rich in pigmentary inclusions and more or less replaced by the natrolite. Arfvedsonite, ægirine, microcline, sphalerite, astrophyllite and epistolite are subordinate constituents and there are small patches of ussingite(?) in the sodalite. Small pigmentary areas resemble altered eudialyte.

Steenstrupine is present in large irregular grains of a strong brown colour which is distributed in an irregular way. The grains are partially anisotropic and are rich in black spots and in inclusions of the groundmass minerals.

Banded Rocks of Dense Appearance in the Naujaite.

The occurrences of these rocks were described on pp. 42 and 52. The rocks have been studied in the thin sections nos. 18512 a, b and c, 21004, 21080, 18646, 21049, 21081, 21082 and 18–13/8 from the south west point of Igdlúnguaq and in one thin section from the west coast of Igdlúnguaq (no. 5).

Analcime makes up the groundmass of these rocks which is the cause of the dense appearance, this in spite of the large grain size of many of the minerals. The analcime is present in large grains which may occupy a whole thin section. Volumetric analyses of some of these rocks are given in the table on p. 236.

The red bands contain a multitude of small eudialyte crystals of lujavritic type (0,01–0,5 millimetre across). In some samples they are randomly arranged, in others a sub-parallel orientation is developed (plate 4, figs. 1, 2 og 3). The scattered grains of nepheline (adjacent grains with similar optical orientations) are corroded and partially replaced by analcime and natrolite. Minor components and accessories are ægirine needles, microcline laths, acmite with inclusions of arfvedsonite (and sometimes present in poikilitic grains of naujaitic type), small grains of sphalerite, poikilitic grains of britholite (with inclusions of eudialyte) and schizolite prisms. There are areas of chalcedony-like natrolite.

The eudialyte crystals have thin, irregular flames of mesodialyte and are generally unaltered. Some grains are, however, altered into pigmentary material, katapleite, eucolite, neptunite, ægirine and britholite. Several altered grains can be associated in aggregates.

The red bands have streaks of denser and darker appearance. These bands contain, in the analcitic matrix, aggregates of acmite with small inclusions of arfvedsonite and furthermore cloudy grains of eudialyte, larger pseudomorphs after that mineral, neptunite, schizolite aggregates and pigmentary material.

The white bands also contain small crystals of eudialyte, but in smaller amounts than the red ones. Nepheline is the predominant mineral and occurs in closely packed, corroded grains from 0.02 to 0.5 centimetre in diameter. There are also aggregates of several small grains of nepheline which have very similar optical orientations. Small laths of microcline may be enclosed in the nepheline. The analcime of the groundmass corrodes the nepheline and can replace it entirely, the former site of the nepheline being marked by shadows of pigmentation in the analcime. There can be zones of fine-grained natrolite around the nepheline. The nepheline shows no preferred orientation.

Further constituents are small laths of microcline (often with the spotted type of twinning), sodalite (without microlites), small irregular grains of ægirine, acmitized arfvedsonite, small prisms of schizolite and sometimes monazite. Small brown steenstrupine grains and small flakes of lepidolite may also be present. There are areas of chalcedony-like natrolite.

In places there are **rocks intermediate between the red and white bands.** They may have concentrations of eudialyte along the contact with the adjacent lujavrite, as it is the case on the west coast of Igdlúnguaq (plate 4, fig. 1). In this locality there are also poikilitic areas composed of aggregates of small grains of monazite with inclusions of nepheline crystals, microcline, square areas of analcime and a very subordinate amount of eudialyte. The nepheline of these areas is in better preserved crystals than in the analcime matrix. In a few cases poikilitic areas of steenstrupine occur as marginal patches of the monazite areas. The steenstrupine is clear, yellowish-brown and isotropic. It encloses well preserved crystals of nepheline. The rock has scattered needles of arfvedsonite and the adjacent lujavrite contains large prisms of arfvedsonite with inclusions of eudialyte. The lujavrite appears to grow into the "dense" rock (plate 4, fig. 1).

The above-mentioned rocks occur in all stages of transition into **darker rocks containing scattered small needles of arfvedsonite** up to a few millimetres long. The needles are orientated in the planes of banding and traces of lineation have also been seen. In these rocks the small crystals of eudialyte display a faint preferred orientation. Further components of the rocks are acmite, nepheline, microcline, ægirine, analcime, natrolite and steenstrupine.

The arfvedsonite encloses small crystals of eudialyte, pseudomorphs after that mineral, small grains of acmite, ægirine, schizolite, altered nepheline and rectangular areas of analcime. The inclusions of acmite can have small patches of arfvedsonite (plate 4, fig. 2).

The prismatic grains of acmite have inclusions of arfvedsonite and brown mica and sometimes outer rims of arfvedsonite.

The nepheline and microcline of these rocks may be entirely replaced by analcime (and natrolite).

Ægirine and eudialyte crystals are scarce, besides scattered large grains of eudialyte (up to two millimetres across) with rather irregular outlines occur. Large pseudomorphs after eudialyte are composed of katapleite, neptunite, dust, white and brown mica, schizolite and britholite (plate 4, fig. 3). The neptunite is often concentrated in the marginal parts of the pseudomorphs. The large pseudomorphs after eudialyte may be "wrapped" by small crystals of that mineral. The pseudomorphs enclose sodalite and areas of analcime of rectangular or hexagonal shape.

Steenstrupine is often associated with the eudialyte pseudomorphs and can be present in large amounts, to the extent that the whole rock is impregnated with steenstrupine (plate 14, figs. 1 & 2; plate 16, fig. 3). This mineral grows then in between the grains of nepheline, sodalite, analcime, arfvedsonite, eudialyte, acmite and microcline. In some samples steenstrupine forms crystals, in others it occurs in crystal skeleton-like masses between rectangular areas of analcime (plate 16, fig. 2). The steenstrupine is clear, yellowish brown and isotropic, but the margins can be darker coloured and anisotropic. There are inclusions of unaltered and altered eudialyte, katapleite, analcime, arfvedsonite, microcline and acmite. The inclusions are smaller than the minerals of the sourrounding rock. There can be threads of a dark, isotropic substance in the outer parts of the grains.

The arfvedsonite-bearing rocks are cut by thin dark zones which are generally at right angle to the lamination. These zones consist of pigmentary material and their eudialyte is strongly altered into katapleite, neptunite, black and brown dust, etc. The eudialyte adjacent to these zones is also strongly altered and may in part be eucolite. Further components of the zones are poikilitic grains of schizolite (with inclusions of arfvedsonite, eudialyte, ægirine and analcime), natrolite, britholite, sphalerite (in crystal skeletons which can be partly replaced by hemimorphite), white mica, neptunite, small needles of ægirine and small grains of arfvedsonite-acmite, often with the arfvedsonite as marginal rims. The needles of arfvedsonite are parallel to the zones which probably represent a later phase of deformation than the one during which the banded rock was formed.

The banded rocks with arfvedsonite can resemble normal lujavrite rather closely.

Patches of naujaite in the banded rocks have, in a groundmass of analcime and natrolite, deformed grains of microcline, large grains of sodalite and large pseudomorphs after eudialyte with katapleite, white mica, neptunite, schizolite, etc. Irregular grains of steenstrupine are associated with these pseudomorphs. The steenstrupine is clear, yellow to brown, isotropic, but with anisotropic areas. There are also large grains of eudialyte with small areas of alteration products of the kind mentioned above. These altered patches can be associated with steenstrupine.

Recrystallized Inclusions of Naujaite in Lujavrite and the Associated Analcime Veins.

There are, in the lujavrites of Igdlúnguaq, coarse-grained rocks rich in analcime and/or natrolite. They have patches of naujaite and are therefore most probably recrystallized naujaites.

The naujaitic patches contain green sodalite with microlites of arfvedsonite and ægirine and there are large corroded grains of microcline with poikilitic inclusions of sodalite. Fine-grained aggregates of natrolite of the external form of naujaitic nepheline may also be present.

The main constituents of the **coarse-grained rocks** are large grains of analcime, natrolite and yellow sodalite. There is in places a large amount of fine-grained natrolite. The grains of analcime can have microlites of arfvedsonite in star-shaped arrangement; the sodalite is free from microlites of arfvedsonite and ægirine. The scarce grains of microcline are partially replaced by fine-grained natrolite and often show the spotted type of twinning.

Accessories are sphalerite, steenstrupine, schizolite, radiating lines composed of numerous small grains of igdloite associated with neptunite and epistolite (Danø and Sørensen, 1959, p. 25) and small grains of pyrochlore.

The coarse-grained rocks have patches rich in fine-grained acmite and small areas of dense natrolite. The acmite contains brown spots, but no inclusions of arfvedsonite have been observed. There are large pseudomorphs after eudialyte of katapleite, etc. They are associated with black threads of a brown to colourless isotropic substance and with crystal skeleton-like grains of steenstrupine which are unaltered and penetrated by the isotropic threads. The latter are, at high magnification, seen to be composed of microlites of a steenstrupine-looking substance. The acmitic patches have streaks composed of numerous small grains of pyrochlore, scales of a brown mica, analcime, natrolite and lepidolite.

The coarse-grained inclusions are cut by thin veins of very dark lujavrite. These veins are composed of aggregates of arfvedsonite and acmite in a scarce groundmass of analcime in which there are small cavities with fine-grained natrolite. There is a good deal of small eudialyte crystals of lujavritic type and a few larger pseudomorphs after eudialyte composed of katapleite, neptunite, etc. Small laths of microcline are scarce. The arfvedsonite is rich in inclusions of acmite, eudialyte and analcime.

Schizolite occurs in large poikilitic prisms (with inclusions of arfvedsonite and acmite) and in aggregates of small grains. Small grains of neptunite occur in the aggregates of arfvedsonite and acmite. There are a few large prismatic grains of ægirine which are associated with aggregates of felt-like ægirine. The latter are probably formed by crushing of the larger grains. A few grains of acmite occur in the felted ægirine and arfvedsonite appears to grow into and replace the ægirine felt.

In the most analcime-rich parts of the veins there are small crystals of steenstrupine.

The steenstrupine is clear and yellowish-grey in the central isotropic parts of the grains; the dark coloured margins are weakly anisotropic. This steenstrupine is associated with and partly surrounded by the red type of steenstrupine. There are also small crystals of that mineral. The steenstrupine is associated with and encloses pseudomorphs after eudialyte. Inclusions are otherwise rare. The steenstrupine is also associated with the ægirine felt. The outer part of some of the crystals of steenstrupine consists of black threads in analcime. Arfvedsonite in contact with steenstrupine can have rims of acmite.

The coarse-grained rocks were studied in the thin sections nos. 18510, 18511 a, b, c and d and 19–13/8 a and b of samples from the southwest point and in nos. 21035 and 21036 from the east coast of Igdlúnguaq.

The large occurrence of steenstrupine mentioned on p. 39 from the southwest point of Igdlúnguaq is situated in the lower recrystallized border zone of an inclusion of naujaite in lujavrite. The steenstrupine-bearing rock is again underlain by a banded sequence of rocks of the types described on p. 88.

The steenstrupine-bearing zone was studied in the thin sections nos. 18495 a, 18496 c, 18498, 18499 a and c, 18500 a and b, 18508, 18518, 21083 a and b, and 21084 a and b.

The groundmass of the steenstrupine-bearing rock is composed of large grains of analcime. Natrolite is also a prominent constituent occurring in large grains, in aggregates of small grains and in amygdules of chalcedony-like, rust coloured fibres. Fine-grained natrolite in rather equidimensional grains forms zones parallel to the strike of the steenstrupine-bearing zone and there are, in the adjacent analcime, fissures parallel to the fine-grained zones. There is a varying amount of naujaitic sodalite.

Large grains of ægirine of the type seen in the naujaite occur, but they are often deformed. Small acicular grains of ægirine occur in parts of the rock and there are large and small grains of arfvedsonite. The last-named mineral has inclusions of ægirine/acmite, especially in the outer parts of the grains. The rare small crystals of eudialyte are rather corroded and with secondary katapleite, etc. Large pseudomorphs after eudialyte are much more common and are composed of katapleite, fibrous aggregates of schizolite, a white and a brown mica, neptunite, ægirine, aggregates of britholite and black ore. Accessories are schizolite and biotite.

The steenstrupine occurs in flat hexagonal crystals which can attain a size of two centimetres. Several well-developed crystals may be associated in larger aggregates with interstitial grains of arfvedsonite, eudialyte pseudomorphs, etc.

The cores of the steenstrupine crystals are clear, yellowish-grey and isotropic, the margins are generally darker coloured and weakly anisotropic. Parts of the crystals with closely spaced fractures are anisotropic. The steenstrupine is often associated with pseudomorphs after eudialyte and contains scarce inclusions of the latter. Inclusions are otherwise rare in the steenstrupine, but occasional small inclusions of the following minerals have been observed: arfvedsonite, acmite, ægirine, schizolite, biotite, neptunite, sphalerite, pyrochlore, thorianite, britholite, neptunite and natrolite. Parts of the steenstrupine grains are rich in rectangular areas of analcime and the steenstrupine may be reduced to a thin network between these areas. The outer parts of the steenstrupine crystals often consist of analcime with black threads and the crystals are surrounded by radiating fractures in sodalite and analcime (plate 14, fig. 3 and plate 16, fig. 2).

There is much evidence of deformation in the steenstrupine-carrying zone. Thus **the border zone between the naujaite and the steenstrupine zone** can be marked by a concentration of small crystals of eudialyte in a matrix of analcime and natrolite. The eudialyte is partially replaced by katapleite. Between the eudialyte-rich zone and the steenstrupine-bearing rock there is a thin zone composed of numerous small plates of katapleite, small remnants of eudialyte, brown mica, ægirine/acmite, schizolite (often in large prisms), thorianite, aggregates of britholite, pseudomorphs after eudialyte and black threads. This zone appears to be formed by out-rolling of a rock with pseudomorphs after eudialyte. The arfvedsonite adjacent to this zone is partially altered into a very fine-grained aggregate of biotite.

In places the naujaite adjacent to the steenstrupine-bearing zone, and also the last-named zone, contain large grains of nepheline which show a sort of strain lamellae parallel to the c-axes. This nepheline is partially replaced by fine-grained natrolite.

The grains of sodalite in the naujaite adjacent to the steenstrupine zone often have a pronounced dodecahedral cleavage developed. Analcime and natrolite penetrate the sodalite along these cleavages so that the larger grains of sodalite may be divided into aggregates of many small grains.

The large poikilitic ægirine grains of the naujaite in contact with the steenstrupine zone are deformed or broken and have irregular extinction. Besides, small needles of ægirine can occur. In places there are large areas composed of aggregates of acmite with some interstitial and marginal arfvedsonite and with small flakes of a brown mica.

The arfvedsonite of the outer part of the naujaite has small inclusions of acmite, especially in the marginal parts of the grains. Some grains of arfvedsonite are partially replaced by a very fine-grained aggregate of a brown mica which is uniaxial negative. In the border between the naujaite and the steenstrupine zone there are often large prisms of arfvedsonite with inclusions of acmite, ægirine and altered eudialyte. This rock contains also prisms of schizolite.

The naujaite adjacent to the steenstrupine zone can contain a good deal of that mineral, especially as small crystals interstitially between the sodalite, nepheline, etc. of the naujaite. The steenstrupine-bearing rocks are rich in analcime and natrolite which replace the sodalite.

The crystals of steenstrupine are of the same type as those of the steenstrupine zone, but there are also brown grains and brown patches in the crystals with a weak aggregate extinction. The crystals are surrounded by radiating fractures in the analcime, but not in the natrolite. The steenstrupine is often associated with pseudomorphs after eudialyte and with thorianite, monazite and igdloite. There are lath-shaped inclusions of analcime. The brown mica formed at the expense of arfvedsonite is almost black in contact with the steenstrupine.

Unaltered grains of eudialyte are very rare in the parts of the naujaite in contact with the steenstrupine zone. Pseudomorphs after eudialyte are, however, common. Only in a few places eudialyte-bearing naujaite has been seen in contact with the steenstrupine zone. The naujaite then contains large areas of eudialyte, several centimetres across, which in thin section are seen to be composed of many small grains of identical or similar optical orientations. They enclose crystals of nepheline in the same way as the eudialyte of the naujaite encloses sodalite. The groundmass of the rock is composed of sodalite, analcime and fine-grained and prismatic natrolite. The yellow sodalite observed in hand specimens is, when studied in thin section, seen to be without microlites of arfvedsonite and ægirine and it is enclosed in fine-grained natrolite.

The eudialyte of this rock is crowded with pigmentation and may be more or less altered into katapleite, etc. The eudialyte is most altered in contact with the steenstrupine zone. This contact zone also contains small plates of katapleite, bent flakes of a brown mica and flakes of white mica.

Steenstrupine grows into this rock and encloses areas of altered eudialyte. The steenstrupine is of the above-mentioned type and is associated with large prisms of arfvedsonite (with inclusions of acmite), small needles of arfvedsonite, ægirine (often in large grains), schizolite, igdloite and pseudomorphs after eudialyte rich in katapleite. The grains of steenstrupine are undeformed.

The Analcime Veins in Lujavrite Adjacent to Recrystallized Inclusions of Naujaite.

These rocks were studied in the samples 18495, 18495 b, 18496 b, 18499 b, 18514 and 21046 from the southwest point of Igdlúnguaq and in sample no. 21022 from the southeast point of Igdlúnguaq.

The lujavrite penetrated by these veins on the southwest point is coarse-grained with prisms of arfvedsonite, several millimetres long, in an analcime-rich groundmass. The arfvedsonite contains inclusions of acmite, ægirine needles, eudialyte and lath-shaped areas of analcime. The inclusions of acmite can have small spots of arfvedsonite. The arfvedsonite is generally randomly arranged and there are small star-shaped groups of arfvedsonite needles. The groundmass of analcime contains large plates of microcline. There are also corroded grains of nepheline (surrounded by fine-grained natrolite) and grains of sodalite, up to one centimetre across, with microlites of arfvedsonite and small areas of natrolite. Lath-shaped areas in the analcime may be pseudomorphs after microcline.

The rare small crystals of eudialyte, also the ones enclosed in arfvedsonite, are often strongly altered into katapleite, neptunite, schizolite, lovozerite and dust. Large pseudomorphs of the size of the eudialyte of the naujaite also occur. The larger grains of eudialyte can, by fractures parallel to the basal face, be divided into several small crystals. Steenstrupine is occasionally associated with the pseudomorphs.

Accessories in the lujavrite are schizolite, epistolite, igdloite, white mica and biotite and there are, as mentioned on pp. 42 and 83, black nodules, poikilitic grains of steenstrupine and aggregates of schizolite.

The relationship between arfvedsonite and acmite in these rocks is most confusing since the two minerals are enclosed in each other. In some samples acmite is associated with pseudomorphs after eudialyte, but not with unaltered eudialyte.

The coarse-grained lujavrite adjacent to the analcime veins is cut by thin zones of normal lujavrite and the large prisms of arfvedsonite may be normal to these zones. There are also thin veins of fine-grained natrolite.

The analcime veins have a groundmass of large grains of analcime separated by smaller grains of that mineral. There are large, partly broken, prisms of ægirine and large grains of arfvedsonite with homoaxial inclusions of ægirine.

Steenstrupine occurs in well-developed crystals in the central parts of the veins, whilst the steenstrupine of the border zones have crystal faces developed against the vein analcime and more irregular outlines against the adjacent lujavrite. The steenstrupine appears to grow in between the prisms of arfvedsonite in the lujavrite. The arfvedsonite is often separated from the steenstrupine by a thin zone of fibrous acmite, but direct contacts between arfvedsonite and steenstrupine have also been observed. It appears as if acmite is best developed in the lujavrite adjacent to the vein. Inclusions are scarce in the steenstrupine, but small amounts of arfvedsonite, ægirine, thorianite, britholite and altered eudialyte can be enclosed. In the aggregates of steenstrupine there are interstitial grains of arfvedsonite, often with incomplete rims of acmite. The inclusions of arfvedsonite in the steenstrupine can have crusts of acmite, but independent inclusions of acmite have also been observed. The steenstrupine along the margins of the veins is associated with large pseudomorphs after eudialyte composed of katapleite, analcime, white mica, brown and black dust, pyrochlore, neptunite and needles of ægirine. Remnants of such pseudomorphs are enclosed in the steenstrupine.

The steenstrupine is of the type found in the steenstrupine-bearing zone mentioned above, but some of the smallest crystals are anisotropic throughout. The outer parts of the grains often consist of black threads in analcime. Small fibres of schizolite, partly altered into a dark powdery substance, grow on the faces of the steenstrupine crystals.

The lujavrite has sometimes developed a black border zone against the veins. This zone is rich in arfvedsonite, acmite, neptunite and also contains rosettes of flakes of a brown mica which have pleochroic halos around small radioactive grains.

A few veins are composed of platy grains of microcline with interstitial natrolite. These veins have numerous small crystals of eudialyte which are somewhat cloudy. Further constituents are ægirine, arfvedsonite, pseudomorphs after eudialyte, britholite and sphalerite (partly interstitial between the plates of microcline). The veins have along the borders on the lujavrite large grains of sodalite (yellow in the hand specimens) without microlites of arfvedsonite and ægirine. These grains are penetrated by fine-grained natrolite. The adjacent lujavrite is unusually rich in platy grains of microcline up to three millimetres long.

The analcime veins of the southeast point of Igdlúnguaq occur in a lujavrite with small grains of arfvedsonite and needles and groups of needles of ægirine in the interstices between undeformed laths of microcline. The arfvedsonite encloses single needles and groups of needles of ægirine. The ægirine may be associated with acmite (plate 8, fig. 1).

The veins contain, in a groundmass of analcime, large prisms of arfvedsonite surrounded and penetrated by aggregates of acmite and brown mica. Small groups of needles of ægirine between the prisms of arfvedsonite are embraced by the acmitic rims around the arfvedsonite. Parts of the acmite have marginal green zones of ægirine. There are strongly corroded large grains of microcline and patches of fine-grained natrolite.

The veins contain large grains which are brown in the hand specimen. They are in thin section seen to be composed of spindle-shaped grains of monazite and of eucolite (partly transformed into katapleite from the margins), apatite, pyrochlore, dust, fibrous schizolite and black ore. The arfvedsonite is always separated from these aggregates by zones of acmite of the external shape of arfvedsonite prisms.

In the borders of the veins there can be compact streaks of felt-like ægirine and a subordinate amount of eudialyte. There are also small dusty grains which are most probably pseudomorphs after eudialyte. The needles of ægirine are orientated in all directions, but the major part is normal to the streaks. Small aggregates of ægirine between the laths of microcline of the adjacent lujavrite display the same orientation as in the streaks.

The Green Veins and Associated Rocks.

The green veins of felted ægirine are of widespread occurrence in Ilímaussaq. In the present paper, only the veins found at Qeqertaussaq, the head of Kangerdluarssuk and Igdlúnguaq will be described. The rocks from each of the three above-mentioned localities will be treated separately because of their different association with various types of vein rocks.

1. The Veins of Qeqertaussaq.

The green veins are mainly composed of small green needles of ægirine varying in length from 0.01 to 0.5 millimetre and occurring in dense green stringers and patches in rocks with more scattered needles of ægirine. The needles are arranged in a haphazard way or there is a more or less pronounced parallel orientation, either parallel to or approximately normal to the strike of the veins. In some veins thin zones with lamination parallel to the strike are found in rocks with a more felted texture (plate 7, fig. 1).

The groundmass is composed of microcline, albite, natrolite and analcime which are irregularly distributed in the veins.

Microcline occurs in large plates of naujaitic habit and in small laths. The plates are conformably enveloped by the ægirine needles and are somewhat deformed and broken along cross fractures. The latter are filled with natrolite, ægirine needles and small steenstrupine crystals. The spotted type of twinning is often developed around the cross fractures. The small laths of microcline, up to 0.6 millimetre long, are more common than the larger plates. They are often deformed and display the spotted type of twinning. Dense masses of small laths of microcline form the matrix of parts of the veins. In these cases the laths are either arranged parallel to the strike of the vein or they form aggregates of unorientated grains.

Albite occurs in scattered small grains but is, in places, the predominant groundmass mineral. The laths, which are about 0.5 millimetre long, have few twin lamellae and they are generally undeformed although bent laths have been observed. The laths may be in parallel arrangement. In places the albite contains inclusions of ægirine needles and deformed laths of microcline.

Some veins have thin zones with a groundmass of microcline enclosed in rocks with albite as a groundmass mineral. The microcline is especially associated with the densest aggregates of ægirine, this mineral being more scattered in the albite rock. The microcline-ægirine zones have a pronounced orientation of ægirine and microcline parallel to the strike of the veins, whereas the preferred orientation is less conspicuous in the albite rock. There are small laths of microcline in the albite and it is seen that microcline zones pinch out in the albite rock in such a way that they appear to be replaced by the latter.

Analcime and natrolite are present in all samples examined and natrolite is, in places, the predominant groundmass mineral. The natrolite forms aggregates of cloudy small grains and more rarely patches of large grains with irregular extinction. Lath-shaped pseudomorphs of natrolite after feldspar also occur. The ægirine needles are interstitial between these pseudomorphs as they are between the laths of microcline. There are a few rust coloured areas of fine-grained natrolite which may be pseudomorphs after sodalite or nepheline.

Large deformed prisms of ægirine occur in places. They are enveloped by the small needles of ægirine and contain inclusions of microcline, eudialyte and lepidolite.

Small crystals of steenstrupine, from 0.05 to a few millimetres across, are very abundant in these rocks, being rare in the dense patches of ægirine and most common in the marginal parts of these patches and in the feldspar-rich parts of the veins, especially where albite forms the groundmass.

The steenstrupine crystals are brown and isotropic and often show a zonal development with a black core surrounded by a brown rim.

Minor constituents of the veins are schizolite, astrophyllite, neptunite, sphalerite, lepidolite and a britholite-looking mineral. Some veins contain a small amount of fine needles of arfvedsonite which may be of later origin than the ægirine.

The green veins cutting the eudialyte zone of the pegmatites are composed of ægirine needles, microcline, albite, natrolite and analcime. Corroded small grains of eudialyte occur being partially altered into katapleite and pigmentary material. The green rock around these grains contains small plates of katapleite, pigmentary material, strongly altered eudialyte, steenstrupine, monazite and schizolite.

The green veins were studied in thin sections nos. 18455, 18461, 21118, 21119, 21131 and 21135 (table VII, p. 237).

The black veins were studied in the thin sections nos. 21120, 21125 and 21136. They are mainly composed of albite, microcline, small needles of arfvedsonite and ægirine, natrolite and analcime. These rocks show a great variation, but the various rock types are, apparently, connected with all forms of transition.

Some rocks are almost free from albite and are then composed of small, thin laths of microcline (up to 0.5 millimetre long) in an interstitial network of small needles of arfvedsonite (up to 0.3 millimetre long). The laths of microcline are generally arranged parallel to the strike of the veins. Small crystals of altered eudialyte and of steenstrupine are common in the network of arfvedsonite. The former mineral contains minute inclusions of arfvedsonite, the latter of arfvedsonite, microcline, altered eudialyte and analcime. These poikilitic crystals of steenstrupine, about 0.5 millimetre across, are clear or brown and almost always isotropic. Zonal structure is not uncommon. The inclusions in the steenstrupine occur in smaller grains than in the surrounding rock.

In other rocks there are laths of albite which are larger than the microcline laths and often contain inclusions of the latter. The laths may attain a size of three millimetres and often have three twin lamellae of which the middle one is thin and wedge-shaped. This twinning is according to the albite, Karlsbad and the complex albite-Karlsbad laws. The albite is sometimes orientated parallel to the strike of the vein, but is more often unorientated, the inclusions of microcline having in both cases preserved the orientation from the surrounding rock. There are apparently all transitions between rocks in which microcline is predominant and where microcline occurs only as small inclusions in albite.

The microcline and albite rocks often have a considerable amount of analcime in the groundmass, most often in the form of small rounded grains conformably surrounded by deformed laths of feldspar and deformed needles of arfvedsonite (plate 6, fig. 1). This texture recalls that of the lujavrites (cf. Ussing, 1911, figs. 17 and 18). The albite laths of these rocks are strongly corroded.

There are, in parts of the albite-microcline rocks, large prisms of arfvedsonite which can attain a length of a few millimetres. They are often crowded with inclusions of tiny needles of ægirine and also have inclusions of microcline, albite and sometimes eudialyte. Clusters of small needles of ægirine are also found as inclusions in the albite but ægirine is otherwise rare in these rocks.

Other rocks again contain laths of albite enclosed in a groundmass of microcline, arfvedsonite and analcime. The laths are several millimetres long, almost undeformed and arranged in a haphazard way. They are twinned according to the combined albite and Karlsbad (and then also complex albite-Karlsbad) laws. They have lobed boundaries and inclusions of microcline, arfvedsonite, ægirine and analcime. The inclusions of microcline are orientated as in the surrounding rock. The large laths of albite are often partially replaced by natrolite and may be entirely replaced by that mineral. The pseudomorphs then contain small laths of microcline of the type enclosed in the albite. The natrolite-rich rocks also contain a good deal of analcime.

The microcline-rich rocks appear to be older than the albite-analcime-bearing ones. The former wedge out in the latter in such a way that their continuation is seen as a few small laths of microcline and small grains of eudialyte and steenstrupine in the albite rock.

The small brown crystals of steenstrupine are, as just mentioned, associated with the arfvedsonite-microcline rocks. The albite rocks have larger crystals of steenstrupine with poikilitic inclusions of albite, microcline, analcime, arfvedsonite and ægirine. The inclusions are in smaller grains than in the enclosing rock. The large crystals of steenstrupine are strongly coloured and often have red spots in their central parts.

Subordinate components of the black rocks are astrophyllite in small flakes or groups of flakes (often with marginal zones of arfvedsonite) schizolite, sphalerite and black ore (table VII, p. 237).

No. 21136 is a sample of a discontinuous dense black rock in a light coloured vein. The light coloured main rock of the vein is composed of large, sometimes cloudy, tabular grains of albite with few twin lamellae that are often bent. The grains are usually arranged in radiating groups (plate 5, fig. 1). There are a few laths of cloudy microcline, and arfvedsonite is present as rare interstitial grains. Large flakes of astrophyllite are abundant, especially in the marginal parts of the vein. They have inclusions of arfvedsonite, albite and microcline and have developed dark rims around radioactive inclusions. There are a considerable number of areas, up to two millimetres across, composed of chkalovite surrounded by beryllium sodalite. The latter clearly replaces the chkalovite and is in turn surrounded by albite containing small "drops" of beryllium sodalite. Accessories of the light coloured rock are large grains of sphalerite (associated with hemimorphite), schizolite, small grains of britholite and monazite and small scattered crystals of brown steenstrupine. There are a few grains of a eucolite-like mineral. The small crystals of steenstrupine form clusters with small grains of a lovozerite-like mineral.

The dense black rock is confined to the spaces between the large grains of albite of the light coloured rock. It is composed of small laths of albite, small irregular laths of microcline, small interstitial grains of arfvedsonite and small rust coloured crystals of steenstrupine. The microcline and arfvedsonite generally parallel the strike of the vein.

Large grains of albite and astrophyllite penetrate the dense rock and contain inclusions of arfvedsonite and microcline.

The multiple veins mentioned on p. 23 were studied in the thin sections nos. 21122, 21123 and 21124 (table VII, p. 237).

The most homogeneous areas of black rocks are composed of aggregates of small needles of arfvedsonite and small laths of cloudy microcline which are partly enclosed in the arfvedsonite. The grains of these two minerals are up to 0.6 millimetre long. The laths of microcline are generally arranged parallel to the strike of the veins. The microcline laths and the arfvedsonite needles can be deformed. Associated with the arfvedsonite are a great number of small brown crystals of the size and shape of the eudialyte from the lujavrite, but showing more resemblance to steenstrupine. They are often zoned. There is in addition a smaller amount of eudialyte grains of a similar size and shape. Small rounded grains of analcime in parts of these rocks are concentrically surrounded by arfvedsonite.

Parts of the black rocks are entirely free from albite, but these parts are confined to very small areas. Normally the rocks contain laths of albite which are much larger than the laths of microcline just mentioned.

These grains of albite have two or three twin lamellae and have lobed boundaries. They contain inclusions of microcline laths showing their original orientation and also of arfvedsonite and steenstrupine. The albite laths are arranged in thin streaks parallel to the strike of the veins in some rocks, but are normally without preferred orientation. In places albite occurs in groups of radiating laths.

The above-mentioned microcline-arfvedsonite rock with small grains of steenstrupine(?) occurs as thin stringers and masses between the laths and groups of laths of albite. In some cases it appears as if the microcline-arfvedsonite rock encloses small areas of albite, but generally the albite encloses microcline, arfvedsonite and steenstrupine and therefore appears to be formed later than the microcline-arfvedsonite rock. The albite-rich parts of the black rocks have only traces of arfvedsonite, microcline and steenstrupine. In parts of these rocks analcime and natrolite compose a large part of the groundmass, both in large grains. The grains of natrolite are most often deformed showing irregular extinction and they can contain a large amount of dust.

Ægirine is practically lacking in the black parts of the multiple veins and is almost entirely confined to the green parts. The latter rocks have, in the groundmass of albite, scattered small needles of ægirine, mainly in the interstices between the grains of albite, but also enclosed in the latter and in grains of natrolite and analcime. There are scattered small needles of arfvedsonite and a few larger prisms of that mineral.

The latter are often crowded with small needles of ægirine (plate 7, fig. 2). Dense green patches are composed of small needles of ægirine arranged in a haphazard way, or more rarely parallel to or perpendicular to the strike of the veins. The patches have scattered small laths of microcline of the type and size as in the black parts of the veins and sometimes deformed. Steenstrupine is rare in these patches and occurs especially in their outer parts. It forms small rust coloured crystals of the type described from the other vein rocks and it is very often associated with irregular grains of arfvedsonite which apparently grow into the dense green patches. The arfvedsonite encloses a great number of needles of ægirine and also small laths of microcline.

The groundmass of the green rocks consists, in addition to albite, of small brown crystals of steenstrupine, small laths of microcline (which are often enclosed in the albite), small grains of altered eudialyte, astrophyllite, lepidolite and a few grains of sphalerite.

The relationship between the green and black rocks is difficult to determine in thin section, since both rock types appear to be older than their albitic groundmass, but the green rock occurs as small areas in the black rock and ægirine is often enclosed in arfvedsonite. A probable sequence is therefore: green rock, black rock, albite-rich rock (plate 7, fig. 3).

As mentioned above albite is the predominant groundmass mineral in the green and in parts of the black rocks. The same is the case in the light coloured parts of the multiple veins. Large laths of albite with few twin lamellae and often in radiating groups have small inclusions of corroded microcline laths, sodalite and fine needles of ægirine. Analcime and natrolite are in places very important, the latter is seen to replace the albite and occurs as pseudomorphs after that mineral. Astrophyllite is very common in single flakes and in aggregates of flakes with inclusions of arfvedsonite. The astrophyllite in contact with the green rock contains numerous small ægirine needles. In places arfvedsonite appears to form rims on the astrophyllite. The latter mineral has dark rims surrounding small radioactive inclusions, the largest of which have been identified as steenstrupine. Associated with the astrophyllite are small round grains composed of radiating brown length-slow fibres of an unidentified mineral.

The light coloured rocks contain flakes of lepidolite and a few irregular grains of a colourless mineral which occasionally has developed a few crystal faces. The latter mineral is weakly anisotropic, uniaxial negative and is very probably eucolite. The mineral is associated with small grains of schizolite, small brown crystals of steenstrupine and small brown grains with aggregate extinction and composed of a micaceous mineral. The mineral contains inclusions of arfvedsonite, astrophyllite, and, in the ægirine-rich parts of the veins, ægirine needles. Parts of the grains are isotropic and of a weak brown colour and have a great resemblance to steenstrupine.

There are large grains of natrolite and small grains of sphalerite, schizolite, epistolite and black ore.

The light coloured rocks contain small rounded, amygdule-like areas, up to two millimetres across, composed of chalcedony. The amygdules may have a concentration of ægirine needles along the margins and they have inclusions of analcime, microcline, ægirine and lepidolite.

There may be two generations of steenstrupine in the multiple veins, the first consisting of the small brown crystals of eudialyte size (lujavritic eudialyte), the second of somewhat larger poikilitic grains.

Along the contacts of some multiple veins there are coarse-grained rocks, especially where a black zone is lacking in the border of the veins. The coarse-grained rock contains large prisms of arfvedsonite which are somewhat deformed, being divided into irregular columns of slightly different optical orientations (plate 6, fig. 2). They have inclusions of analcime and a few prismatic grains of ægirine. There are small grains of neptunite in cross fractures and small scales of a brown biotite-like mineral on some of the surfaces of the prisms. The large prisms of arfvedsonite are associated with aggregates of small needles of arfvedsonite, small laths of microcline, small grains of altered eudialyte and a good deal of small brown crystals of steenstrupine. It is thus seen that there are small patches of the dense black rock even where it cannot be observed macroscopically. Further components are analcime, natrolite, sodalite, albite, schizolite, sphalerite and in one sample epistolite and astrophyllite.

2. The Veins at the Head of Kangerdluarssuk.

On pp. 26–29 four veins occurring to the north of Lilleelv were mentioned.

Vein no. 2 was studied in sample no. 21154. It is a dark rock with patches of felted ægirine. The groundmass is composed of laths of microcline and albite, which are up to two and one millimetre long, respectively. The albite contains a few small inclusions of microcline and also encloses small needles of ægirine and arfvedsonite. It has few twin lamellae. Between the laths of feldspar there is an interstitial network of aggregates of small ægirine and arfvedsonite needles (plate 9, fig. 1). The latter mineral is predominant and contains inclusions of ægirine. However, independent small needles of ægirine also occur. A few strongly altered crystals of eudialyte are associated with the arfvedsonite network. Further components are sphalerite, lepidolite and schizolite.

Scarce small poikilitic grains of steenstrupine, up to two millimetres across, also occur. There is a small amount of interstitial analcime and natrolite (table VIII, p. 237).

The smallest steenstrupine grains are colourless, the larger ones brown. They can be zoned with cloudy and isotropic central zones and weakly anisotropic margins. The inclusions of arfvedsonite, microcline and subordinate ægirine are smaller than in the surrounding rock. Thus the arfvedsonite needles are up to 0.2 millimetre long inside the steenstrupine, but 0.6 millimetre in the rock (plate 9, fig. 1).

Vein no. 3 is, as mentioned on p. 26, of a rather complex type being composed of various coarse- and fine-grained rocks.

The coarse-grained rocks: The first type to be mentioned is the one with large prisms of arfvedsonite arranged perpendicular to the borders of the vein (21162 b). The groundmass is composed of analcime and microcline. The latter mineral occurs in large corroded plates (up to three millimetres long) and in small laths (up to 0.6 millimetre long) enclosed in analcime. The large prisms of arfvedsonite are almost always twinned and have inclusions of eudialyte and of ægirine/acmite, the latter being present especially in the marginal zones of the prisms. There are also aggregates of small needles of arfvedsonite and a few independent needles of ægirine. Eudialyte occurs as small zoned crystals, up to one millimetre across, with an irregular network of mesodialyte. The crystals are often rust coloured and partly altered into a steenstrupine-like brown material. There are a few small pseudomorphs after eudialyte composed of katapleite, neptunite, etc. Steenstrupine occurs in small crystals of brown to black colour and of a very irregular internal structure. There are also a few larger poikilitic grains of steenstrupine, or perhaps glomeroblasts, with inclusions of microcline and arfvedsonite. They are associated with altered eudialyte. The altered eudialyte may also be associated with clusters of small angular grains of monazite and further components of the rock are schizolite, neptunite, lepidolite and ilvaite (?).

The light coloured rocks with large crystals of eudialyte (nos. 21158, 21159 b, 21159 d and 103) have, in a groundmass of analcime, large, strongly corroded grains of nepheline and crystals of eudialyte. The analcime is so coarse-grained that one grain or a few grains make up a whole thin section.

The nepheline is, to varying extent, replaced by analcime and fine-grained natrolite and also in places by a "gieseckite"-like substance. It encloses small laths of microcline separated from the nepheline by thin rims of analcime. Similar inclusions occur in patches of fine-grained natrolite which are consequently interpreted as altered grains of nepheline.

The crystals of eudialyte show a very conspicuous and very regular zoning with thin zones of mesodialyte in normal eudialyte (plate 3, fig. 2). No traces of eucolite have been observed. Some crystals also have "flames" of mesodialyte which form an irregular network through the crystals. The larger crystals have small areas of the shape of eudialyte crystals, but composed of katapleite, etc. The smaller crystals can have brown crusts. The eudialyte often occurs in aggregates composed of several small crystals. Small pseudomorphs composed of katapleite, neptunite, rust, etc. occur, especially in the analcime groundmass. There are also a few clusters of monazite (erikite).

There are a few irregular grains of arfvedsonite and also star-shaped groups of prisms of that mineral. These prisms have patches of felt-like ægirine/acmite in their outer parts or interstitially. The prisms have inclusions of eudialyte.

The analcime groundmass contains a few small laths of microcline and also small laths of albite. The latter can form small groups of laths and have generally few twin lamellae. Ægirine occurs as scarce small needles and as a few corroded bi-terminated crystals. Further components are sodalite, lepidolite, britholite and black ore.

Adjacent to the fine-grained components of the vein the coarse-grained rock rich in eudialyte is more strongly altered than further away. There are also traces of deformation and crushing. Thus, the eudialyte occurs in aggregates of crystals which have very similar optical orientations, a feature which might be explained by incipient crushing or glomeroblastic growth. The zoning of the eudialyte is, however, best developed along the margins of the aggregates which speaks in favour of a formation by crushing, since the undeformed eudialyte has zoning all around the crystals. Rusty crusts of a steenstrupine-like mineral occur on fractures in the deformed eudialyte and in some cases such crusts are developed in interior zones of the crystals parallel to the crystal faces.

Apart from the above-mentioned crusts, steenstrupine is rare in this rock type occurring in scattered small crystals of irregular internal structure and colouration.

The steenstrupine grains are often zoned in a "conchoidal" way which recalls structures formed by crystallization of colloidal matter. The grains are isotropic or show weak aggregate extinction. They are most dark coloured in the cores, but there are often black coatings which are connected with black threads penetrating a short distance into radiating fractures around the crystals.

A third coarse-grained rock type is rich in small prisms of arfvedsonite which are a few millimetres long (no. 21159 a). These prisms are arranged in a haphazard way or in star-shaped groups. They have small aggregates of felt-like ægirine which are especially concentrated along the margins of the arfvedsonite, or where the prisms are bent. The groundmass is composed of analcime. Further components are corroded grains of nepheline (partly replaced by natrolite and analcime), zoned crystals of eudialyte, small laths of microcline, scarce small laths of albite and a few small grains of ægirine. The eudialyte is, in places, associated with a rust coloured, in part red, steenstrupine which occurs in small crystals of irregular internal structure and often along the surfaces of the crystals of eudialyte. The arfvedsonite-rich rock appears to replace the eudialyte-rich rock.

As a final example of the coarse-grained rocks, a type with needles of ægirine and a good deal of albite will be mentioned (nos. 21159 c and d). Ægirine occurs as minute needles and as small bi-terminated crystals. The laths of albite have generally few twin lamellae, but polysynthetically twinned grains have also been observed. The laths are intergrown in an irregular way and sometimes form radiating groups. Analcime appears to replace the albite and has small inclusions of that mineral. Zoned crystals of eudialyte are common. Microcline occurs as small laths and the parts of the rock rich in that mineral have small irregular grains of arfvedsonite. There are a few larger grains of neptunite with inclusions of arfvedsonite and associated with cloudy areas of katapleite, etc. Further components are lepidolite, sphalerite (with hemimorphite) and "erikite". There are thin veins of fine-grained natrolite. Steenstrupine has not been observed in this rock type.

The fine-grained rocks: The coarse-grained rocks mentioned above are cut by zones of fine-grained rocks (table IX, p. 238).

The coarse-grained rock with the large prisms of arfvedsonite is cut by thin veins of black lujavrite (no. 21162 a). Microcline is the main mineral of these veins occurring in large and small plates. The microcline shows a certain, but in no way perfect, parallel orientation in a direction oblique to the strike of the vein. The larger plates are somewhat deformed with the spotted type of twinning in zones of bending. Between the plates and laths of microcline are prisms of arfvedsonite (with irregular extinction) and aggregates of small needles of arfvedsonite (with inclusions of microcline and neptunite). Ægirine is very scarce and is especially found as inclusions in the arfvedsonite or between the arfvedsonite needles in the aggregates. Small crystals of eudialyte "flamed" by mesodialyte occur as independent grains or enclosed in the arfvedsonite. Cloudy pseudomorphs with katapleite, neptunite and rust are much more common.

Steenstrupine occurs in brown and cloudy grains which in a crystal skeleton-like way grow in between the laths of microcline.

The steenstrupine is isotropic or has weak aggregate extinction. It encloses, in addition to the microcline, arfvedsonite, altered (and more rarely unaltered) eudialyte and "erikite".

There are a few grains of sodalite, a sparse interstitial matrix of analcime and small areas of fine-fibrous schizolite with flakes of lepidolite and surrounded by arfvedsonite. Neptunite occurs in a great number of small grains.

Some of the fine-grained parts of the vein are composed of a greenish black rock with small inclusions of green rocks. The dark rock was examined in the thin sections nos. 21158, 21161 and H 18467 d. It is of lujavritic appearance and may be divided into two main types, one with the groundmass composed of microcline, the other with a groundmass of analcime (with scarce inclusions of microcline). Both types carry arfvedsonite and steenstrupine.

The microcline of the first-named rock type generally shows no preferred orientation. The rock has an interstitial network of aggregates of fine-grained arfvedsonite with inclusions and interstitial grains of ægirine/acmite and there are small patches of analcime with corroded remnants of nepheline.

In the analcime-rich rocks microcline may be entirely lacking or it occurs only in scattered small laths. In thin zones very small and thin laths of albite have been observed. Strongly corroded grains of nepheline are surrounded by fine-grained natrolite and are in places so closely spaced and have so similar optical orientations that they may well have been formed by deformation of larger grains of nepheline. These rocks have numerous small prisms of arfvedsonite and also a few larger prisms with inclusions of microcline, eudialyte and steenstrupine and cut by zones of analcime. The large prisms are associated with large crystals of eudialyte and have small aggregates of felt-like ægirine/acmite in their outer parts and where they are bent. Small needles of ægirine/acmite can also be concentrated in the analcime adjoining the arfvedsonite.

The greenish black rocks contain smaller amounts of ægirine than of arfvedsonite, the ægirine being present in tiny needles or as felt-like aggregates of many small needles. The ægirine felt forms patches with inclusions of neptunite and small rust coloured grains composed of an aggregate of a strongly birefringent mineral which can be associated with eudialyte. The matrix of the patches is generally composed of analcime and some natrolite, but also of microcline in the microcline-rich rocks. The patches appear to be enclosed mainly in the microcline-rich rocks. Arfvedsonite grows into the aggregates of ægirine felt.

Small zoned crystals of eudialyte "flamed" by mesodialyte occur in the greenish black rock.

The eudialyte is altered, to various degrees into katapleite, neptunite, a micaceous mineral and a cloudy precipitate, and there are also small areas of "erikite". The pseudomorphs after eudialyte can have inclusions of arfvedsonite and ægirine/acmite. In parts of the analcime-rich rock eudialyte has disappeared and there are instead numerous dusty areas with a few plates of katapleite and much smaller than the eudialyte crystals. The areas are closely spaced and may represent remnants of "rolled out" grains of eudialyte. The eudialyte is most strongly altered in the parts of the rock richest in nepheline.

Steenstrupine occurs in the microcline-rich rocks as small red grains of a rather irregular shape and associated with the arfvedsonite. There are also irregular grains of a brown colour having aggregate extinction. The marginal parts of the grains are darkest. There are inclusions of arfvedsonite and ægirine and the grains appear to grow in a glomeroblastic way.

The analcime-rich rocks contain reddish-brown grains of steenstrupine with an irregular colour distribution. They are almost isotropic and occur in aggregates of small grains or in larger grains of irregular shape. In both cases there are inclusions of arfvedsonite, nepheline and altered, as well as unaltered, eudialyte. The brown steenstrupine can form coatings on the grains of eudialyte. The coatings are composed of concentrically arranged thin shells of brown and colourless material.

Accessories are monazite, igdloite and britholite.

There are, in the greenish black rocks, coarse-grained inclusions which, in a groundmass of analcime, have large grains of nepheline and eudialyte. These two minerals are most strongly deformed and altered adjacent to the fine-grained rock. The eudialyte has then brown areas of a steenstrupine-like substance in zones of fracturing (cf. p. 105).

The above-mentioned fine-grained rocks are very probably formed at the expense of deformed coarse-grained rocks and their nepheline and eudialyte are, at least partly, to be regarded as remnants of deformed grains from these rocks. This way of formation may also explain the banded nature of parts of the analcime-rich rock. There are, in places, concentrations of arfvedsonite, ægirine and reddish-brown steenstrupine in the border zone between the fine- and coarse-grained rocks.

There are several types of green, fine-grained rocks in this vein. One type (nos. 18467 a, 18467 c and 100) is, in the hand specimen, seen to have thin black needles of ægirine, a few millimetres long, and small grains of brown steenstrupine and red eudialyte in a more fine-grained green matrix. There are inclusions of the eudialyte-rich, coarse-grained rock.

The rock contains, in a groundmass of analcime, numerous needles and small prisms of ægirine which are generally without crystallographical terminations. There is no preferred orientation and the larger prisms can be bent. There are numerous small eudialyte crystals of lujavritic type and up to one millimetre across. They are almost unaltered, but with irregular extinction. Small pseudomorphs after eudialyte occur locally and are composed of neptunite, dust, etc. Further components are scattered laths of microcline, small grains of neptunite, scarce small irregular grains of arfvedsonite (which appear to grow in between the ægirine), sphalerite, fibrous schizolite and small aggregates of a strongly birefringent mineral. There are a few streaks of felted ægirine with arfvedsonite, neptunite and pseudomorphs after eudialyte.

Steenstrupine occurs as scattered reddish-brown crystals which are darkest in the central parts and anisotropic and of lighter colour along the margins. They are associated with ægirine and eudialyte and contain inclusions of these minerals. Some grains of steenstrupine have the same extinction position as the adjoining eudialyte, but the optical axes of the two minerals are at right angles.

A rock of this type occurs in the northern contact of the vein where the latter is cut by a small brook. It is separated from the naujaite by a thin zone of analcime and has developed a millimetre thin dark zone in contact with the latter. The dark zone is composed of arfvedsonite, ægirine, pseudomorphs after eudialyte and aggregates of small crystals of the brownish red type of steenstrupine with inclusions of arfvedsonite and ægirine. Arfvedsonite often forms the border on the analcime zone and eudialyte is not present in the outermost part of the green rock.

The analcime rock just mentioned (no. 18467 e) has, in a coarse-grained groundmass of analcime, scarce small needles of ægirine and arfvedsonite, red steenstrupine, schizolite, natrolite, a colourless mica, epistolite and sphalerite. The last-mentioned mineral occurs in small rounded grains and as elongated crusts on fractures in the analcime. Parts of the analcime are developed as crush breccias with angular fragments of cloudy analcime enclosed in colourless analcime.

The parts of the vein richest in steenstrupine have been studied in 13 thin sections which all have the number 18467. These rocks are, in hand specimen, seen to be composed of a greyish groundmass with thin green streaks and patches. The streaks are straight or they can show contortions ("fluxion banding").

The groundmass is composed of small round grains of analcime which can reach a size of a few millimetres. Nepheline is generally lacking in these rocks but there are areas of the analcime with small strongly corroded grains of nepheline which can have very similar optical orientations when they are closely spaced. They have inclusions of microcline with rims of analcime and the larger grains are surrounded by fine-grained natrolite. Microcline laths are very scarce and in restricted areas there are small and thin laths of albite which can be in parallel orientation.

Small needles and prisms of ægirine and arfvedsonite are scattered over the rock or they form aggregates of many small needles. Besides there are larger concentrations in the green streaks and patches which will be described below.

The needles of ægirine and arfvedsonite of the groundmass generally show no preferred orientation. The ægirine is green in the independent grains, and acmitic in the aggregates. The acicular ægirine "wraps" the round grains of analcime, the eudialyte pseudomorphs and the steenstrupine. The relationship between ægirine and arfvedsonite is difficult to determine, but most evidence is in favour of a later formation of the arfvedsonite. Thus, the grains of arfvedsonite in the aggregates, where the ægirine is felt-like, are larger than the ægirine grains, undeformed and also enclose ægirine felt. Furthermore arfvedsonite often grows along the borders of the aggregates. A few larger prisms of arfvedsonite have, however, marginal ægirine/acmite.

Small crystals of eudialyte occur in parts of the rock, but much smaller areas of pigmentation, katapleite, neptunite, etc. are more common. They may form aggregates locally. Larger pseudomorphs after eudialyte and containing the same minerals also occur. Accessories are large prisms of schizolite (with inclusions of arfvedsonite, steenstrupine, analcime and albite), sphalerite, neptunite, igdloite, white mica, epistolite(?) and, in places, numerous fine small prismatic crystals of britholite (cf. DANØ and SØRENSEN, 1959, plate 1, fig. 2). There are small amygdules of chalcedony.

The green streaks and patches are composed of small needles of ægirine/acmite (about 0.1 millimetre long) and a smaller amount of arfvedsonite. There is no preferred orientation. The arfvedsonite appears to grow into the ægirine felt. Further components are neptunite, pseudomorphs after eudialyte, steenstrupine and schizolite. The last-named mineral occurs partly as large rust coloured prisms, partly as aggregates of many small prisms in irregular arrangement and to varying extent replaced by a brownish-black earthy substance. Very fine threads of ægirine are associated with the aggregates.

The analcime rock between the streaks and patches is relatively richer in arfvedsonite (in proportion to ægirine) than the latter and contains steenstrupine and eudialyte pseudomorphs of the type found in these rocks. It appears therefore as if the analcime-arfvedsonite rock replaces the green streaks and patches.

The steenstrupine of the green rocks partly occurs as single well-developed crystals, and partly as aggregates of many small well-developed crystals, especially in the green streaks. The crystals of steenstrupine are wrapped by the ægirine needles (plate 9, fig. 2).

The steenstrupine is of the red type described in a previous paper (BUCHWALD and SØRENSEN, 1961, p. 25). It is reddish-brown in thin section and often has a central dark coloured and isotropic core surrounded by lighter coloured and anisotropic marginal zones. Some crystals are anisotropic throughout. The crystals can be up to two millimetres in cross section. There are inclusions of arfvedsonite, altered eudialyte, some ægirine, analcime, black spots and more rarely feldspar, but inclusions are rare in most places and are often lacking.

The aggregates of steenstrupine crystals have a pronounced mosaic-like (polygonal) texture (BUCHWALD and SØRENSEN, 1961, plate 4, figs. 1 and 2). In some cases there are interstitial ægirine needles and small arfvedsonite grains with inclusions of ægirine. These two minerals also occur along the borders of the aggregates and the needles wrap around the steenstrupine. In places, however, all traces of interstitial and marginal ægirine and arfvedsonite have disappeared so that the crystals of steenstrupine have mutual borders. The border zones often have a strong brown colour.

There are a few larger poikilitic crystals of steenstrupine, a few millimetres across, with inclusions of arfvedsonite, ægirine, laths of albite and microcline, altered eudialyte and britholite. The feldspar laths are arranged parallel to the faces of the steenstrupine crystals. This feature, as well as the mode of arrangement of ægirine and arfvedsonite in the interstitial areas between the steenstrupine of the aggregates, indicate that the crystals of steenstrupine have exerted a crystallization pressure on their surroundings during growth.

In some cases the central parts of the steenstrupine crystals have a very irregular and spotted development recalling pseudomorphs after eudialyte. These parts have weak aggregate extinction and are surrounded by red and clear steenstrupine.

The bands rich in steenstrupine have a higher arfvedsonite content than is normal in the green rocks. It is also seen that the parts of the rocks richest in unaltered eudialyte are poorest in steenstrupine and britholite.

The steenstrupine-rich rocks contain many black fractures.

Some of the green rocks, in hand specimen, have been interpreted as crushed and partly recrystallized naujaite. They have a few deformed plates of microcline, remnants of sodalite and cloudy pseudomorphs after eudialyte.

The naujaite adjacent to the vein is strongly altered and rich in analcime and natrolite. It also contains aggregates of acmite, arfvedsonite and brown mica. There are thin veins of felted ægirine rich in zoned crystals of eudialyte of the type found in the coarse-grained rocks of the vein. The eudialyte is associated with brown grains and patches of a steenstrupine-like mineral. The groundmass of these veins is composed of analcime. The green veins may be interpreted as crushed apophyses from the coarse-grained parts of the vein.

Vein no. 4 was described on p. 28. It is composed of fine-grained green and black rocks and of coarse-grained rocks carrying steenstrupine, ussingite, etc. (table VIII, p. 237).

The fine-grained green rock, which makes up the major part of the vein, was examined in the thin sections nos. 18468 b, 21144 b and 21149 b and c.

The rock is composed of ægirine needles, rare arfvedsonite needles, albite, microcline, natrolite, lovozerite, steenstrupine, lepidolite, schizolite, igdloite, sphalerite, britholite and in places ussingite.

Needles and slender prisms of ægirine, up to two millimetres long, make up about half of the rock. The needles are orientated at random or parallel to the strike of the vein and are often bent or broken. A few larger prisms of ægirine of the type found in the coarse-grained patches also occur. In parts of the rock the pyroxene is acmitic with small inclusions of arfvedsonite.

Small needles of arfvedsonite are rare and may grow along the margins of the ægirine needles.

Albite is the predominant feldspar and occurs in small rounded grains less than 0.1 millimetre across. They are mostly without twin lamellae and enclose small laths of microcline.

In parts of the rock deformed laths of microcline form the major part of the matrix. The grains have irregular outlines, are up to 0.2 millimetre across and have developed the spotted type of twinning. The aggregates of microcline have interstitial albite and the microcline can be separated from the latter by thin zones of analcime.

Very few crystals of eudialyte, of the type found in the lujavrites, have been observed, but small crystals of lovozerite, up to 0.7 millimetre across, are much more common. They are widespread in the matrix between the ægirine needles, but also form aggregates of numerous small grains. The lovozerite can be enclosed in the larger prisms of ægirine.

Small zoned crystals of steenstrupine, up to one millimetre across, are scattered over the green rock (plate 13, fig. 2). They are yellow, clear and isotropic in the cores, anisotropic and brown along the margins. There is also a brown colouration along fractures in the interior of the crystals. The scarce inclusions of lovozerite, ægirine, arfvedsonite and microcline are in much smaller grains than in the surrounding rock. The inclusions are especially concentrated in the outer parts of the crystals and are arranged parallel to the faces of the latter. The crystals are often enveloped by the ægirine needles, but there are also grains with rather ragged outlines which appear to grow in between these needles.

The green rock locally contains a good deal of ussingite, especially adjacent to the coarse-grained patches mentioned below. The ussingite replaces the microcline and is most often present as fine-grained aggregates which can be crowded with small ægirine needles. The larger grains of ussingite, however, are almost free from inclusions.

The britholite of this rock is seen in contact with albite, microcline, ussingite and natrolite.

The few large prisms of schizolite have inclusions of ægirine and are arranged almost normal to the lamination.

Surfaces of movement have crusts of a fibrous mineral which has some resemblance to schizolite, but the grain size is too small for a safe identification. There may be some very fine-grained carbonate in the fractures.

The light coloured nodules in the green rock mentioned on p. 28, were examined in no. 21144 c. These nodules are composed of rounded grains of albite (about 0.1 millimetre across and mostly untwinned), irregular laths of microcline, small "blebs" and amygdules of analcime in the albite, a subordinate amount of ægirine and arfvedsonite needles and small grains of altered lovozerite and steenstrupine. The amygdules of analcime have isotropic cores, possibly composed of sodalite. The rims of the nodules are practically free from the dark-coloured minerals and are mainly composed of albite and analcime.

The lamination of the green rock is conformable to the nodules, although deviations occur.

In restricted parts of the green rock the albite contains small "blebs" and amygdules of analcime which recall the nodules mentioned above. This feature is also seen microscopically in rocks without macroscopic traces of nodules.

The fine-grained black rocks were studied in thin section nos. 21145 a and b. Parts of the black rock, of very dense appearance, are composed of a felted mass of small needles of ægirine/acmite up to two millimetres long. The needles often have green cores and colourless margins. Some areas of this rock have very few small interstitial grains of arfvedsonite, but there are also zones very rich in arfvedsonite which grows between the acmite grains and along their cleavages. This arfvedsonite contains small inclusions of acmite. There are small scattered grains of steenstrupine and schizolite.

Other parts of the black rock have greyish-black round nodular patches which recall the nodules of the green rock. These nodules are "wrapped" by needles of ægirine and arfvedsonite, up to one millimetre long. Arfvedsonite predominates over ægirine. Further components of the matrix between the nodules are albite, corroded laths of microcline and some ussingite, analcime, steenstrupine, britholite and lepidolite.

The ussingite occurs in cloudy patches associated with analcime and extremely fine-grained natrolite.

The ægirine has green cores and almost colourless margins and may have incomplete rims of arfvedsonite. There are also small grains of acmite with inclusions of arfvedsonite.

The albite encloses arfvedsonite and ægirine, but there are no inclusions of these minerals in the microcline.

Steenstrupine occurs as small zoned crystals of the type described above, but of slightly darker colour. The marginal zones can be red. The crystals have inclusions of arfvedsonite and are conformably enveloped by ægirine and arfvedsonite.

The greyish-black nodules have a smaller amount of arfvedsonite and ægirine than the surrounding black rock and arfvedsonite is predominating. There is a good deal of microcline laths in a groundmass of albite (with "blebs" and amygdules of analcime), sodalite, natrolite, analcime and ussingite. The albite grains are untwinned and of irregular shape.

The coarse-grained patches of the vein were examined in nos. 18468, 21148 and 21149.

The patches are composed of large grains of ægirine, steenstrupine, ussingite and microcline in a fine-grained groundmass of rounded grains of albite, small laths of microcline, fine-grained ussingite, ægirine needles, sodalite, analcime and fine-grained natrolite. In parts of the rock microcline is the predominant groundmass mineral. Accessories are lovozerite, sphalerite, chkalovite, beryllium sodalite, lepidolite, igdloite, groups of small prisms of britholite, schizolite and some eucolite. In coarse-grained patches occurring along the margins of the vein there are large grains of eucolite. Thin fractures are filled with fine-grained natrolite and a very fine-grained carbonate-looking mineral.

The large prisms of ægirine have irregular colouration, irregular extinction and may be divided into columnar zones of different optical orientation. They have inclusions of lovozerite and may be wrapped by small needles of ægirine. In the eucolite-bearing patches there are inclusions of eucolite in the ægirine.

Small needles of ægirine are prominent in parts of the coarse-grained patches where they are associated with fine-grained ussingite.

The eucolite occurs in grains of irregular shape and of corroded appearance. It has small irregular areas of mesodialyte, especially in the marginal parts of the grains. The basal cleavage is well-developed. Most of the grains have closely spaced lines of liquid inclusions, but the marginal zones are often clear and without these inclusions. The eucolite is practically free from alteration products; the grains are divided into sectors of slightly different optical orientations. The sectors are separated by veins of ussingite, albite and microcline. Some of the grains recall the poikilitic eudialyte of the naujaite and have round inclusions composed of ussingite, sodalite, lovozerite, microcline and albite. The eucolite has been observed in contact with ussingite, albite, microcline, analcime, lovozerite, steenstrupine, ægirine and lepidolite. The grains of eucolite are often surrounded by aggregates of small crystals of altered lovozerite. It has not been possible to prove that these aggregates are secondary after the eucolite (plate 13, fig. 1).

Steenstrupine occurs in crystals up to half a centimetre across and often in aggregates composed of several crystals. The crystals are zoned having clear isotropic cores and anisotropic brown margins (BUCHWALD and SØRENSEN, 1961, p. 24). Small inclusions of lovozerite are very common, especially in the marginal parts of the crystals. The inclusions can be partially replaced by the steenstrupine, their place being marked by small specks of pigmentation. These remnants after lovozerite are generally arranged in lines parallel to the crystal faces of the steenstrupine (Plate 13, fig. 3 and DANØ and SØRENSEN, 1959, plate 2, figs. 3 and 4). Inclusions are otherwise rare, but small inclusions of arfvedsonite, ægirine, microcline and britholite have been observed. They are often arranged parallel to the crystal faces of the steenstrupine. The latter mineral can be surrounded by dense aggregates of small crystals of lovozerite. The higher concentration of lovozerite in these places, than elsewhere in the rock, might be explained by a "concretionary" growth of the steenstrupine which has pushed the lovozerite crystals aside.

The steenstrupine of the eucolite-bearing rock can grow on the surfaces of that mineral and may even penetrate a short distance into the eucolite along its cleavages. A few inclusions of eucolite have been observed in the steenstrupine (plate 13, fig. 1).

The lovozerite from this occurrence has been described by DANØ and SØRENSEN (1959, p. 29). It has small areas of the pink, unaltered mineral with polysynthetic twinning, but the greater part of the small crystals, which are up to one millimetre across, are altered into a micaceous mineral and black "dust". There are aggregates of many small crystals of lovozerite associated with small needles of ægirine. Parts of the rock have streaks of small dusty areas, up to 0.1

millimetre across, which appear to have been formed by rolling-out of larger grains of lovozerite.

Microcline occurs in large plates and in aggregates of small irregular laths. The grains are somewhat deformed and often show the spotted type of twinning. The microcline grains are cut by zones of fine-grained albite and the microcline aggregates have interstitial grains of albite of irregular shape. The large plates of microcline have small "drops" of albite adjacent to irregular fractures.

In addition to the albite mentioned above there are also scattered aggregates of round, untwinned grains. These aggregates are most common adjacent to the fine-grained rocks and the albite can have "blebs" of analcime.

Ussingite occurs in large grains and in glomeroblast-like areas composed of numerous small grains of slightly different optical orientation. The small grains are cloudy, the larger grains have pigmentation along irregular fissures.

In the fine-grained ussingite there are numerous needles of ægirine; the larger ussingite grains are free from ægirine, but contain in places large grains of sphalerite and beautifully developed prismatic crystals of schizolite.

The ussingite clearly replaces microcline and sodalite.

The large grains of sphalerite enclosed in the ussingite are partially replaced by zones of sheaf-like aggregates of very fine-grained hemimorphite. These altered grains are responsible for the cavities with yellow crusts mentioned on p. 28. The hemimorphite occurs, where irregular fractures in the ussingite intersect; the crystals of schizolite are also strongly altered into a birefringent mineral aggregate when adjacent to these fractures.

The large prisms of schizolite have inclusions of eucolite, lovozerite and ægirine.

In the border between the coarse-grained patches and the fine-grained green rock there are large grains of sodalite and chkalovite in a fine-grained rock of albite, ægirine, steenstrupine and lovozerite. The sodalite is penetrated by ussingite and albite and contains prisms of ægirine. Furthermore it has small areas of analcime. The rounded grains of chkalovite have been seen in contact with albite, ussingite and microcline, but are generally separated from these minerals by thin zones of beryllium sodalite. There are inclusions of microcline, albite, eucolite, lovozerite, steenstrupine, lepidolite, britholite and ægirine. The latter mineral is most common and the needles are arranged as in the adjacent green rock.

The needles of ægirine in the green rock, enclosing the coarse-grained patches, are mainly arranged parallel to the border of the latter. In addition the green rock contains grains of ægirine, steenstrupine, lovozerite and ussingite of the appearance of those occurring in the coarse-grained patches.

The fact that the areas of ussingite in the fine-grained rocks are rich in ægirine needles and that the numerous small grains of ussingite in these areas have very similar optical orientations might be a result of a later formation of the ussingite compared to the minerals of the green rock. The ussingite should then, according to this view, grow from the coarse-grained patches into the surrounding green rock.

On the other hand, there are very few inclusions of albite in the ussingite, but thin zones of fine-grained albite cut through the ussingite areas. These zones are occupied by small untwinned albite grains which grow across the fractures. Similar zones also occur in some of the borders between ægirine prisms and ussingite. Where the small albite grains of the groundmass border on ussingite they generally have outwardly convex borders. These features may indicate a later formation of albite than that of ussingite (see further p. 173).

In a late phase the rocks of the vein were cut by thin fracture-fillings of natrolite.

The naujaite adjacent to the vein was examined in thin section no. 21146. The crystals of sodalite show incipient crushing. The large prisms of ægirine show irregular colour distribution with the strongest green colour in the cores. Arfvedsonite occurs in large prisms (with small inclusions of ægirine/acmite) and in small needles (which may be concentrated along the margins of the ægirine). There are large grains of cloudy eudialyte penetrated by irregular bands of eucolite with anomalous interference colours (first order grey with bluish and reddish tinge). The optical axes of eudialyte and eucolite are parallel. The grains of eudialyte are slightly crushed with fracture fillings of schizolite, ægirine, neptunite, lepidolite, arfvedsonite, altered lovozerite and possibly katapleite.

3. The Veins at Igdlúnguaq.

The most prominent green vein (between **I. 1** and **G. 3** in plate 1) was examined in the samples nos. 18506 and 21102.

Along the margins of the vein it is clearly seen that the latter has been formed at the expense of deformed naujaite since the vein contains large grains of naujaite minerals. The large platy crystals of microcline are often broken, but rarely show the spotted type of twinning (plate 3, fig. 3). They are partially replaced by analcime with patches of sodalite (remnants of poikilitic inclusions of that mineral?). The prisms of ægirine are broken and bleached and the sodalite (with microlites of arfvedsonite) is partly crushed into aggregates of numerous small dodecahedrons with analcime penetrating along the cleavages. Eudialyte occurs in large grains of irregular shape and in small crystals. Small prisms of arfvedsonite are present and the matrix of the rock is made up of analcime and natrolite.

Stringers of felt-like ægirine make up the matrix between the naujaite minerals. The needles of ægirine are often bent so that they conform to the outlines of these minerals. In places it is seen that the needles are derived from larger grains of naujaitic ægirine. The outer part of the vein and the adjoining naujaite contain a few small grains of steenstrupine which can enclose needles of ægirine. The grains are surrounded by radiating fractures in analcime and microcline.

The central part of the vein is also rich in microcline but in smaller grains than those in the naujaite. The microcline is penetrated and partially replaced by analcime and natrolite. There are large pseudomorphs after eudialyte and small, very rare crystals of that mineral. The pseudomorphs are composed of katapleite, neptunite, schizolite, britholite, analcime and numerous needles of ægirine.

The needles of ægirine, which make up the felted matrix of the vein, are arranged in a network between the above-mentioned minerals.

The abundant steenstrupine crystals are concentrated in narrow zones of the vein parallel to its strike. They form aggregates with interstitial needles of ægirine and have only scarce inclusions of ægirine, microcline, thorianite and lath-shaped analcime (plate 9, fig. 3).

The steenstrupine is clear, yellowish brown and isotropic, but the margins can be darker coloured and anisotropic. Some crystals show repeated zoning. The crystals have dark patches with aggregate extinction.

There are large, poikilitic grains of schizolite and the pink and dense natrolite is, in thin section, seen to be extremely fine-grained and chalcedony-like. The natrolite has a fine rusty pigmentation.

In narrow zones there are closely spaced fractures parallel to the strike of the vein. The fractures are especially developed in microcline and analcime and also frequently in the steenstrupine. This is best seen where the crystals of steenstrupine are arranged with their basal faces parallel to the fractures. This steenstrupine has closely spaced fractures corresponding to a basal cleavage and it is anisotropic. Crystals of steenstrupine, which are not orientated in this way, have no cleavage developed.

The naujaite adjacent to the vein (no. 21054) is rich in analcime and large prisms of natrolite, the latter having microlites of arfvedsonite and ægirine and zones of irregular extinction. There are large areas composed of aggregates of prismatic grains of acmite with spots of brown mica and small grains of arfvedsonite. Further constituents are ægirine needles, schizolite and large pseudomorphs after eudialyte with britholite and large plates of katapleite.

The inclusions of felted ægirine in black lujavrite mentioned on p. 45 were examined in no. 21077. The green rock consists of small needles of ægirine which are mainly arranged normal to the strike of the vein and which may be broken. A few large prisms of ægirine show a spotted colouration and prisms of acmite have rims of ægirine in many cases. The groundmass is composed of analcime with abundant small laths of microcline and a few large, deformed plates of microcline intergrown with analcime and fine-grained natrolite. There are aggregates of apatite. The central parts of the apatite grains have prismatic cleavage and blue interference colours and recall britholite; the margins are of more common apatitic appearance. Scattered large prisms of arfvedsonite have inclusions of felted ægirine.

The black lujavrite enclosing the green rock has large prisms of arfvedsonite arranged randomly in a matrix of analcime with small needles of ægirine. There are small aggregates of ægirine felt between the prisms of arfvedsonite (plate 8, fig. 2) and also many inclusions of ægirine needles in the arfvedsonite. It appears as if the arfvedsonite replaces the green rock. The lujavrite contains a few groups of radiating needles of natrolite.

The Brown Acmitic Veins.

These veins were studied at Igdlúnguaq and examined in the samples nos. 18515, 21005, 21007, 21017, 21019, 21026, 21039, 21040, 21041, 21042, 21043, 21053, 21091, 21092 and 20–13/8.

These veins have, as mentioned on p. 48, coarse-grained patches of analcime and natrolite in a dense matrix of brown or black colour.

The dark parts of the veins are composed of acmite/ægirine and/or arfvedsonite with a minor amount of interstitial analcime and natrolite. Accessories are steenstrupine, small flakes of a brown mica, neptunite, britholite, ore, and in rare cases small crystals of eudialyte of lujavritic type. There may also be pseudomorphs after eudialyte which are rich in plates of katapleite.

The acmite is present in rather large prisms, in small grains and in aggregates of small grains (0.2–1.0 millimetre long). The aggregates often have the external shape of prismatic crystals and the mutual borders of the individuals of the aggregates are frequently rectilinear with the prism zone well developed. The larger grains of acmite can be arranged parallel to the strike of the veins, but the grains are often randomly arranged. Small flakes of a brown mica are associated with the aggregates.

The grains of acmite can have cores of ægirine which display the same optical orientation and the same birefringence as the acmite. Some veins also contain large prisms of ægirine (up to one centimetre long and more) which are generally arranged parallel to the strike. They have homoaxial marginal zones of acmite with spots of brown mica and these zones are surrounded by aggregates of acmite with brown mica and interstitial arfvedsonite. The shape of these aggregates conform to that of the ægirine core. The large prisms of ægirine/acmite are broken and often show irregular extinction.

In parts of the veins there are small acicular crystals of ægirine (up to two millimetres long) and there may also be small grains of ægirine of granulated appearance in the above-mentioned aggregates of acmite.

Arfvedsonite occurs as large prisms approximately parallel to the strike of the veins and as elongated groups of small grains (about one millimetre long) arranged normal to the strike. There are also small independent prisms of arfvedsonite and irregular grains in the interstices of the acmite aggregates mentioned above. The large prisms of arfvedsonite have inclusions of single grains and small aggregates of acmite and furthermore of eudialyte crystals of lujavritic type (which may be rich in katapleite), small flakes of a brown mica and prisms of schizolite. The arfvedsonite may be partly replaced by acmite (plate 10, fig. 1).

The proportion of acmite to arfvedsonite varies considerably from sample to sample. Some samples only consist of large grains of ægirine with marginal acmite. Others are made up of aggregates of acmite with interstitial arfvedsonite and in some cases with large prisms of arfvedsonite. Finally, the darkest veins are composed of small grains of arfvedsonite. They are poor in acmite (plate 10, fig. 3) but generally have concentrations of that mineral along their margins.

The relationship between acmite and arfvedsonite is very difficult to establish. The acmite has, in some thin sections, small inclusions of arfvedsonite. Acmite as rims and along the cleavages of the arfvedsonite also indicates that acmite may be younger than the arfvedsonite (plate 10, fig. 1). But inclusions of single grains and aggregates of acmite in arfvedsonite are common. Arfvedsonite also occurs as irregular interstitial grains in the aggregates of acmite and is seen to grow along the grain boundaries and the cleavages of the acmite. One grain of arfvedsonite can penetrate into several grains of acmite. The grains of arfvedsonite in the acmite aggregates have the same optical orientation over restricted areas as if larger grains of arfvedsonite are replacing the acmite. It should also be mentioned that the acmite in some rocks has thin, incomplete rims of arfvedsonite.

To make things still more complicated, it is occasionally seen that the large prisms of arfvedsonite are deformed to varying extent. In the first stages of deformation the grains have an irregular extinction by being divided into small areas of slightly different optical orientations. The original inclusions of acmite occur between these areas. In later stages the arfvedsonite is granulated and the large grains are transformed into aggregates of many small grains. The large prisms were parallel to the strike of the vein, the aggregates are arranged in streaks normal to the veins with all transitions into the original parallel orientation (plate 10, fig. 2). The arfvedsonite of these streaks contains no inclusions of acmite; instead small fibres of acmite occur interstitially. It is also seen that the large prisms of arfvedsonite have acmite in fractures and zones of bending. From these zones the acmite appears to grow into the arfvedsonite along the cleavages of the latter. These large grains of arfvedsonite can then have a concentration of small flakes of the brown mica and of acmite along the margins.

The coarse-grained, light coloured patches of the veins have natrolite in large grains and in aggregates of small grains, large grains of analcime, sodalite without microlites (yellow in the hand specimen), schizolite prisms, lepidolite, arfvedsonite, acmite, neptunite, pyrochlore, igdloite and steenstrupine. Igdloite and pyrochlore occur on fractures and are associated with neptunite and a red micaceous mineral. They form streaks of fine-grained aggregates.

Dense white patches in the coarse-grained rocks are composed of very fine-grained natrolite with small irregular grains of microcline showing the spotted type of twinning. The analcime-rich parts of these rocks have larger plates of microcline (with the spotted twinning).

In the contact between the coarse-grained rock and the acmite vein small prisms of acmite occur. These crystals protrude from the acmitic aggregates of the vein which are composed of grains of acmite of more irregular shape (plate 11, fig. 2).

Steenstrupine occurs in the parts of the brown veins richest in acmite and in the borders of the coarse-grained patches where it can be associated with the prisms of acmite just mentioned.

The steenstrupine is of the type seen elsewhere at Igdlúnguaq and occurs in zoned crystals usually with anisotropic margins and isotropic cores, although it can be anisotropic throughout. Brown patches have aggregate extinction. The steenstrupine in the borders of the coarse-grained patches has developed crystal faces towards the analcime and natrolite, while the borders on the acmite and arfvedsonite of the veins are more irregular (plate 11, fig. 2). The steenstrupine has apparently grown into the aggregates of acmite and contains inclusions of that mineral. Inclusions of arfvedsonite are much more rare and are often separated from the steenstrupine by rims of acmite. In the arfvedsonite-rich parts of the veins, inclusions of arfvedsonite can be separated from the steenstrupine by acmite rims, but there are also inclusions of acmite in these places which may have rims of arfvedsonite. Locally there are inclusions of ægirine crystals in the steenstrupine, but the central parts of these inclusions may be made up of aggregates of acmite.

The steenstrupine of the brown veins is associated with schizolite, lepidolite, britholite, pyrochlore, igdloite and neptunite. The crystal faces towards the coarse-grained patches often have crusts of fine-grained pyrochlore and acmite.

The borders of the veins, as mentioned above, have concentrations of acmite, but there is almost always a zone of natrolite between vein and naujaite, although it may be thin in some cases. The zone is composed of prismatic grains of natrolite and of aggregates of tiny crystals of that mineral. Clusters of the brown mica flakes are common in the natrolite and there is, in places, a concentration of small crystals of eudialyte of lujavritic type (with "veins" of mesodialyte). The latter crystals are altered into katapleite, neptunite, rust, etc. which explains the brown colour in the hand specimen. Small rounded grains of britholite occur in the most analcime-rich parts of the border zone and are associated with small prisms of ægirine. The latter can have rims of arfvedsonite. The britholite is sometimes enclosed in the ægirine. In restricted areas of the adjacent naujaite there are larger grains of a similar apatite mineral associated with poikilitic grains of eudialyte, aggregates of acmite and brown mica. This eudialyte is partially altered into katapleite, etc., especially in the marginal parts, and steenstrupine can grow on the surface of the altered eudialyte.

In places steenstrupine forms the border zone of the brown veins and penetrates a short distance into the naujaite between the grains of sodalite, eudialyte, etc. There is generally, however, a zone of acmite between the steenstrupine and the naujaite. The steenstrupine has inclusions of altered eudialyte and the adjoining grains of that mineral are generally altered into katapleite, rust, etc., at least in a thin zone in contact with the steenstrupine.

The naujaite adjacent to the veins can have a fairly high concentration of microlite-free sodalite (yellow in hand specimen), but is generally composed of poikilitic grains of ægirine and eudialyte with inclusions of microlite-bearing sodalite. The sodalite adjacent to the veins can be crushed and is penetrated by natrolite along the dodecahedral cleavages. It has "micro gash joints" along fractures parallel to the veins. The eudialyte and microcline also show evidence of deformation.

The ægirine of the naujaite is generally deformed and shows an irregular extinction. The ægirine has patches of acmite. In places it is seen that the parts of the ægirine grains facing the veins are bent or broken and orientated parallel to the strike of the vein. The broken ends, and also the parts of the grains adjoining the vein, can be transformed into acmite with patches of brown mica. This acmite takes part in the acmite aggregates in the border zone of the veins. Large grains of arfvedsonite penetrate these aggregates. There are also poikilitic areas of arfvedsonite intergrown with ægirine/acmite in the naujaite adjacent to the vein. This arfvedsonite has inclusions of the ægirine/acmite and adjacent inclusions often have the same optical orientation.

Small needles of ægirine are, as mentioned above, rare in the brown veins, but in one sample there is a zone of green, felt-like ægirine in the border between vein and naujaite (fig. 31). The large ægirine grains of the naujaite are split up into aggregates of small needles which are orientated in streaks parallel to the strike of the vein. Small needles of ægirine also occur between the larger grains of acmite in the marginal zone of the vein and it is seen that these grains can have cores of ægirine. These aggregates of ægirine/acmite have a very small amount of interstitial arfvedsonite; other components of this border zone are pseudomorphs after eudialyte, chalcedony-like natrolite, sodalite, schizolite (with inclusions of arfvedsonite), poikilitic grains of steenstrupine (with inclusions of acmite and eudialyte pseudomorphs), biotite and astrophyllite.

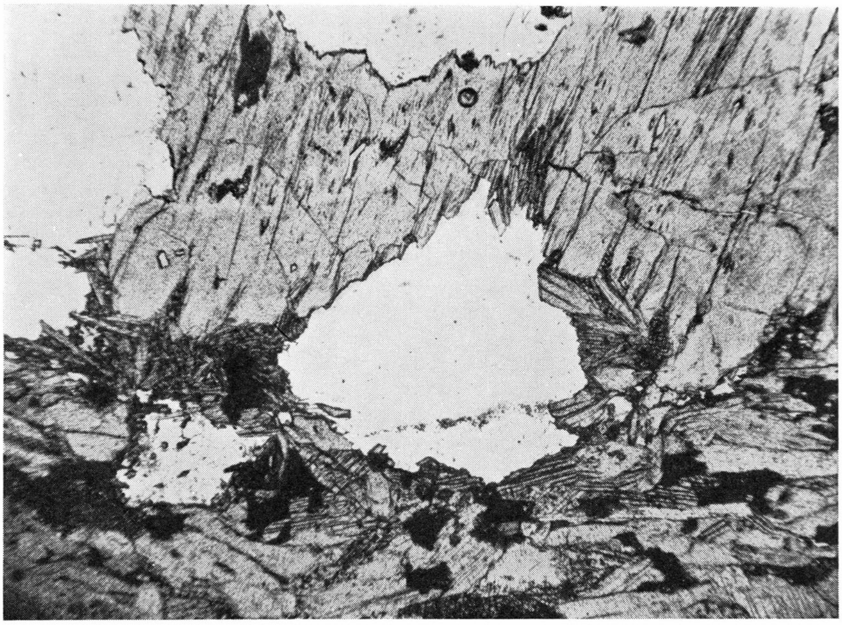

Fig. 31. 21017b. × 30, 1 nic. A large naujaitic ægirine anhedra (upper part of the photograph) is substituted by ægirine felt along the contact with an acmite vein (lower part of the photograph). Small needles of ægirine can be seen in the latter zone. The white inclusions in the naujaitic ægirine are of sodalite. The dark grains in the acmite zone are arfvedsonite and eudialyte pseudomorphs. The white area in this zone is a small microcline lath surrounded by analcime. (Igdlúnguaq).

In some cases it is clearly seen that the brown veins are formed as "impregnations" between the primary minerals of deformed naujaite. This impregnation consists of aggregates of acmite with small amounts of interstitial arfvedsonite, fine-grained natrolite, sodalite (yellow in the hand specimen), analcime, small eudialyte crystals (of lujavritic type) and lepidolite. The borders of these veins have concentrations of steenstrupine and pseudomorphs after eudialyte enclosed in natrolite.

The field relations of **the only albite-bearing vein at Igdlúnguaq** were described on p. 48. The petrography of this vein will be treated here because of the high content of acmite. The vein was studied in the nos. 12, 13, 14 and 16–13/8.

The poikilitic grains of arfvedsonite of the adjacent naujaite have rims of acmite where the enclosed grains of sodalite are altered into analcime. There are also acmite aggregates with interstitial grains of arfvedsonite which have inclusions of acmite. The aggregates have small flakes of a brown mica.

The naujaite between the veins contains small patches of albite. The latter mineral is present in polysynthetically twinned laths. The patches also contain deformed laths of microcline (with the spotted type of twinning), deformed and corroded grains of nepheline, sodalite (yellow in the hand specimen) and analcime. There are folded black streaks of arfvedsonite and acmite with a high concentration of the latter along the borders. Larger prisms of arfvedsonite have acmite on fractures and along the borders and aggregates of acmite have interstitial arfvedsonite and lath-shaped areas of analcime. There is a good deal of lepidolite. Minor components are small crystals of eudialyte (of lujavritic type and especially present in the acmitic zones), round grains and "crystal skeletons" of britholite, fluorite and a few irregular grains of steenstrupine.

The upper vein of lujavrite has developed a black border zone on the underlying naujaite. This zone contains, in a groundmass of small albite laths, laths of microcline, large grains of nepheline with inclusions of microcline, small eudialyte crystals of lujavritic type, sodalite, analcime, acmite and small and large grains of arfvedsonite. The latter mineral also occurs in groups of radiating needles. The large prisms of arfvedsonite are twinned and have acmite along the margins, along fractures and as inclusions, especially in the marginal parts of the grains. Further components are schizolite, round grains of britholite, and large pseudomorphs after eudialyte composed of katapleite, neptunite, and some associated steenstrupine. Inside this border zone the lujavrite is of normal development with the small grains of arfvedsonite in the interstices between the laths of microcline. This arfvedsonite contains inclusions of acmite.

The Analcime-Natrolite Veins.

These rocks have a close resemblance to the coarse-grained patches of the acmitic veins (cf. p. 119) and to some of the recrystallized naujaitic rocks (cf. p. 91). They were studied in the specimen no. 21047 from the southwest point of Igdlúnguaq and in nos. 21097, 2, 3 and 7 from the west coast of Igdlúnguaq.

These veins are mainly composed of coarse-grained analcime and natrolite. Minor components and accessories are microcline, sodalite, nepheline, chkalovite, acmite, arfvedsonite, steenstrupine, igdloite, pyrochlore, schizolite, britholite and large grains of sphalerite.

The analcime may enclose small needles of arfvedsonite and more rarely of acmite. The grains are often deformed showing a mosaic-like development. The large twinned grains are then divided into smaller areas between which slight displacements of the twin lamellae have taken place. The analcime is also cut by rust coloured zones with small grains of natrolite and black pigmentation. The marginal parts of the analcime grains often show a spotted twinning.

The large prisms of natrolite generally have an undulatory extinction and, in places, are transformed into aggregates of many small round grains. There are also areas of chalcedony-like natrolite and fracture fillings of fine-grained natrolite. The natrolite may be intimately intergrown with analcime and the age relation between the two minerals is then very difficult to determine. But zones of fine-grained natrolite cut the analcime; natrolite is therefore, at least partly, younger than the latter.

Large and small grains of microcline with irregular outlines and with the spotted type of twinning occur. They may be enclosed in the analcime.

Large grains of sodalite, which are yellow in hand specimen, are free from dark microlites, but in parts of the veins there are also small sodalite grains of naujaitic type with microlites of arfvedsonite. The grains of sodalite are crushed in places.

Large grains of nepheline showing undulatory extinction may occur. They are divided up by zones of analcime and fine-grained natrolite into aggregates of smaller grains of almost identical optical orientation.

A few round grains of chkalovite have been observed as inclusions in the analcime. They are surrounded and cut by very thin zones of a mineral which may be beryllium sodalite.

There are small aggregates of acmite with some arfvedsonite and in some samples also with prisms of an unidentified mineral. The latter occurs in length-fast crystals with parallel extinction. They are optically negative and most probably biaxial. The refractive indices are a good deal higher than those of the balsam and the birefringence is low (first order grey). The mineral has a prismatic cleavage and a type of strain lamellae parallel to the latter.

The large grains of steenstrupine are zoned and weakly anisotropic, at least in the marginal zones. The grains have rather irregular outlines and are surrounded by radiating fractures in the analcime. The steenstrupine is associated with pseudomorphs after eudialyte (with neptunite, etc.), acmite, arfvedsonite needles, brown mica, lath-shaped areas of analcime, pyrochlore, igdloite and a red micaceous mineral. The steenstrupine is practically free from inclusions, except for small grains of thorianite, but the aggregates of steenstrupine grains have interstitial arfvedsonite.

Igdloite and pyrochlore occur as fine-grained fracture-fillings in the analcime. They are associated with a red micaceous mineral which has parallel extinction, a length-slow character, mica type absorption and it is most probably optically positive. They are also associated with schizolite, arfvedsonite, britholite and steenstrupine. The fracture-fillings may be folded.

Prismatic areas composed of black material and a strongly birefringent mineral are probably pseudomorphs after schizolite.

The sodalite and microcline of the naujaite adjacent to these veins are partially crushed and the rocks are rich in analcime and natrolite. Here there is often a thin rim of analcime around the poikilitic inclusions of sodalite in eudialyte. The naujaite also contains small aggregates of acmite with inclusions of arfvedsonite plus associated neptunite. Small grains of black ore occur in fractures in the analcime.

The Albitite at Tugtup agtakôrfia.

The albititic main rock of this occurrence was studied in the samples nos. 1 a, 18489 a and b, 18490, 18491 b, f and g, 21108 a and b, 21109 and 21110.

In parts of the vein albite makes up almost 100 per cent of the rock; in other parts there are fairly high amounts of microcline, analcime and/or sodalite.

The albite occurs in two varieties, cleavelanditic and sugary-grained. The cleavelandite has few twin lamellae (albite twinning) and the parallel laths may reach a size of several centimetres. The laths are practically undeformed, the "bending" of the laths mentioned on p. 59 is, microscopically, seen to be caused, not by a bending of the grains, but by the arrangement of contiguous laths under a small angle. The sugary-grained albite has few or no twin lamellae and the diameter of the round grains varies from a fraction of a millimetre to one or two millimetres. The sugary-grained rock has a few laths of albite of a rather irregular shape in a matrix of round grains; the cleavelandite contains streaks of rounded grains of albite between the long laths (plate 12, fig. 2).

Microcline has been observed in all samples examined. Generally there are only very few small laths of microcline (mainly less than one millimetre) between or enclosed in the grains of albite (plate 12, fig. 2), but patches of the albitite are composed of lath aggregates of microcline which often shows the spotted type of twinning. There are streaks of round grains of albite in the interstices of these aggregates and the albite encloses small laths of microcline. The aggregates may also be penetrated by analcime. Large grains of microcline of the size found in the adjacent naujaite are also enclosed in the albitite. The grains are corroded, but generally have the characteristic chess board twinning preserved. They are cut by stringers of rounded grains of albite and sometimes show the spotted type of twinning around these zones. The stringers often have black borders rich in fine black dust and they may be "folded" (plate 12, fig. 1).

The large grains of sodalite, which are yellow in the hand specimen, are generally without microlites of arfvedsonite, although grains with such microlites occur. The sodalite is enclosed in, and penetrated by, analcime and is associated with large grains of microcline of the type mentioned above. The microcline is corroded by the analcime and has streaks of albite.

The analcime of the albitite is generally present as round grains. They have inclusions of small needles of arfvedsonite and ægirine and contain a subordinate amount of fine-grained natrolite. Albite is enclosed in the analcime.

The albitite contains scattered grains of a number of subordinate minerals. Lepidolite occurs in large and small flakes which can be bent. Acmite forms aggregates composed of a number of small grains. The external shapes of these aggregates recall the prismatic crystals of arfvedsonite. The latter mineral does occur as inclusions in the acmite and as interstitial grains in the aggregates. Large, cloudy flakes of epistolite are mainly found in fractures in the rock. Eudialyte has not been observed in the albitite, but there are small pseudomorphs after that mineral which are mainly composed of katapleite. The needles and prisms of schizolite have brownish black alteration products. Single grains of sphalerite and igdloite occur and there are areas rich in black pigmentation. Black coatings on fractures and grain boundaries are common in the albitite.

The steenstrupine from this vein has been mentioned by BUCHWALD and SØRENSEN (1961, p. 24).

The crystals are often anisotropic throughout and they are then generally of brownish colour in thin section. Some of the larger grains have, however, isotropic cores of grey colour, surrounded by brown, anisotropic marginal zones which are rich in fractures (op. cit., plate 3, fig. 1). The crystals are practically free from inclusions and they can have flakes of epistolite on the faces (plate 12, fig. 1). The crystals are generally separated from the grains of microcline by thin rims of albite and many grains of steenstrupine are enclosed in analcime.

The border zones of the albitite were examined in the thin sections nos. 8, 302, 18491 c, e and f, 21060, 21061, 21064 and 21108.

Analcime is generally the predominant groundmass mineral, although sugary-grained albite also occurs in considerable amounts in some rocks. Large plates and aggregates of small laths of microcline are common and large grains of sodalite are conspicuous. The latter have sometimes microlites of arfvedsonite. The rock is cut by zones of the fibrous, natrolite-like mineral mentioned on p. 227.

The most conspicuous minerals of the border zones are, however, arfvedsonite and acmite.

The arfvedsonite has small inclusions of sodalite and the prisms are generally surrounded by aggregates of acmite with interstitial arfvedsonite (plate 12, fig. 3). Some of the grains of acmite have homoaxial inclusions of arfvedsonite, but the opposite relationship has also been observed. There are independent small prisms of acmite and aggregates of acmite associated with brown mica, neptunite and interstitial arfvedsonite. Parts of the border zones are made up of irregularly developed prisms of acmite in rather dense aggregates with small interstitial grains of arfvedsonite and a few small inclusions of that mineral. These prisms of acmite can have cores of green ægirine. Further constituents of the aggregates are lath-shaped areas of analcime, aggregates of small prisms of schizolite and flakes of lepidolite in fractures.

Another rock type in the border zone is rich in small fibres of the natrolite-like mineral. The fibres are arranged in sheaf-like groups and are associated with fibrous natrolite. Further components of this rock are grains of sodalite (some of which have microlites of arfvedsonite and scarce ægirine) and large prisms of arfvedsonite with fibrous acmite along the margins and in the interstices. There are also examples of arfvedsonite occurring as rims on acmite and having inclusions of that mineral. This latter texture has been seen in contact with pseudomorphs after eudialyte, although direct contact between acmite and pseudomorph is more common. The rock also contains large plates and aggregates of small laths of microcline associated with small grains of albite, ussingite, analcime and the natrolite-like mineral. Small crystals of eudialyte are scarce, larger pseudomorphs after that mineral are more common. The latter are composed of neptunite, katapleite, rusty pigmentation and lovozerite.

The steenstrupine of the border rocks mentioned above is of the type found elsewhere in the albitite, but here it contains a good deal of inclusions of eudialyte pseudomorphs (and more rarely of unaltered eudialyte), lovozerite, acmite and arfvedsonite (often surrounded by rims of acmite). The acmite can have cores of ægirine. There is often a rim of ussingite between steenstrupine and microcline.

The ussingite-bearing rocks have small round groups of prisms of schizolite and a few flakes of astrophyllite (?). Further components of the border rocks are lepidolite, epistolite and sphalerite. Cross fractures have analcime, lepidolite and epistolite.

The naujaite adjacent to the vein was studied in no. 18493. It is rich in analcime which encloses and penetrates cloudy grains of sodalite and microcline. The grains of sodalite are often crushed and penetrated by fine-grained natrolite along the fractures. The large plates of microcline have streaks of fine-grained albite and black pigmentation on fractures and along grain boundaries. The streaks can be S-shaped.

Large poikilitic grains of ægirine with a slight undulatory extinction are associated with aggregates of acmite. There are also independent aggregates of acmite with arfvedsonite as inclusions and interstitial grains. These aggregates have the external shape of prismatic crystals. The single grains of ægirine have light coloured marginal zones. Large grains of arfvedsonite, with poikilitic inclusions of sodalite, are replaced to a varying extent by acmite, but also contain inclusions of that mineral. Schizolite is present in the acmitic aggregates which replace the arfvedsonite. Eudialyte is very scarce in this border zone, but pseudomorphs are common.

In places, it is seen that the sodalite enclosed in the poikilitic grains of arfvedsonite and ægirine, is replaced by an aggregate of small laths of microcline, rounded grains of albite and a matrix of analcime.

The naujaite adjacent to the vein is rich in fine-grained zones of natrolite.

The lujavrite of the lower part of the albitite-containing fracture is rich in rounded grains of sodalite up to two millimetres across. Some of the grains have dark microlites in their central parts. The sodalite is enveloped by laths of microcline which are up to one millimetre long.

The laths are parallel to the banding and practically undeformed. Nepheline and albite have not been observed.

Arfvedsonite is the predominant dark coloured mineral in up to one, and more rarely two, millimetre long needles and prisms between the laths of microcline. In parts of the rock there is a large amount of acmite in smaller grains than the arfvedsonite. The arfvedsonite appears to be later than the acmite, occurring as interstitial grains in aggregates and as marginal rims on single grains of acmite. Inclusions of arfvedsonite in acmite have, however, also been observed.

Small crystals of eudialyte (from 0.01 to 0.7 millimetre long) are partially altered into neptunite, etc. Small prisms of schizolite have inclusions of arfvedsonite. A small amount of interstitial analcime and natrolite is present (table V, p. 236).

Scattered poikilitic grains of steenstrupine, up to two millimetres across, grow in between the microcline and arfvedsonite and are somewhat flattened parallel to the lamination. The steenstrupine is of the type found in the albitite, but here it encloses arfvedsonite, acmite, sodalite, microcline and eudialyte. The inclusions are orientated as in the adjacent lujavrite but occur in smaller grains inside the steenstrupine (plate 16, fig. 1). Some of the enclosed eudialyte crystals are replaced by plates of katapleite. The enclosed acmite can have rims of arfvedsonite, but this is not the usual form.

The border zone between this lujavrite and the overlying albitite was examined in no. 21110. The part of the lujavrite in contact with the albitite is almost entirely composed of grains of acmite with inclusions and interstitial grains of arfvedsonite. The acmite prisms are up to 1.5 millimetre long, the arfvedsonite grains less than half a millimetre long. Subordinate components of the border zone are analcime, eudialyte crystals, pseudomorphs after eudialyte, deformed laths of microcline and large grains of sodalite without microlites but with inclusions of the other minerals of this zone.

The lujavrite adjacent to the acmitic border zone is also rich in acmite which often forms rims on the arfvedsonite prisms. The opposite relationship between these two minerals has also been noted. Otherwise this rock only differs from the above-mentioned lujavrite in a slight deformation of the microcline laths and in a larger amount of analcime.

The border zone of the lujavrite is thus characterized by a concentration of acmite, sodalite (without microlites) and analcime.

The albitite in contact with the lujavrite has, in a groundmass of analcime, large grains of microcline and irregular grains of sodalite without or almost without microlites. The large plates of microcline are slightly deformed. Further constituents are intergrowths of arfvedsonite and acmite, needles of ægirine, pseudomorphs after eudialyte rich in neptunite, large grains of sphalerite with enclosed eudialyte pseudomorphs, steenstrupine, schizolite, lepidolite, astrophyllite (?) and igdloite.

The inclusions of lujavrite in the albitite referred to on p. 62 were examined in nos. 18491 d, 21062 and 21063.

In a groundmass of analcime the inclusions have prismatic grains of acmite and deformed laths of microcline with the spotted type of twinning. The acmite also forms felt-like aggregates with interstitial arfvedsonite. The larger grains of acmite (up to two millimetres long) have central patches of ægirine.

Lepidolite is abundant and can occur in such large amounts, that parts of the inclusions only consist of acmite and lepidolite.

A few small remnants of eudialyte have been observed, however, pseudomorphs after that mineral composed of katapleite, neptunite, a white mica, astrophyllite (?), pigmentary material, analcime, etc. are more abundant (table V, p. 236).

The grains of steenstrupine are one centimetre or more across and of the type described from the albitite. The grains appear to have grown in between the adjacent minerals and there are inclusions of acmite, microcline, analcime and eudialyte pseudomorphs. Inclusions are, however, rare when compared with the steenstrupine of the lujavrite mentioned above. The steenstrupine is associated with monazite-like grains.

Minor constituents are schizolite, astrophyllite and round grains of igdloite.

The coarse-grained analcime rocks associated with the inclusions of lujavrite have remnants of platy microcline. Further components are lepidolite, acmite and large grains of steenstrupine without inclusions.

The vugs of analcime crystals in the albitite seem, in the hand specimen, to be penetrated by white stringers and veins of albite and microcline. The thin section examination indicates, however, that these areas of albite and microcline are penetrated by thin, irregular analcime stringers which branch out from the larger masses of analcime. The analcime is therefore most probably formed in vugs or solution cavities in the albitite. The presence of inclusions of epistolite, schizolite, steenstrupine, albite and acmite in the analcime, supports the view that the analcime was formed in solution cavities. The analcime, albite and microcline are all cut by thin zones of extremely fine-grained fibres of the natrolite-like mineral.

The rocks carrying chkalovite and beryllium sodalite will be treated in a paper under preparation. These two minerals occur in amygdule-like areas in the upper, analcime-rich part of the albititic vein.

VI. DISCUSSION

Only the lujavrite, the pegmatites, the late veins, and the minerals of these rocks will be discussed.

The discussion is divided into the following chapters:

The naujaite pegmatites.
The lujavrite.
The coarse-grained inclusions in the lujavrite and the associated analcime veins.
The thin veins composed of ægirine felt, acmite, albite, and/or analcime-natrolite.
The alkali-aluminium silicates.
The ægirine/acmite and arfvedsonite—oxidation-reduction processes.
The steenstrupine and other rare minerals.

The Naujaite Pegmatites.

Two types of pegmatites may be distinguished in accordance with the nomenclature suggested by LANDES (1933) for the granite pegmatites, namely simple and complex. The former type may be unzoned or zoned, the latter contains replacement bodies.

1. Simple pegmatites: The unzoned simple pegmatites are most widespread. They form small lens-shaped or irregular bodies in the naujaite and are generally less than 50 centimetres across. These pegmatites are composed of the same minerals as the surrounding naujaite, but in larger grains and without poikilitic texture. They correspond closely to the pegmatitic patches of other types of plutonic rocks and they are probably formed by crystallization of small magma pockets within the partly, or entirely, consolidated naujaite.

The zoned simple pegmatites display an asymmetrical type of zoning and occur as lens-shaped, sill-like bodies parallel to the banding of the naujaite and apparently associated with a joint set parallel to this banding.

An asymmetrical type of zoning is also seen in slightly inclined granite pegmatites according to CAMERON et al. (1949), whereas more steeply inclined pegmatites display a more symmetrical type of zoning.

The banded naujaite pegmatites have an upper zone rich in large grains of microcline and arfvedsonite, a patchy intermediate zone of ægirine prisms and a lower eudialyte zone. The concentration of large grains of microcline in the upper part of the pegmatites recalls the structure of some slightly inclined granite pegmatites mentioned by SOLODOV (1959) which have developed a blocky zone of microcline and muscovite along their hanging wall.

The zoning of the pegmatites studied by USSING (1911) and by the writer is asymmetrical. It should, however, be mentioned that STEENSTRUP (USSING, 1894, p. 146) has given a somewhat different description of the pegmatite of the south coast of Qeqertaussaq. His observations are as follows: the vein displays a pronounced banding. The central "band", which has an average thickness of 10 centimetres, is composed of very pure and coarse-grained eudialyte. Between this and the overlying sodalite syenite there is an approximately 20 centimetres thick zone composed mainly of large grains of feldspar and arfvedsonite with some scattered eudialyte. Below the eudialyte band there is a coarse-grained mixture of feldspar, sodalite and arfvedsonite with a good deal of eudialyte, and with gradual transition into the underlying sodalite syenite. This description was made before eudialyte was excavated from this pegmatite (the cave seen in fig. 2, DANØ and SØRENSEN, 1959) so that originally there might have been a lower feldspar zone. However, neither USSING nor the writer have observed traces of this zone; it is therefore believed that the statement of STEENSTRUP is based on memory rather than on field notes.

Structure of the zoned pegmatites: The upper borders of the pegmatites are generally sharp, the lower borders are either gradual or sharp. When gradual there are all stages of transition into eudialyte-rich naujaite, the larger pegmatites of this type often being found in eudialyte-rich bands of the naujaite.

The patchy intermediate zone is composed of interlocking prisms of ægirine, of stellate groups of thin needles of ægirine and of patches of green ægirine felt. This rock is the part of the pegmatites richest in "rest"minerals, namely: polysynthetically twinned albite, rinkite, scattered grains of eudialyte, lepidolite, schizolite, sphalerite, molybdenite, apatite, neptunite, igdloite, pyrochlore and varying amounts of analcime and natrolite. The analcime-rich patches have star-shaped groups of arfvedsonite needles.

The lower eudialyte zone is composed of crystals of eudialyte with interstitial grains of the minerals found in the uppermost zone of the pegmatites. There is a network rich in ægirine prisms of the type found in the intermediate zone and also with green masses of more fine-grained ægirine. The eudialyte around the latter is cut by zones of felt-like ægirine with katapleite, neptunite, monazite, steenstrupine, etc.

The mode of formation of the zoned pegmatites: The occurrence of these pegmatites in lens-shaped bodies associated with fractures parallel to the banding of the naujaite and the occasional gradual transitions between the pegmatites and the underlying naujaite indicate that the pegmatites have crystallized from a magma with a certain amount of rest elements trapped within partly consolidated naujaite.

As a first approximation the way of formation of these pegmatites might be explained in analogy with that of some of the pegmatites of gabbro massifs and of basic sills.

The pegmatites of these rocks may, as indicated by JAHNS (1954) and LOVERING and DURRELL (1959), have developed a pronounced concentric zoning. The outer zone is of the same mineralogical composition as the adjacent rock and may pass gradually into the latter. The large crystals of pyroxene are often perpendicular to the borders of the pegmatites. The central parts of these pegmatites may have quartz, perthite, albite, hornblende and other minerals indicating that they have resulted from fractional crystallization of a gabbro magma rich in rest elements. It therefore appears as if a volatile-rich magma has been trapped in a "pocket" within the partly crystallized gabbro and that this magma consolidated under conditions which prevented the volatiles from escaping so that the crystallization differentiation of the magma was favoured.

The asymmetrical zoning of the naujaite pegmatites renders such a mode of formation rather unlikely since there are no indications of crystallization from the margins of the magma pocket.

The differentiation of the naujaite pegmatites in upper and lower zones of different compositions should be explained in a somewhat different way. As discussed by USSING (1911) and the present author (1958) the crystallization of the naujaite proceeded from the top of the magma chamber downwards in such a way that the upper bands of the banded sequences were formed earlier than the lower ones.

This somewhat awkward order of formation recalls the interpretation presented by VLASOV et al. (1959) of the so-called differentiated complex of the Lovozero massif of Kola. This complex, in places, displays a very distinct horizontal banding with bands from top to bottom of urtite, lujavrite, foyaite, urtite, etc. The main minerals of these bands are nepheline, ægirine and microcline, that is, the main components of the magma are Na_2O, Al_2O_3, Fe_2O_3, K_2O and SiO_2. The composition of the original magma was, according to VLASOV et al., such that nepheline was the first mineral to crystallize under the formation of the almost monomineralic urtite in the upper part of the magma chamber. During the crystallization of this rock the underlying magma was depleted in the nepheline components and was simultaneously enriched in the components of ægirine so that this mineral crystallized out forming lujavrite which is composed of ægirine, nepheline and microcline. But the underlying magma was now impoveriched in Na and Fe and was correspondingly enriched in the components of microcline so that the foyaite composed of that mineral and some ægirine and nepheline was formed. In this rock microcline has crystallized out earlier than the nepheline. During the crystallization of the foyaite the underlying magma was enriched in the components of nepheline: a new layer of urtite was formed, etc. This type of crystallization differentiation is facilitated by a high content of volatiles in the magma.

It is interesting to note that the highest concentrations of rare minerals are found in the parts of the differentiated complex where the differentiation is most pronounced; the more monomineralic tendency, the higher concentration of rare elements. The latter are therefore concentrated along the foot wall of the urtite bands, pegmatites being especially found at these places. Pegmatites are lacking in the undifferentiated parts of the complex.

The pegmatites of the differentiated complex are associated with fractures parallel to the banding and do not show any intrusive relationship. They are believed to have been formed under impermeable bands of urtite which have prevented the escape of volatiles from the underlying magma.

Returning to the naujaite pegmatites described in this paper, it is seen that they are situated in banded naujaite in Qeqertaussaq and that the pegmatite to the north of Lilleelv wedges out into eudialyte-rich naujaite. If the crystallization of the naujaite took place from the top downwards there might have been a local accumulation of volatile-rich magma under irregularities in the lower surface of the consolidated naujaite. If this accumulation was trapped, during the crystallization of the surrounding rocks, a pegmatite could develop. This mechanism of formation gives an explanation of the fact that the upper contact of the pegmatites is generally sharp, whereas the lower one may be gradual.

During the crystallization of the trapped pegmatite magma, the eudialyte crystals were separated from microcline, arfvedsonite, etc. and they were accumulated in the lower part of the pegmatite, possibly by gravitative separation. Minor amounts of the minerals of the upper part of the pegmatite were precipitated together with the eudialyte crystals and scattered grains of the latter mineral occur in the microcline-rich upper zone. The fact that the eudialyte and not the heavier arfvedsonite accumulated first in the lower part of the pegmatite is believed to be due to the original composition of the liquid which favoured the early precipitation of eudialyte.

The coarse-grained intermediate ægirine rock and the network of ægirine in the eudialyte zone appear to be slightly later than the latter zone. The ægirine rocks are considered to have been formed by a squeezing out of the rest liquid from the upper and lower zones. The squeezed-out material was accumulated in the central parts of the pegmatite. In this way it is explained that the coarse-grained ægirine rocks and their associated, more fine-grained, green rocks are the parts of the pegmatite richest in rare minerals containing typical rest elements such as rare earths, niobium, lithium, manganese, titanium, phosphorus, zink, molybdenum and sulphur. The albite and lepidolite of the upper part of the pegmatite may be associated with these rocks.

The pegmatites are then mainly composed of the same minerals as the naujaite but without the poikilitic texture of the latter. Instead a differentiation has taken place with a development of monomineralic zones and there is in the last differentiates a higher concentration of rest elements than in the pegmatoid naujaite.

This development should be compared with that of the pegmatites of the Lovozero alkaline massif (VLASOV et al. 1959). In this massif the pegmatites are developed in different ways in the different complexes (eudialyte lujavrite complex, differentiated complex and complex of poikilitic syenites). The following remarks are therefore to be considered only as a brief summary of the general mode of development of these pegmatites. Simple and differentiated pegmatites are distinguished. The former are schlieren-like small bodies composed of the same minerals as the enclosing rock. The latter are zoned and may form larger bodies.

The differentiated pegmatites generally have an outer zone of nepheline, ægirine I, microcline and arfvedsonite with some eudialyte, murmanite, lamprophyllite and ramsayite. The pegmatites rich in potash feldspar often have the latter concentrated in their apical parts. The weakly differentiated pegmatites have central zones composed of feldspar and ægirine II with minor eudialyte, lamprophyllite, lomonosovite, murmanite, chinglusuite and nordite. The larger differentiated pegmatites of the poikilitic sodalite syenites have inner monomineralic zones and "blocks" composed of sodalite (hackmanite), ægirine II and minor steenstrupine, nordite, karnasurtite and rare earth apatite and they may have cores of prismatic natrolite with minor apatite and karnasurtite.

These pegmatites have clearly been formed by growth from the margins towards the central zone and therefore they can not be directly compared with the naujaite pegmatites. However, the upper and lower bands of the latter may be compared with the outer zones of the Lovozero pegmatites and the fine-grained parts of the coarse-grained ægirine patches of the naujaite pegmatites may be compared with the ægirine II of Lovozero which occurs in radial aggregates of thin prisms. A direct comparison should only be made between the naujaite pegmatites and those of the differentiated complex of Lovozero since these rocks are apparently formed by related processes. The zonal structure, however, is only weakly developed in these Lovozero rocks and occurs especially in the endocontact zones composed of microcline, nepheline, eudialyte, etc. Ægirine may be accumulated in the central parts of these pegmatites. The rare minerals are loparite, apatite, lamprophyllite, ramsayite, murmanite and ænigmatite.

In the Khibina alkaline complex of Kola (FERSMAN, 1929), the epimagmatic and pegmatitic phases of pegmatite formation (in the sense of FERSMAN) are separated by a development of radial aggregates of ægirine II associated with eucolite, albite and yellow sphene.

2. Complex pegmatites: Two of the pegmatites described in this paper may be termed complex, namely the one of the south coast of

Qeqertaussaq and that occurring to the north of Lilleelv. They contain, in their upper parts, replacement bodies rich in albite, and occasionally also in analcime and natrolite.

The replacement bodies of the naujaite pegmatites: The albite of the replacement bodies was formed earlier than analcime and natrolite and may be replaced, to varying extent, by these two minerals. Large grains of microcline, sodalite, nepheline and eudialyte are probably relics from the primary pegmatite. The large grains of ægirine are believed to be of a similar origin since they are strongly deformed. Aggregates of small grains of microcline may have been formed by crushing of the original large grains, but there may also have been a minor formation of microcline at this stage (late microcline is known from the replacement bodies of some pegmatites in Lovozero, VLASOV et al., 1959). Some of the lepidolite flakes may be relics, but there is definitely a formation of small flakes of that mineral in the replacement phase of pegmatite formation. Associated with the replacement bodies are steenstrupine, sphalerite, schizolite, neptunite, igdloite, monazite, britholite, fluorite and ægirine (in felted masses and as radiating prisms).

The albite is sugary-grained or cleavelanditic and has only few twin lamellae.

Arfvedsonite is very rare in the replacement bodies.

The replacement body of the pegmatite of the south coast of Qeqertaussaq replaces the upper band of felt-like ægirine and is also seen to grow at the expense of the microcline-, ægirine- and eudialyte zones of that pegmatite, containing partially digested inclusions of minerals from all these rocks. There are two pronounced replacement bodies in the pegmatite at Lilleelv. The largest one occurs in the highest part of the pegmatite at the easternmost end of the exposure and especially replaces the upper part of the pegmatite but it also contains a good deal of large deformed prisms of ægirine indicating that patches of coarse-grained ægirine have been replaced. The other occurrence is in the central part of the exposure where an analcime-rich rock appears to have grown at the expense of a coarse-grained ægirine rock. The albititic replacement body of the upper part of this pegmatite has deformed streaks of ægirine felt. Besides there are small scattered patches of lujavritic affinity containing fine-grained microcline and arfvedsonite (see p. 75).

A few comparisons with other areas should be made before the origin of the replacement bodies described above can be discussed.

In the larger pegmatites of Lovozero there are replacement bodies and zones composed of albite, ussingite, microcline II, fine-crystalline natrolite, analcime, chabazite, gibbsite, mica, lithium micas, neptunite, chalcedony, chkalovite, steenstrupine, hydrocerite, erikite, nordite, karnasurtite, psilomelane, schizolite, etc. The replacement bodies may occur in the central parts of the pegmatites or along the outer border of the core of prismatic natrolite. They can also form irregular bodies and veins which, in places, have replaced most parts of the original pegmatite and have even penetrated into the enclosing rocks. The replacement bodies have the highest concentrations of rare earths, Th, Li and Be found in the pegmatites. It is a remarkable feature of these rocks that the primary prismatic natrolite of the pegmatites is corroded and replaced by albite and ussingite.

The replacement bodies of the central parts of the most strongly zoned pegmatites of the differentiated complex contain albite, natrolite, analcime, chabazite, elpidite, katapleite, labuntsovite, eudidymite, clay minerals, etc.

The pegmatites of the Langesundfjord, described by BRØGGER in 1890, are in many respects related to the naujaite pegmatites of Ilímaussaq. They occur along the west border of the larvikite in a zone penetrated by the schistose nepheline syenites called ditroite by BRØGGER (see further p. 149). The pegmatites may be associated with the ditroite and may have gradual transitions into the latter. They are of irregular form and can have central zones containing albite and ægirine.

There are two main types of pegmatites: 1. melinophane-homilite veins without the rare minerals found in agpaitic pegmatites and 2. katapleite-eucolite veins containing ægirine, lepidomelane, barkevikite, nepheline, sodalite, feldspar, rosenbuschite, låvenite, mosandrite, astrophyllite, tritomite, etc. Some of the veins of the second group contain orangite and thorite. The veins are often rich in zeolites.

In the first stage of crystallization of the pegmatites the following minerals were formed: nepheline, feldspar, sodalite, ægirine, lepidomelane, barkevikite, eucolite, mosandrite, tritomite and others. The minerals of the second pneumatolytic stage are: fluorite, albite, ægirine, zircon, sulphides and other minerals. The primary minerals were altered during this phase (microcline into albite, eucolite into earthy masses, nepheline into sodalite, etc.). In a third stage of crystallization the following were formed: analcime, natrolite (later than the analcime), ægirine needles, sulphides, brown mica and quartz in druses. During the last stage carbonates were formed. The minerals of the first phases are often broken, but the zeolites are undeformed indicating that they were formed after the cessation of the deformation.

These few remarks demonstrate clearly that there is, in these famous pegmatites, a stage of replacement processes and BRØGGER was one of the first petrologists emphasizing the importance of such processes. It is to be hoped, however, that the order of formation of the minerals of these pegmatites may be re-studied. BRØGGER based his interpretation, at least partly, on the degree of idiomorphism of the minerals, but this is no sure criterion when replacement bodies are studied. For instance, BRØGGER regarded the tritomite to have been formed during the first phase of crystallization. The author has examined a number of specimens containing this mineral and found that the beautifully developed crystals of that mineral are enclosed in analcime-rich rocks. It is therefore likely, in the author's opinion, that the tritomite also belongs to the phase of replacement.

The plutonic rocks of the Oslo region are clearly of miascitic type, but some of the ditroitic rocks display a distinct agpaitic affinity. The katapleite-eucolite pegmatites are also of agpaitic type but showing transitions into miascitic pegmatites. This indicates, as discussed by the writer in earlier papers (1958 and 1960 a), that agpaitic rocks may develop by strong fractionation of common miascitic magmas in which there is a sufficient concentration of "rest elements" and volatiles.

Replacement bodies in granite pegmatites: Replacement bodies occur in some nepheline syenite pegmatites but are much more widespread in granite pegmatites. It may therefore be useful to consider briefly the replacement bodies of granite pegmatites.

Already Brøgger (1890, p. 205) made a comparison between granite pegmatites and nepheline syenite pegmatites and found pronounced differences, especially in their rare minerals. The former contain minerals such as allanite, zircon, gadolinite, spodumene, beryl, columbite, euxenite, fergusonite, uraninite, monazite, amblygonite, triphylite, cassiterite, etc. The latter pegmatites contain more complex minerals containing the rare earth metals, Nb, Ta, Zr and Ti, namely minerals such as rinkite, eudialyte, astrophyllite, katapleite, and others. This difference between the two groups of pegmatites is, according to Brøgger (op. cit., p. 214), caused by differences in composition of the mother magmas, in the different roles of "agents minéralisateurs" and in differences in temperature and pressure of formation.

Rocks of the type found in the replacement units of granite pegmatites are only found within the bodies of the latter rocks (cf. Safiannikoff (1955), Heinrich (1958) and L. R. Page (personal communication)). Their formation is therefore assumed to be closely connected with the evolution of the pegmatite system. There may also, in cases, be a rather gradual transition from the zones of the pegmatites into the replacement units, since the interior zones may contain minerals (for instance cleavelandite) which are especially developed in the replacement units.

The complex type of granite pegmatites containing replacement units and fracture fillings may, according to Cameron et al. (1949, p. 99), be formed in the following three ways (if only magmatic pegmatites are considered):

i. By fractional crystallization of a pegmatite magma *in situ* in a restricted system.

ii. By successive deposition in an open system (for instance in fractures through which the pegmatitic "solutions" migrate).

iii. By crystallization in two stages: a. a magmatic or epimagmatic one during which pegmatitic "solutions" crystallized into a zoned pegmatite in a restricted system; b. a pneumatolytic or hydrothermal stage during which fluids passing through the pegmatite effected successive replacement in an open system.

The first named hypothesis is favoured by most pegmatite specialists. The formation of the replacement bodies may, according to this hypothesis, be explained in a number of ways:

a. The state of the pegmatite "solution" changes during the crystallization from essentially magmatic to essentially hydrothermal and the late hydrothermal fluids are responsible for the replacement processes (PAGE et al., 1953).

b. Resurgent boiling (accompanied by fractional distillation of volatiles) of the residual liquid of pegmatite magma in a restricted system and condensation of the vapour at points within the pegmatite system may be the cause of the replacement processes (JAHNS, 1955).

c. Liquid immiscibility in the pegmatitic magma could result in late liquids which might be responsible for the replacement processes (e. g. NEUMANN, 1948).

d. A change in the activity of the alkalies and the acidity-alkalinity of the magma in connection with an increasing importance of volatiles in the later metasomatic stages of pegmatite formation may explain the replacement processes (GINZBOURG, 1960).

e. The replacement is caused by supersaturation of the late pegmatite liquid and by changes in the stability relations upon the appearance of an aqueous, carbonated phase, i. e. there is an excess of alkalies and an increased activity of water and carbon dioxide (BROTZEN, 1959).

Although many petrologists agree in a formation of the replacement units in accordance with hypothesis 1, it appears from the summary above, that several interpretations of these rocks are possible. One might conclude this review by quoting CAMERON et al. (1949, p. 106) who state: "replacement bodies and fracture fillings are a varied assemblage and it seems unlikely that a single explanation will account for all the members".

Hypothesis 2 is rather unlikely if the pegmatites are regarded as magmatic rocks, since it is difficult to see how the restricted pegmatite bodies, which are without traces of feeder channels, could have been formed by successive injections of pegmatitic magma. This explanation demands channels through which the "solutions" expelled during the consolidation of the mother magma could freely migrate. It should however be pointed out that VARLAMOFF (1958) and others have demonstrated a zonal arrangement of the rare mineral pegmatites around the supposed mother granites.

The fact that the composition of the pegmatites changes gradually with the distance from the granite might be explained by the assumption that the pegmatite magma is also gradually changed as it moves outwards from the granite through open channels. A more likely magmatic explanation is, however, that pulses of pegmatite magma of different compositions have been expelled at intervals during the consolidation of the granitic magma. The most volatile (and mobile) components are expelled first and have given rise to hydrothermal veins and quartz-cassiterite veins furthest away from the granite. The subsequent pulses give rise to the formation of increasingly simple pegmatites, the simplest being found in the contact of and inside the granite. This last explanation, which has a strong resemblance to the views expressed by FERSMAN, however, no longer operates with continuously open channels and is really a case of hypothesis 1.

Hypothesis 2 can, in the opinion of the present author, only be used when the pegmatites are interpreted as metasomatic rocks.

Hypothesis 3 is, at first sight, rather unlikely, since it is difficult to see why the solutions responsible for the replacement, if coming from sources outside the pegmatite system, only form replacement bodies in the pegmatites and not in the adjacent rocks (see, however, p. 176).

The formation of the replacement units, as mentioned by VARLAMOFF (1958) and GINZBOURG (1960), is often separated from the main phase of crystallization by a phase of deformation and crushing of the primary minerals (cf. BRØGGER, the present paper p. 136).

The paragenesis of granite pegmatites: There is no general agreement among pegmatite specialists on the order of formation of the accessory minerals of the pegmatites. The accessories of the replacement bodies may be relics from the primary zones or they may be formed during the replacement processes. Some authors (e. g. SCHALLER, 1925) state that accessories are introduced with the replacing fluids. It appears, moreover, that one and the same mineral, in different localities, may have been formed in different stages of the pegmatitic process and that some minerals, as for instance lepidolite and spodumene, may occur in at least two generations. These differences are probably caused by differences in original composition of the pegmatite magma, in varying closeness to the mother granite, in differences in temperature of formation, and in differences in external rock pressure and in internal volatile pressure.

A common order of formation of the minerals of the granite pegmatites is the following (mainly based on the tables of FERSMAN and on the observations of BROTZEN, 1959):

The outer zones are composed of plagioclase, quartz, biotite and potash feldspar with minor amounts of minerals such as zircon, allanite, monazite, euxenite, fergusonite, apatite, magnetite and sphene. The interior potash feldspar-rich zones contain beryl, muscovite, columbite, amblygonite, spodumene, molybdenite and sometimes monazite. The replacement bodies are mainly composed of sugary-grained or cleavelanditic albite with varying amounts of muscovite, lepidolite, spodumene, Li-Mn-phosphates, beryl, cassiterite, tantalite-columbite, microlite, Mn-apatite, fluorite, pollucite and sulphides.

The primary stages of formation of the granite pegmatites are thus characterized by the separation of minerals containing K, Ca, Zr, Ti, Mg, Fe, rare earth metals, and some Nb, Ta, Be, Li, P, Th and U. Li-minerals are, in these stages, only separated in very lithium-rich pegmatites. The elements which are especially concentrated in the replacement units are Na, Li, Mn, Sn, Be, Ta, Nb, S, F, Cs and P.

Comparison of granite- and naujaite pegmatites: The geochemical evolution of the granite pegmatites may be compared with that of the naujaite pegmatites discussed in this paper. In the main stage of formation of the latter pegmatites there is a separation of K, Ca, some Na, Fe, Zr, Ti, and minor amounts of rare earth metals and Li. The ægirine-rinkite-albite stage is characterized by Fe, Na, Ti, Zr, rare earths, Zn, P, and some Mn, Mo, Nb, Sr and S. The replacement rocks have a higher concentration of Si and Na than the preceding rocks and rather pronounced accumulations of Th, rare earths, Li, Mn, Zn, Nb, P, F and H_2O.

The replacement processes result, thus, in an increase in the amount of Si, Na, rare earths, Th, Li, Mn, P, F and H_2O. In Lovozero the replacement bodies contain, as mentioned on p. 136, the highest amounts of rare earths, Th, Li and Be found in the pegmatites, that is, an evolution rather similar to that of Ilímaussaq. The amounts of K, Ca, Zr, Ti and Fe decrease sharply when the replacement processes set in.

This trend of geochemical evolution corresponds in some respects with that observed in the replacement units of granite pegmatites. Thus, the elements: Na, K, Ca, Zr, Ti, Fe, Be, Mn, Li, P, F and S behave in a similar way in the two rock types. The main differences are found when the behaviour of rare earths and Th is studied, these elements being separated mainly during the primary crystallization of the granite pegmatites and mainly during the replacement stage in the agpaitic pegmatites. A further difference is, as is the general case in nepheline syenites, that the naujaite pegmatites are poor in Ta, U and the Y-group of the rare earth metals.

Unfortunately no detailed geochemical studies have been undertaken of the evolution of the naujaite pegmatites. It is to be hoped that such examinations may be carried out in the future, especially of the distribution of the elements between the minerals of the different pegmatite stages. Such studies have been carried out in Lovozero.

In spite of the geochemical similarities of granite and agpaite pegmatites, the mineralogical evolution of these rocks differs in most respects, since, as it has been pointed out by BRØGGER and later by GOLDSCHMIDT (1930), the minerals containing the rare elements are different in the two rock types. Albite, lepidolite, apatite, fluorite and sulphides are practically the only common minerals in the replacement bodies of granite and agpaite pegmatites.

The origin of the replacement bodies of the naujaite pegmatites described here may now be discussed.

It should first be pointed out that replacement bodies have not been found in all the zoned pegmatites of the naujaite. It is, therefore, not possible to regard these bodies as "necessary" stages of crystallization of the pegmatites. Two ways of formation are then possible (cf. hypotheses 1 and 3 of p. 137):

i. In the pegmatite of the south coast of Qeqertaussaq, the radioactive rock occurs in the thickest part of the pegmatite where the roof is most "arched". In the pegmatite to the north of Lilleelv the largest replacement body occurs in the highest exposed part of the pegmatite. One might therefore assume that in the upper part of the trapped pegmatite magma, there was an especially high concentration of water and other volatiles from which the radioactive rock could crystallize out. The replacement bodies could thus be formed by extreme fractionation of the pegmatite magma. In pegmatites, where the replacement bodies are lacking, one might then assume that the upper, volatile-rich part of the magma has left the system.

ii. The replacement bodies are clearly younger than the green felted ægirine, since deformed streaks composed of this material are enclosed in the albite. The green veins elsewhere in Ilímaussaq are seen to occupy zones of deformation in the naujaite and they appear to have been formed after the consolidation of that rock, since the naujaite minerals are crushed and deformed adjacent to the veins. The replacement body in the upper part of the pegmatite of the south coast of Qeqertaussaq is associated with the green upper band and with the green vein cutting the pegmatite and the enclosing naujaite. The two most prominent replacement bodies of the pegmatite at Lilleelv occur where the pegmatite is cut by the second green vein and very close to the exposure of the third green vein. It is furthermore of importance for the understanding of the formation of these rocks to note that rocks very similar to the replacement bodies occur as independent veins and lenses elsewhere in Ilímaussaq. As will be discussed in later chapters these rocks are simultaneous with or later than the lujavrite. This is in excellent agreement with the occurrence of patches of lujavritic affinity in the replacement bodies of the pegmatite at Lilleelv.

From these considerations it is concluded that the replacement bodies of the naujaite pegmatites were formed from fluids of external origin which passed through fractures in the naujaite where they formed independent veins in places. The formation of the replacement bodies was separated from the crystallization of the pegmatites by a period of deformation during which the felted ægirine rocks (and the lujavrites) were formed. The formation of the replacement bodies will be further discussed on p. 176.

The Lujavrite.

Lujavritic rocks make up a considerable part of the Ilímaussaq complex and it is consequently impossible to discuss this rock group thoroughly on the basis of the small areas described in this paper. However, a discussion of the lujavrites of these areas is important for the understanding of the steenstrupine-bearing veins and the observations made at Igdlúnguaq and Qeqertaussaq may be of importance for later, more exhaustive studies. For this reason some aspects of the lujavrite problem will be discussed here. In an earlier paper (SØRENSEN, 1958, pp. 33–38) the petrology of the lujavrites was treated in a preliminary way and two possible modes of origin were outlined: 1. the lujavrite may be considered to be formed from a melanocratic rest magma remaining after the crystallization of naujaite and kakortokite; 2. the lujavrite may be interpreted as a metasomatic rock formed in zones of deformation in connection with a subsidence in parts of the complex. These views will be discussed in the light of the observations presented in the present paper. First, however, a brief summary of the field relations of the lujavrite will be given:

1. Structure: The maps in plate 1 and fig. 32 of the southwest point of Igdlúnguaq indicate that the *mise en place* of the lujavrite in this locality was strongly influenced by the jointing of the older naujaite, the most prominent lujavrite veins being parallel to the strike of the most pronounced joint sets. A closer study reveals, however, that the joints in the different naujaite inclusions are not strictly parallel, apparently because of small dislocations in connection with the emplacement of the lujavrite. The study of the banding of the naujaite also demonstrates such a deformation. Thus, in the northeastern part of fig. 32 the banding of the naujaite strikes approximately N 170° with a steep westerly dip. Just to the north of the map, in the next naujaite lens, the strike is N 40° with a northwesterly dip of about 30°. Considerable tilting and rotation have taken place here during the emplacement of the intervening lujavrite.

The banding of the naujaite wedges out after short distances and it is therefore not surprising that the above-mentioned bands cannot be traced towards the southwest. Only one white band at **I. 5-6**, petrographically identical to the white band in the northeastern lens, may

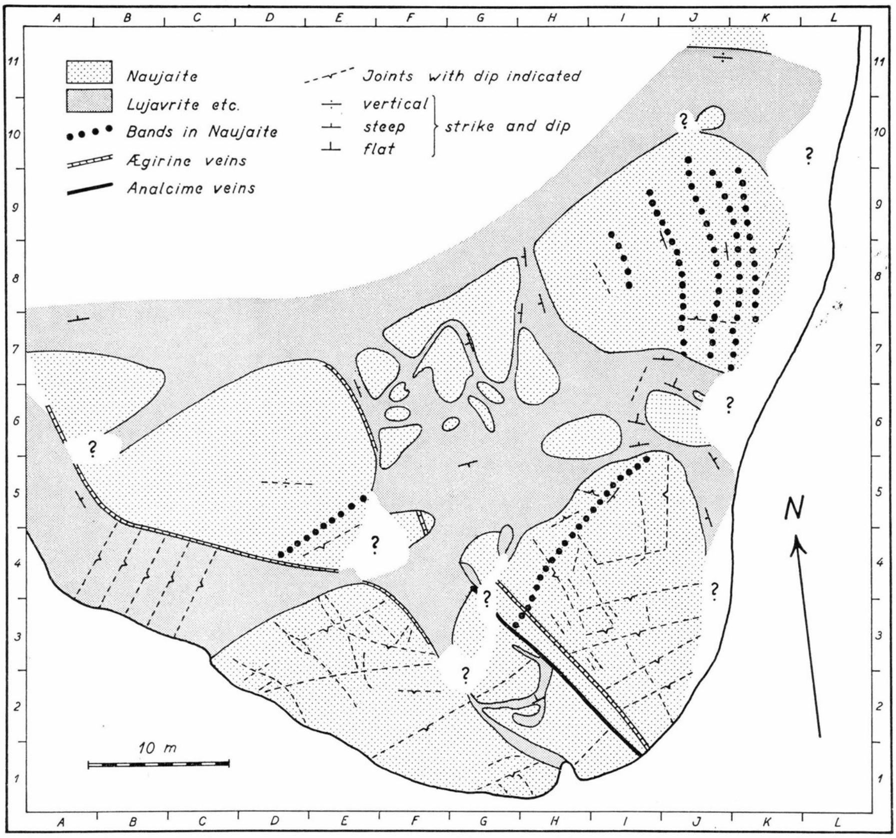

Fig. 32. Simplified map of the southwest point of Igdlúnguaq (cf. plate 1).

be a continuation of the latter, but a considerable dislocation has taken place, as is seen in the map. This white band may again be identical to the white band occurring at **E. 5** indicating a still larger dislocation. As mentioned on p. 34, the white band of **I. 5-6** cuts a small pegmatitic patch in the naujaite and may therefore be a vein rather than a band. However, the white rock is identical to the white bands in the other lenses and displays the features of a band, being of typical naujaitic development. (Should this rock turn out to be a vein, it would have no influence on the following discussion, since the rock is clearly pre-lujavritic). It is therefore assumed, that the parts of white bands mentioned above may have been continuous prior to the emplacement of the lujavrite and on this assumption the mode of deformation may be worked out.

The dislocation between **G. 3** and **E. 5** indicates a pronounced horizontal component of displacement along one or more of the lujavrite veins or along one of the thin ægirine and analcime-natrolite veins occurring between the two points mentioned. The green vein displaces the band slightly at **G-H. 3** and can, therefore, be excluded as the zone along which the strong displacement took place. If it is assumed that this green vein was once continuous with the green veins at **F. 4** and **E. 6** it is seen that the horizontal displacement of the white band in question cannot be explained by horizontal movement alone along any of the lujavrite veins since these veins cut the green vein without pronounced displacements.

The green vein at **E. 6** might then be correlated with that at **E. 4** but this also gives an unsatisfactory explanation of the deformation of the white band, since the space problem connected with the displacement of the different naujaite lenses will be very serious in this case.

Displacement along the fracture containing the analcime-natrolite vein at **G. 3** and **G. 4** and possibly continuing in the acmite vein at **E. 5** should also be considered. Two occurrences of "dense" analcime rocks at **G. 4** and **H. 2**, that is, situated on both sides of this zone, might then have been displaced along the zone, but in a direction opposite of that having affected the white band. If the dense rock is displaced as indicated, no movements along this zone can explain the deformation of the white band. Even if the "dense" rocks have never been continuous a movement of the white band along the zone is most unlikely since the fracture containing the acmite vein at **E. 5** is very poorly developed in many places and apparently with only weak traces of crushing.

The last possibility, of a simple gliding along one fault plane, is that the white band between **G. 3** and **E. 5** has been displaced along a fault in one of the zones containing the lujavrite veins, but prior to the formation of the lujavrite and the thin veins considered above. The writer has found no way to explore this possibility but thinks that it is rather unlikely when it is remembered that similar displacements have taken place between other naujaite lenses, but along other directions.

It is therefore concluded that tilting and rotation of the naujaite lenses occurred during the emplacement of the lujavrite. This accounts for the almost undisturbed course of the vertical green vein and the strong displacement of the inclined white band and for the presence of lenses of unbanded naujaite between the banded ones.

This favours the view that the lujavrite-naujaite association, in this locality, may be considered as an intrusion breccia. There appears to be no reasons in support of the view that the lujavrite replaces the naujaite, except, perhaps, in the case of a few of the thinnest lujavrite veins.

Igdlúnguaq is situated in the central part of the Ilímaussaq massif where the banding and lamination of the rocks are generally almost horizontal. It may therefore be assumed that the banding of the naujaite in this locality was also horizontal before the emplacement of the lujavrite. On this assumption the strike and dip readings of the veins, joints and naujaite bands were displaced on the Wulff net in such a way that the plots of the naujaite bands were placed at the centre of the projection, that is, corresponding to a horizontal position of these bands. By displacing the other poles by the same angle it was found that one joint set was originally almost horizontal and that there was a vertical set striking around N-S. The green veins, the analcime-natrolite veins, and the acmite veins occur in fractures which originally were almost vertical and striking between N 120 and 160. The measurements made in the two easternmost large naujaite lenses were plotted separately, but being few and rather inaccurate it is evident that there was not a perfect agreement between the results obtained in these two areas. However, it is believed that they indicate a trend, although a rather approximate one.

In Qeqertaussaq it was found that the vein-filled fractures are orientated mainly around N-S and E-W and that the most pronounced joint sets are horizontal and steep with a NW-SE-strike.

In the small area on the west coast of Igdlúnguaq the lujavrite veins are mainly N-S and E-W and the joints and thin veins diagonal to these directions.

The veins at the head of Kangerdluarssuk and the albitite of Tugtup agtakôrfia strike around E-W.

A correlation of the rather tentative results from Igdlúnguaq with the observations at Qeqertaussaq, where the naujaite banding is almost horizontal, indicates that the *mise en place* of the lujavrite and most of the green veins was closely related to an orthogonal joint system in the naujaite. The rather regular arrangement of the joints in such a system and in diagonal sets favours the view that these joints were formed in connection with the consolidation of the naujaite. In a late phase the orthogonal system served as "feeder channels" during the emplacement of the lujavrite, the diagonal joints served as shear planes along which small adjustments occurred and in which analcime-natrolite and acmite veins were formed. Later, cross joints were developed in the lujavrite.

2. The black borders between lujavrite and naujaite: The lujavrite has generally developed a thin black border zone in contact with the naujaite and with the various types of coarse-grained inclusions. These zones are rich in arfvedsonite, analcime, and sometimes also in acmite. The arfvedsonite prisms may be normal to the contact. There are, in places, concentrations of small eudialyte crystals which may be enclosed in the arfvedsonite. The adjacent lujavrite and naujaite are generally rich in analcime (and acmite) and often contain steenstrupine crystals.

The black zones may be interpreted as recrystallized chilled zones or as reaction zones between lujavrite and naujaite. The writer has found no evidence in support of the first explanation and considers the second one much more likely. Thus, the black border zones may grade into lujavrite of normal appearance but rich in analcime. The writer therefore believes, as will be discussed later, that the border zones were formed in connection with the emplacement of the lujavrite, perhaps as a result of deuteric processes.

3. The lujavrite and the green veins: No green veins cut the lujavrite in the parts of Ilímaussaq visited by the author or in other parts of Ilímaussaq (JOHN FERGUSON, personal information). On the contrary, veins of lujavrite apparently cut the green veins at Igdlúnguaq. As described on p. 45 inclusions of green felt-like ægirine occur in the border zone of the lujavrite at **F. 3** which also indicates that the lujavrite is younger than the ægirine felt. However, it should be remembered that these inclusions occur in the dark border zone of the lujavrite which, as mentioned above, may be slightly later than the emplacement of the lujavrite. The inclusions are therefore not unambiguous evidence of the age relation. To sum up: the observations at Igdlúnguaq indicate that the fractures in which the green veins occur were probably older than the lujavrite and that the green veins are probably also older than that rock.

In the multiple veins of Qeqertaussaq and the veins at the head of Kangerdluarssuk green felt-like rocks and black, lujavritic rocks occur in the same fractures in naujaite. The exact relationship of these rocks is rather difficult to determine because of later albitization, etc., but most data obtained favours the view that the black rocks are younger than the green ones.

4. The lujavrite and the acmite- and analcime-natrolite veins: These veins do not intersect the lujavrite, but are apparently cut by the latter rock. Such veins may also be contiguous with lujavrite veins. In the writer's opinion, these features may be best explained by assuming that the fractures containing the acmite and analcime-natrolite veins are older than the lujavrite but that the fracture fillings may be simultaneous with or later than that rock (see further p. 168).

Thin fillings of fine-grained natrolite are seen in fractures in the lujavrites.

5. The lujavrite and the albititic veins: The albitite at Tugtup agtakôrfia is clearly younger than the lujavrite, containing inclusions of that rock and having strongly altered the adjacent lujavrite into acmite, analcime, etc. It is also seen that the vein is later than the border zone between naujaite and lujavrite since the upper, horizontal part of the vein occurs in this border zone.

Thin albite-bearing veins have also been found in zones of deformation in lujavrites from other parts of Ilímaussaq not described in this paper. At Søndre Siorarssuit, for instance, there are, at an altitude of 410 metres, thin white veins, up to one centimetre thick, with inclusions of lujavrite, miarolitic cavities and cutting the lamination of the lujavrite. The veins have streaks of granulated arfvedsonite and microcline in a matrix of larger grains of analcime and albite (with few twin lamellae). Cloudy natrolite and areas of fine-grained albite (or chalcedony (?)) also occur.

6. The lujavrite and the "dense" analcime rocks: The "dense", often banded analcime rocks (see p. 42) are closely associated in space with the lujavrites. The occurrences of the "dense" rocks at Igdlúnguaq are especially found between the lujavrite veins and the naujaite. The "dense" rocks have rolled-out remnants of naujaite and may have been formed in zones of deformation in that rock. Their crystals of nepheline and eudialyte may then have been formed by crushing and recrystallization of naujaitic nepheline and eudialyte.

The lujavrite has developed thin black border zones on these rocks which might indicate a younger age of the lujavrite, but as mentioned above, the border zones may also be regarded as reaction zones between adjoining rocks in a late, perhaps deuteric, phase.

In places the "dense" rocks are separated from the lujavrite and they may be contiguous with lujavrite veins. Locally, small prisms of arfvedsonite occur in the "dense" rocks which may then pass into lujavrite-like rocks.

Small inclusions of "dense" rocks have been found in the coarse-grained inclusions in the lujavrite. It is therefore concluded that the "dense" rocks are older than the final consolidation of the lujavrite.

7. The lujavrite and its coarse-grained inclusions: The latter rocks will be treated in a separate chapter. They are clearly formed at the expense of rocks enclosed in the lujavrite.

8. The steenstrupine-bearing lujavrites: Inclusions of green lujavrite in black lujavrite are common in some areas. These inclusions may be arranged in a "pillow"-like way, but the field and thin section observations indicate that the green rocks are being replaced by the black ones and the "pillows" are therefore interpreted as a type of injection breccia.

The green rocks are composed of ægirine and microcline with varying amounts of albite, nepheline, eudialyte, analcime, natrolite, steenstrupine, schizolite and accessories. The marginal parts of the inclusions are penetrated by microcline, analcime and arfvedsonite from the enclosing black lujavrite. The latter contains small ægirine needles adjacent to the inclusions and is composed of microcline, albite, nepheline, analcime, sodalite, eudialyte, arfvedsonite, acmite and accessories.

The brown lujavrites are, according to the little data available, older than the green lujavrite since they are veined by that rock. In the green rocks there are also inclusions of acmite wrapped by ægirine needles. The brown rocks often contain inclusions of strongly altered naujaite.

9. Discussion:

A. The magmatic aspects of the lujavrite formation: The lujavrites of the larger masses possess a very pronounced igneous habit. The rocks displaying horizontal lamination may be termed *cumulates* in the sense of WAGER et al. (1960) and these rocks may well have been formed by bottom deposition of the minerals. First nepheline and sodalite were deposited, then the feldspars and some eudialyte crystals and finally, the interstitially trapped magma crystallized into arfvedsonite, some eudialyte, steenstrupine and other minerals. There are also cases of primary deposition of arfvedsonite needles. The equidimensional grains of nepheline and sodalite have clearly disturbed the packing of the feldspar laths and the latter are often deformed, possibly as a result of the pressure exerted by the weight of the overlying rocks.

The banding developed in some horizons may then be a result of varying conditions of deposition. As suggested by UPTON (1961) the light coloured, nepheline-rich bands may have been deposited under quiet conditions, the darker bands under flow. It should however be pointed out that lineation is generally inconspicuous in the banded rocks which is contrary to strong currents in the magma (cf. BROUWER, 1912). The banding may also be compared with the conditions at Karnasurt mountain in Lovozero (VLASOV et al. (1959, fig. 11)) where, in the lower part of the eudialyte lujavrite complex, there is a repeated succession of eudialyte lujavrite—foyaite—urtite. The eudialyte here is found in the largest concentration in the urtite composing up to 50 per cent of that rock. This banding is believed to be formed by crystallization differentiation. The white bands of Ilímaussaq are also of urtitic composition and they may be very rich in eudialyte (cf. the table p. 234).

The magmatic origin of the lujavrite is indicated by the intrusion breccia at Igdlúnguaq with tilted fragments of naujaite enclosed in the lujavrite.

The tilting of the naujaite inclusions and the assimilation of naujaite in the lujavrite may account for the space now occupied by the lujavrite. Thus no space problem exists here.

The mineral association of the lujavrites is closely related to those of the other agpaitic rocks of Ilímaussaq, the main differences being: the higher content of mafic minerals, a finer grain size and the presence of two feldspars which appear to have been formed in mutual equilibrium. It is therefore natural to conclude, as it has been done in the earlier papers on the massif, that the lujavrite was formed from a melanocratic rest magma remaining after the crystallization of naujaite and kakortokite. The emplacement of the lujavrite, according to Ussing (1911), the author (1958) and Ferguson (1962 b), accompanied a phase of subsidence of parts of the already consolidated rocks. According to the writer the northern part of the massif subsided in relation to the kakortokite in its southern part. The lujavrite should, according to this interpretation, be compared with the schistose or laminated foyaites, lujavrites and tinguaites occurring in cone sheets and ring systems in a number of alkaline complexes of other regions (cf. Sørensen, 1958, for further references). The lamination of the rock is then most probably a result of this way of formation (cf. Ussing, 1911, p. 328–334).

The lujavrite may thus be compared with the tinguaites which occur as a late phase in a number of non-agpaitic alkaline complexes.

B. The metasomatic aspects of the lujavrite formation: As mentioned in the introduction to this chapter the writer has, in a previous paper (1958), considered the possibility that the lujavrites were of metasomatic origin.

This view was based on the following observations: rocks composed of felted ægirine of probable hydrothermal origin grade into green lujavrites and may be enclosed in black lujavrites; lujavrite veins are contiguous with albite and analcime veins; the green lujavrites may in places be interpreted as rolled-out kakortokite; green rocks are often enclosed in black lujavrite; and similar rocks in other regions have been interpreted as metasomatic rocks.

Brøgger (1890) described zones of schistose nepheline syenite (ditroite) from the west border of the larvikite of the Oslo region. These zones are in places ægirine-bearing, per-alkaline and associated with pegmatites. According to Oftedahl (1960) they were formed during cauldron subsidence after the consolidation of the larvikite. Solutions and gases from a nepheline syenite magma crystallizing at a deeper level penetrated the deformation zone and the schistose nepheline syenite was formed by alteration of the crushed larvikite, the schistosity most probably being protoclastic. The pegmatites are later than the deformation.

Emmons (1953) and Stobbe and Murray (1956) have described nepheline syenites, in part eucolite-bearing lujavrite, from shear zones in the upper part of a granite batholith in Wisconsin. These nepheline syenites are considered to have been formed *in situ* by metasomatic processes. Similar occurrences have been described by Huang (1959) from Texas.

Many examples of strong metasomatic alteration accompanying cauldron subsidence have been described (cf. MARTIN et al., 1960).

In analogy with these occurrences in other regions, the lujavrites might be regarded as metasomatic rocks formed in zones of dislocation. Some type of fluidization process may have been in operation (cf. REYNOLDS, 1954). Some of the observations presented in the present paper will be considered in the light of the metasomatism hypothesis:

i. The thin green and black veins: At Qeqertaussaq and the head of Kangerdluarssuk green ægirine felt and fine-grained black rocks of lujavritic habit are associated in fractures in the naujaite. As mentioned above, the black rocks may be later than the green ones and they may represent the farthest off-shoots of lujavrite veins in the naujaite. The black rocks differ, however, in a few respects from the common lujavrite, namely in the lack of nepheline and in the altered state of the very scarce eudialyte. The nepheline deficiency may be explained by assuming that the black rock has replaced or assimilated the pre-existing ægirine-rich rocks in the fractures through which the lujavrite was emplaced, that is, ægirine has been substituted by arfvedsonite:

$$\underset{\text{(ægirine)}}{5\,NaFe^3Si_2O_6} + H_2O = \underset{\text{(arfvedsonite)}}{Na_3Fe^2{}_4Fe^3Si_8O_{22}(OH)_2} + Na_2O + 2\,SiO_2 + O_2$$

It is thus seen that there is a release of SiO_2 when ægirine is substituted by arfvedsonite and it is therefore understandable that the crystallization of nepheline is prevented in the first stages of lujavrite formation. However, as mentioned on p. 99, small grains of analcime of the size and shape of lujavritic nepheline occur in some veins.

In the thin vein (no. 2) cutting the pegmatite to the north of Lille-elv a nepheline-free black rock also substitutes a green rock rich in ægirine needles. Thin black zones in vein no. 3 at the head of Kangerdluarssuk are in the same way free of nepheline. The thicker black parts of the multiple vein no. 3 are rich in corroded grains of nepheline arranged in such a way that they appear to have been formed by crushing of large crystals of nepheline of the type seen in the coarse-grained components of this vein. The eudialyte crystals of these rocks give a similar impression. The black rocks in vein no. 3 may thus have been formed by recrystallization of deformed zones in the vein. Some of these rocks recall the "dense" analcime rocks at Igdlúnguaq.

The black rock of vein no. 4 appears to have been formed at the expense of the fine-grained green main rock of the vein since arfvedsonite is later than ægirine and traces of the white nodules of the green rock are preserved in the black zone. The black rock is without nepheline but contains microcline, albite, sodalite, analcime and ussingite.

The black rocks of the green veins at Qeqertaussaq and the head of Kangerdluarssuk, are, as mentioned above, most probably later than the green rocks of these veins. A similar age relation of green and black rocks is seen in the mountain wall of the north coast of Tunugdliarfik.

Thus, in the thin green and black veins, the black rocks may replace the green ones. It is uncertain whether this should be regarded as a metasomatic "lujavritization" or an infiltration of lujavrite magma. In the case of the green and black lujavrites of the north coast of Tunugdliarfik the green rocks are clearly enclosed in the black rock which appears to be of an intrusive nature. The relation between green and black rocks, therefore, does not prove a metasomatic origin of the black lujavrites.

ii. The "dense" analcime rocks of Igdlúnguaq may, as mentioned above, be considered as recrystallized zones of deformation in the naujaite. The development of arfvedsonite needles in these rocks transforms them into lujavrites, apparently by processes taking place *in situ*. This is a strong argument in favour of a metasomatic origin of rocks of lujavritic type.

iii. The thin lujavrite veins at Igdlúnguaq are rich in analcime and secondary arfvedsonite and contain remnants of naujaite minerals. These veins may occur in association with the "dense" analcime rocks and might therefore also be considered to be of metasomatic origin, representing a further stage of development of arfvedsonite and feldspar than the "dense" rocks. However, analcime clearly replaces the nepheline and feldspars of the veins since lath-shaped and square areas of analcime occur which correspond, in size and shape, to the nepheline and feldspars of the lujavrite. It therefore appears to be most likely that naujaitic minerals have been assimilated by lujavrite and that there has been a late analcitization accompanied by the formation of arfvedsonite. The black border zones are probably of this age. The thin lujavrite veins are more fine-grained than the larger masses of lujavrite which speaks in favour of a magmatic origin of these veins.

iv. "Ghost" naujaite banding(?) in lujavrite: At Igdlúnguaq, just to the northeast of the map of plate 1, a lujavrite-naujaite border is normal to the banding of the naujaite. Thin white stringers occur in the lujavrite on strike of the adjacent naujaite bands (cf. Sørensen, 1958, fig. 10). These stringers become contorted and folded a short distance from the border, and white rings (spheroids) are also seen on the surface of the lujavrite (fig. 12). The white stringers are of malignitic composition (see p. 78) being composed of corroded nepheline crystals and some acmite, eudialyte pseudomorphs, microcline and other minerals in a groundmass of analcime. These stringers have some resemblance to rolled-out naujaite as it is seen in the "dense" analcime rocks. This, in connection with their contiguity with the naujaite bands, might indicate that the lujavrite was formed by *in situ* replacement of the naujaite or by some type of *in situ* assimilation. Away from the contact the contorted stringers indicate strong movements in the lujavrite (see further p. 154).

v. Spheroids in the lujavrite: The white stringers just mentioned recall, as to mineralogical composition, the white rims of the spheroids which are found locally in the lujavrites (cf. pp. 34 and 57). The cores of these spheroids are very poor in nepheline, sodalite and feldspars. Enclosed in the analcime are arfvedsonite, acmite and eudialyte crystals. These cores have a strong resemblance to some of the thin lujavrite veins. The white rims of the spheroids are composed of analcime, acmite, microcline, albite, sodalite, corroded nepheline, eudialyte crystals, ussingite and other minerals. The minerals of the spheroids are orientated as those of the surrounding lujavrite.

The modal analyses of the spheroids indicate that the amounts of dark minerals, light coloured minerals and eudialyte are practically constant in lujavrite, spheroid rim and spheroid core. Unfortunately, chemical analyses are still lacking of these rocks. However, the modal analyses (see p. 234) show that the spheroids are richer in H_2O and rest elements than the surrounding lujavrite. Inside the spheroids there has been a splitting up into a silica-rich rim containing acmite and a silica-poor, more water-rich core containing arfvedsonite.

The spheroids should, if a metasomatic point of view is applied, be pseudomorphs after pre-lujavritic structures or be products of "concretionary growth" or "metamorphic differentiation". The author has found no primary structure or no mechanism which could support these interpretations. In the author's opinion it is therefore necessary to look for a magmatic explanation of this feature. Three possibilities may be suggested:

a. The similarity of the white stringers mentioned above and the spheroids may indicate that the latter are formed by assimilation of naujaitic material. The parts of the lujavrite magma modified in this way may by consolidation have given rise to the formation of the spheroids, possibly because of limited miscibility or slow diffusion processes at the low temperature of crystallization (see further p. 180).

b. Inclusions of green lujavrite are common in the black lujavrite in many parts of Ilímaussaq. These inclusions often are spheroidal and with light coloured marginal rims. It has been observed that analcime and arfvedsonite are formed in these inclusions and the spheroids with white rims might then be entirely replaced green inclusions.

c. DREVER (1960) has described small globules of dolerite in picrite, sometimes with a considerable amount of natrolite in the uppermost parts. These globules are interpreted as results of liquid immiscibility at high temperature. The globules are enriched in Na, Al, Si, Fe, Ti and H_2O. TUTTLE and FRIEDMAN (1948) and FRIEDMAN (1950) have examined the system H_2O–Na_2O–SiO_2. At temperatures between 225° C and the critical temperature of solutions saturated with sodium silicate (ca. 390° C), four phases occur in equilibrium: crystals, melt, a water-rich liquid phase and a vapour phase. Below 225° C no immiscibility takes place, above the critical temperature only one water phase exists. It appears from these experiments that liquid immiscibility may exist at moderate temperatures in melts rich in Na and H_2O. It is therefore tempting to interprete the spheroids as a result of liquid immiscibility in the lujavrite magma, water-rich magma patches being separated from the more water-poor magma which may, however, have been saturated with water at the given physical and chemical conditions (cf. NEUMANN, 1948 and SMITH, 1948).

If two immiscible lujavritic magma phases were formed in this way the precipitated minerals should be in equilibrium with both phases. This may well have been the case since the same type of feldspar, nepheline, eudialyte and arfvedsonite occur in both phases and in parallel orientation. In the water-rich phase the crystallization continued at such a low temperature that analcime substituted the primary alkali aluminium silicates and that steenstrupine could be formed instead of eudialyte. The nepheline, etc. enclosed in the steenstrupine may, as is seen at the east end of Tugtup agtakôrfia, be protected against the concluding phase of analcitization.

The occurrence of acmite instead of arfvedsonite in the rims of the spheroids may, according to the two first-named interpretations be due to a higher concentration of silica at these places because of incomplete diffusion processes. The local presence of ussingite in the rims is in agreement with this view. According to the last-named interpretation the acmite in the marginal rims is a result of a higher partial oxygen pressure (see p. 193), possibly combined with a release of SiO_2 during the analcitization of the feldspars.

vi. On the origin of the "dense" analcime rocks: The "dense" analcime rocks might be regarded as a further stage of separation of the immiscible liquids mentioned above, that is, the water-rich liquid phase was, in places, mechanically squeezed out from the main magma. However, this distribution of the rocks could also be produced by diffusion processes in the lujavritic magma. Water and other volatiles were, according to this view, concentrated in the marginal (and coldest) parts of the magma (BARTH, 1952 and KENNEDY, 1955).

The "dense" rocks resemble the white, urtitic bands in the lujavrite and it might therefore be suggested that a spatial separation of the light and dark coloured components of the rock had taken place. It should, in this connection, be remembered that the banding of the lujavrite most probably represents a time sequence. If this is combined with deformation the different crystallization products might well be separated in space.

The fact that closely spaced nepheline grains in many of these rocks have very similar optical orientations should, according to the above-mentioned explanations, be a result of crystallization under stress of the nepheline. The local folding could then be due to flow.

However, the existence of small inclusions of "dense" rocks in the coarse-grained inclusions in the lujavrite indicates that the "dense" rock is older than the last-named rock. Furthermore, there are transitions from obvious zones of crushing in the naujaite into "dense" rocks (as for instance at **I-J. 6** in plate 1) and crushed and deformed naujaite minerals occur in the "dense" rocks. The writer therefore prefers the view that the latter rocks are formed by recrystallization of zones of deformation in the naujaite and that the deformation is connected with the emplacement of the lujavrite. There may have been a local mobilization (*palingenesis*) of the naujaite in these zones. The folding may then either be due to rolling-out or flow.

The local development of arfvedsonite and steenstrupine in the "dense" rocks should then be regarded as a product of a late analcitization.

If this interpretation of the formation of the "dense" rocks is correct, detailed studies of the relation of these rocks to the lujavrite should reveal the intrusion mechanics of the latter rock. Unfortunately, the special nature of the "dense" rocks was not recognized in the field and is it therefore to be hoped that these rocks may be re-studied.

vii. On the origin of the white stringers in the lujavrite: In the light of the discussions on the spheroids and the "dense" rocks, the white stringers mentioned on p. 151 should be briefly considered. A comparison of the modal analyses of these rocks with those of the spheroids (see p. 234, nos. 4 & 6) indicates that the white stringers are almost identical with the rims of the spheroids. The spatial association of white stringers and white rings (i. e. spheroids) also indicates that the stringers and spheroids may be related. The stringers may then have been formed either by a partial assimilation of naujaitic material in the lujavrite or also by a rolling-out of immiscible spheroidal patches in the lujavrite magma. The cause of the orientation of the stringers normal to the naujaite contact is unknown, but it should be pointed out that this occurrence of lujavrite is surrounded by naujaite on the three sides and that it is also underlain by that rock (cf. fig. 9 and Sørensen, 1958, fig. 4). Special conditions of movements in the lujavrite magma may be expected in such a "corner position". The white stringers contiguous with naujaite banding are therefore no proof of a metasomatic origin of the lujavrite.

C. Conclusion on the origin of the black lujavrite: Some of the abovementioned features may suggest a metasomatic origin of the black lujavrite, but the combined observations are in better agreement with the magmatic interpretation. It is therefore concluded that the black lujavrites were formed from a melanocratic rest magma which was emplaced during a phase of subsidence of the early rocks of the Ilímaussaq complex. The intrusion of the lujavrite into zones of dislocation in the naujaite was apparently preceded by a crushing of the pre-existing naujaite (to give the "dense" analcime rocks) and by a formation of felt-like ægirine-microcline rocks in thin zones and veins.

The fine grain size of the lujavrite is remarkable when this rock is compared with the other agpaitic rocks of Ilímaussaq and when it is remembered that the *mise en place* of the lujavrites undoubtedly was accompanied by large amounts of volatiles. It is the opinion of the writer that the fine grain size is partly caused by the low temperature of crystallization, partly by a rapid loss of volatiles in many cases, and partly by a crystallization under stress. The low temperature of formation was predicted by Ussing (1911, p. 161) on the basis of the co-existence of two alkali feldspars. The data presented on pp. 217 and 225 strongly support the view that the lujavrite really crystallized at very low temperatures (see also Ussing, op. cit., p. 328–334).

It may finally be of some interest to compare the make up of Ilímaussaq with that of Lovozero. Both complexes have in their lower parts strongly banded rocks (kakortokites and the differentiated complex, respectively). The upper part of the agpaitic rocks of Ilímaussaq consists of the poikilitic naujaite. In Lovozero there are small masses of poikilitic rocks, in part sodalite-bearing, which may be almost identical to the naujaite. Between the upper naujaite and the lower kakortokite of Ilímaussaq the breccia zone composed of lujavrite and naujaite occurs. According to Ferguson (1962 a and b) the lujavrites were formed in the agpaitic magma chamber between the upper naujaite and the bottom accumulated kakortokite. In Lovozero eudialyte lujavrites make up the major part of the top of the massif with a lower horizon of porphyritic lujavrites. If the poikilitic syenites of that massif are correlated with the naujaite of Ilímaussaq, as it has been done by Eliseev and in part by GERASSIMOVSKY, the evolution of the two massifs is almost identical. However, VLASOV et al. (1959) regard the poikilitic rocks as the youngest nepheline syenites of Lovozero, in which case the evolution in the two complexes differs considerably.

The Coarse-grained Inclusions in the Lujavrite and the Associated Analcime Veins.

As mentioned in the descriptive part of this paper there are dark and light coloured coarse-grained inclusions in the lujavrite.

The dark rocks have, in a groundmass of analcime, large arfvedsonite prisms, acmite, nepheline, microcline, sodalite, eudialyte pseudomorphs, steenstrupine, schizolite, britholite, apatite and monazite. The arfvedsonite often occurs in groups of radiating prisms. The large prisms of arfvedsonite are partially altered into acmite and/or biotite and they contain inclusions of acmite and altered eudialyte. Nepheline can be so abundant and the feldspar content so low that the rocks may be of ijolitic type. The larger nepheline grains are of naujaitic type, the smaller ones are apparently formed by crushing of such grains. The large pseudomorphs after eudialyte may be associated with steenstrupine.

These coarse-grained inclusions may have scattered fragments of naujaite and they are veined by very dark lujavrite. They are clearly in a state of dissolution in that rock.

The lujavrite adjacent to the inclusions is rich in arfvedsonite and analcime and also contains steenstrupine, black nodules and schizolite.

The dark, coarse-grained rocks may be considered as pegmatitic patches in the lujavrite and they have some resemblance to the irregular pegmatite bodies found in gabbro and other basic plutonic rocks. The rocks are, just as the gabbro pegmatites, composed of the rock-forming minerals of the adjacent plutonic rock but in larger grains and associated with a minor amount of minerals of typical late formation.

The gabbro pegmatites are either considered to be formed by crystallization of a volatile-rich rest magma (cf. WALKER, 1953) or to be altered xenoliths in the gabbro. Thus WILSHIRE (1961) has, from New South Wales, described xenoliths in an analcime basalt plug. These xenoliths are surrounded by pegmatites which are formed either by de-gassing of the xenoliths resulting in a concentration of volatiles around these bodies, or by diffusion of alkali-rich volatiles towards the cold xenoliths. The larger of these pegmatites often have a central zeolite amygdule, but they are mainly composed of the minerals of the adjacent rock.

In the upper part of many basic and alkaline sills there are pegmatitic pockets and veins rich in zeolites, ilmenite and other late minerals.

Coarse-grained rocks of the type described above from Ilímaussaq also occur in Lovozero where they may be associated with coarse-grained natrolite-sodalite rocks. This association is also found in Ilímaussaq where the **coarse-grained, light coloured rocks** are composed of analcime, natrolite, yellow sodalite, remnants of naujaite minerals such as nepheline, microcline, green sodalite, eudialyte pseudomorphs and acmitic patches. Accessories are sphalerite, steenstrupine, schizolite, igdloite, epistolite, neptunite, pyrochlore, lepidolite and brown mica. Also these light coloured rocks may be penetrated by very dark lujavritic veins in which scattered grains of ægirine may be surrounded by ægirine felt. Arfvedsonite appears to penetrate into the ægirine felt.

In Lovozero the sodalite-natrolite rocks often occur as cores in pegmatitic patches in which the marginal zones are composed of microcline, ægirine, nepheline, eudialyte and other rock-forming minerals. In Ilímaussaq there is a tendency towards a similar distribution of the minerals, but in cases it is clearly seen that the analcime-natrolite rocks are formed at the expense of naujaite (often occurring as rims on inclusions of that rock). For this reason the writer prefers the interpretation that the light coloured parts of the coarse-grained inclusions are formed by recrystallization of naujaite enclosed in lujavrite, sometimes accompanied by a partial mobilization, and that the darker parts of the coarse-grained inclusions are lujavrite modified by assimilated naujaitic material. The fact that the inclusions are cut by lujavrite veins indicate that they cannot be considered as late differentiates of the lujavrite magma. Introduction of lujavritic rest elements into the inclusions has probably contributed to the formation of steenstrupine, etc.

The coarse-grained rocks are in places extremely rich in steenstrupine as for instance in the lower border zone of the naujaite inclusion at **I. 6** in plate 1. This border zone was rather strongly deformed prior to the formation of the steenstrupine as recorded by bending and crushing of the primary naujaite minerals. There is also a concentration of small eudialyte crystals in thin zones set in a matrix of analcime and natrolite; that is, an association recalling the "dense" analcime rocks discussed above. Streaks composed of small grains of katapleite, etc., were probably formed by rolling-out of altered grains of naujaitic eudialyte. In the katapleite zone the matrix is composed of analcime and natrolite with remnants of naujaite minerals and a neo-crystallization of prisms and needles of arfvedsonite and ægirine needles. Steenstrupine occurs, not only in the recrystallized zone of crushing, but also in the overlying naujaite and in the underlying banded rocks and lujavrite.

The steenstrupine-bearing zone is enclosed in lujavrite, but in such a way that the lamination of that rock is contiguous with the banding of the steenstrupine zone (see plate 1). The zone is apparently formed in connection with the emplacement of the lujavrite by introduction of rest elements from the lujavrite into the recrystallized naujaite.

Branching out from the steenstrupine zone, **veins of analcime** penetrate the dark and rather coarse-grained lujavrite. The arfvedsonite of this lujavrite is often in star-shaped groups and it contains inclusions of acmite, ægirine needles, eudialyte crystals and lath-shaped areas of analcime. The groundmass of the lujavrite is composed of analcime, nepheline, sodalite and microcline. The analcime occurs partly in lath-shaped areas which are most probably pseudomorphs after feldspar. Black nodules, poikilitic steenstrupine and schizolite are prominent. The border zone between lujavrite and analcime veins is black and rich in arfvedsonite prisms and acmite.

The analcime veins are composed of large analcime grains in a matrix of smaller ones. Further components are ægirine and arfvedsonite (with homoaxial inclusions of ægirine). There is often a concentration of steenstrupine, pseudomorphs after eudialyte and acmite along the borders. The steenstrupine grows into the adjacent lujavrite.

A few veins are composed of platy microcline (in larger grains than in the lujavrite), interstitial natrolite, and some eudialyte crystals, ægirine, arfvedsonite and marginal yellow sodalite. The adjacent lujavrite here is also rich in microcline in larger grains than commonly found in that rock.

The analcime veins around an inclusion of naujaite at the southeast point of Igdlúnguaq occur in a microcline-rich lujavrite with interstitial needles of arfvedsonite and ægirine between the feldspar plates. In the borders of some of these veins there are compact streaks of felt-like ægirine and a subordinate amount of eudialyte. The veins have, in a groundmass of analcime, arfvedsonite prisms (partially replaced by acmite and biotite), ægirine needles (partially enclosed in the acmite rims of the arfvedsonite), strongly corroded grains of microcline, fine-grained natrolite and eucolite associated with monazite, apatite, pyrochlore, schizolite, etc.

The ægirine needles may have been formed by crushing of larger prisms of that mineral, or hydrothermally. As in vein no. 4 at the head of Kangerdluarssuk (to be discussed in the next chapter), the fine-grained ægirine rock is associated with eucolite and altered microcline.

The analcime veins are mineralogically very similar to the light coloured parts of the coarse-grained inclusions in the lujavrite and to some of the veins discussed in the next chapter. They also recall the replacement bodies of the naujaite pegmatites, but are, in contrast to these, free from albite.

The mineralogical resemblance to the recrystallized inclusions of naujaite and the spatial association with these rocks indicate that the veins have been formed by mobilization of naujaite recrystallizing in the presence of lujavritic rest fluids. They have been able to penetrate a short distance into the adjacent lujavrite which is coarse-grained and arfvedsonite- and analcime-rich in these places. The mobilization was most probably slightly later than the *mise en place* of the lujavrite since the veins cut the lamination of the lujavrite, but being influenced locally by the latter. In cases the lamination may be disturbed by the veins but this is very difficult to establish definitely because of the strongly modified contact zone of the lujavrite in these places.

The occurrence of microcline, eudialyte-eucolite and ægirine in some of the veins; and analcime, steenstrupine, eudialyte pseudomorphs and acmite in others may be best interpreted as follows: the mobilization commenced at high temperature giving rise to the microcline veins and continued at lower temperature and a higher partial water pressure giving rise to the analcime rocks. The high concentration of microcline in some of the lujavrites adjacent to the veins may have been formed at the expense of the potassium released during the recrystallization of the naujaite.

The analcime veins cut the lujavrite, but the field and thin section examinations leave no doubt that these veins, as described above, are formed by recrystallization and mobilization of naujaite enclosed in lujavrite. The veins are thus to be considered as *palingenic* rocks. This interpretation is in disharmony with that given of similar phenomenae in Lovozero (Vlasov et al., 1959, fig. 10). In this massif there are, at the contacts of bodies of poikilitic syenites and the enclosing lujavrite, pegmatites branching out from the syenite and into the lujavrite. These pegmatites contain microcline, ægirine, eudialyte, ramsayite, murmanite, lamprophyllite and others and they pass gradually into the poikilitic syenites. Along the borders of lujavrite and pegmatite there are thin ægirine zones. These features are taken by Vlasov et al. to prove that the poikilitic syenites are younger than the lujavrite, in disagreement with Eliseev, who considers the poikilitic rocks (in places closely related to the naujaite of Ilímaussaq) to be older than the lujavrite, that is, an age relation corresponding to that observed in Ilímaussaq. The lujavrites adjacent to the borders of the poikilitic sodalite syenites of Lovozero are sodalitized, albitized and natrolitized.

The Thin Veins Composed of Ægirine Felt, Acmite, Albite and/or Analcime-Natrolite.

Each of these four vein types will be treated separately. The veins are finally compared, mutually and with related occurrences in other regions.

1. The Green Veins: These veins have been studied at Qeqertaussaq, Igdlúnguaq and the head of Kangerdluarssuk. The development of the green veins of the former two localities differs from that of the veins in the latter locality.

The ægirine veins of Qeqertaussaq and Igdlúnguaq are mainly composed of ægirine needles and microcline laths with varying amounts of analcime and natrolite. The veins have remnants of deformed naujaite minerals, especially ægirine and microcline, but also pseudomorphs after eudialyte and perhaps after nepheline and sodalite. Displacement has taken place along the most prominent green vein at Igdlúnguaq and the minerals of the adjoining naujaite are deformed. Evidence of deformation is less pronounced at Qeqertaussaq.

The ægirine needles and microcline laths sometimes have the appearance of crushed naujaitic ægirine and microcline, but there are also cases of a direct crystallization of ægirine needles and small microcline laths, notably where these minerals occur in fractures in the naujaite minerals (e. g. in eudialyte).

At Qeqertaussaq the formation of ægirine and microcline was succeeded by albitization resulting in the partial disappearance of the microcline. The albite recalls that of the replacement bodies of the naujaite pegmatites and is accompanied by steenstrupine, schizolite, sphalerite, lepidolite, astrophyllite, neptunite, britholite, eucolite, epistolite and others. Chkalovite occurs in amygdules. In this connection it is of some interest to note that the replacement bodies of the pegmatites studied in this paper are spatially associated with green veins and that there is a concentration of steenstrupine at the intersection of a green vein and the pegmatite of the south coast of Qeqertaussaq.

At Igdlúnguaq albite has not been observed in the green veins. Instead natrolite and analcime occur; it should be noted that these minerals replace the feldspars in the green veins of Qeqertaussaq.

Steenstrupine occurs in the marginal parts of the streaks and patches of felt-like ægirine in the veins of Qeqertaussaq, especially in the albite-bearing ones. At Igdlúnguaq it is found in thin zones in the veins.

At Qeqertaussaq the green rocks are associated with black rocks in the multiple veins and appears to be older than these (see p. 146).

In the borders of some of the multiple veins of Qeqertaussaq there are small local patches of coarse-grained rocks with large prisms of arfvedsonite which may be normal to the walls of the veins. These prisms are associated with analcime, natrolite, sodalite and ægirine crystals. The arfvedsonite prisms may be surrounded by fine-grained masses of arfvedsonite, microcline and albite (plate 6, fig. 2).

The naujaite adjacent to the green veins at Igdlúnguaq is rich in large plates of microcline and large prisms of natrolite; analcime, acmite and schizolite also occur.

The green veins of Igdlúnguaq and Qeqertaussaq are very thin. In contrast to this **the veins at the head of Kangerdluarssuk** may be thicker and more dyke-like.

The veins no. 1 and 2 at this place recall those of Qeqertaussaq being mainly composed of ægirine and microcline and one of them grading into a black, lujavritic rock.

Vein no. 3 is multiple being composed of coarse-grained rocks along the margins and of fine-grained green and black rocks in the central parts. The fine-grained rocks appear, according to the field and thin section observations, to be younger than the coarse-grained ones.

Several types of coarse-grained rocks may be distinguished in this vein. Most prominent is a rock with large prisms of arfvedsonite arranged at right angle to the border, but there is also, in places, an assemblage of black arfvedsonite-, red eudialyte-, and white feldspar- and analcime-rich rocks. These coarse-grained rocks have, in a groundmass of analcime, large grains of arfvedsonite and microcline, zoned crystals of eudialyte, strongly corroded grains of nepheline, and furthermore natrolite, albite, ægirine, sodalite, lepidolite, schizolite, britholite, monazite, neptunite, sphalerite and steenstrupine. The last-named mineral occurs as small grains of irregular internal structure, but is lacking in the rocks rich in albite and ægirine, in which zoned eudialyte crystals, lepidolite and monazite occur. The arfvedsonite of the coarse-grained rocks may be in groups of radiating needles and sometimes with aggregates of ægirine felt along the margins of the large arfvedsonite prisms.

The black fine-grained rocks are of lujavritic appearance and may have been formed at the expense of crushed coarse-grained rocks (see p. 108). In this connection it should be mentioned that true veins of lujavrite crop out about 50 metres to the east of the easternmost exposure of the vein.

In a groundmass of analcime, the green fine-grained rocks of this vein have corroded nepheline grains, microcline, albite, natrolite, ægirine, arfvedsonite, rare eudialyte crystals (of lujavritic type), eudialyte pseudomorphs, steenstrupine, schizolite, sphalerite, neptunite, igdloite, white mica, epistolite (?) and britholite. There are dense streaks of arfvedsonite and ægirine/acmite with steenstrupine, eudialyte pseudomorphs, schizolite and neptunite. The analcime-rich rock between these streaks has a higher arfvedsonite/soda pyroxene ratio than the streaks and appears to replace the latter.

The naujaite adjacent to this vein is penetrated by stringers of ægirine felt which can contain large grains of eudialyte of the type found in the coarse-grained rocks of the vein.

The fine-grained green rocks of vein no. 4 are composed of ægirine needles, microcline laths, albite with few twin lamellae, natrolite, lovozerite, steenstrupine, lepidolite, igdloite, schizolite, sphalerite, britholite and in places ussingite. Rare small arfvedsonite needles may grow along the ægirine boundaries. The albite encloses microcline, ægirine and arfvedsonite. In places the green rock contains small light coloured nodules composed of microcline and albite (with blebs and amygdules of analcime). Traces of these nodules may be seen microscopically in rocks in which they cannot be seen macroscopically. These nodules are approximately of the size of the sodalite grains of the adjoining naujaite and may be formed by alteration of these.

The coarse-grained patches of this vein have large grains of ægirine, ussingite, microcline, steenstrupine and in places eucolite in a fine-grained matrix of albite (with a few twin lamellae), microcline, ussingite, ægirine needles, sodalite, analcime and fine-grained natrolite. Accessories are lovozerite, sphalerite, chkalovite, beryllium sodalite, lepidolite, igdloite, britholite and schizolite. The ussingite-bearing rocks are enclosed in the fine-grained green rock.

The eudialyte of the naujaite adjacent to vein no. 4 is partially transformed into eucolite.

2. The Brown Acmitic Veins: The veins at Qeqertaussaq and at the head of Kangerdluarssuk are very poor in acmite. Acmitic veins are, however, prominent at Igdlúnguaq, and the albitite at Tugtup agtakôrfia has developed border zones rich in acmite. In this paragraph only the veins at Igdlúnguaq will be considered.

The brown veins are often formed in zones of deformation in the naujaite. Their marginal parts are generally composed of ægirine/acmite and/or arfvedsonite with a little interstitial analcime and natrolite and minor amounts of brown mica, neptunite, britholite, schizolite, eudialyte pseudomorphs, astrophyllite (?) and in rare cases eudialyte crystals of lujavritic type. The acmite grains can have cores of ægirine. The arfvedsonite of the veins occurs either in large prisms (with inclusions of eudialyte, biotite, acmite and schizolite), or in elongated groups of small grains normal to the strike of the vein and formed at the expense of the large prisms. Acmite may be developed along the margins of the arfvedsonite grains.

There is almost always a thin zone made up of larger prisms and of aggregates of small grains of natrolite between the acmite veins and the naujaite. In this zone there may be a concentration of small eudialyte crystals of lujavritic type. There are also small clusters of biotite and, in places where the border zone is rich in analcime, small prisms of ægirine and small round grains of britholite. Yellow sodalite may also occur in the border zone. The ægirine of the adjacent naujaite is often acmitized and deformed in contact with the veins and the altered parts of the grains contribute to the make up of the brown veins. There may also be a development of ægirine felt between the large naujaitic ægirine grains and the acmitic veins (fig. 31). Small needles of ægirine, which are partially altered into acmite, occur in the acmite zone and may therefore be older than the latter.

In these veins there are coarse-grained patches made up of natrolite prisms, analcime, yellow sodalite, fine-grained natrolite, and in one case large grains of chkalovite. Further components of these patches are steenstrupine, schizolite, lepidolite, arfvedsonite, acmite, neptunite, pyrochlore, igdloite and britholite. There may be strongly corroded remnants of microcline. The steenstrupine occurs especially along the margins of the coarse-grained patches towards which it has developed crystal faces. It has irregular borders on the acmite into which it appears to grow.

The acmitic veins have apparently been formed in zones of deformation in the naujaite and their acmite is, at least partly, formed at the expense of the ægirine and perhaps arfvedsonite of the naujaite. There may, in an early stage of the development of the veins, have been a formation of large grains of arfvedsonite, but some of these may be remnants of arfvedsonite from the naujaite. The formation of the crush zones and their fillings of acmite was accompanied by an almost complete removal of the components of the other minerals of the naujaite. The acmitic veins may thus, in a way, be compared with styloliths in limestones and with the iron-stained shear zones in many granites.

The acmite was succeeded by the formation of natrolite, etc., along the borders of the veins, as well as in their central parts. The formation of natrolite and analcime was accompanied by steenstrupine in an early stage and by igdloite and pyrochlore in a late stage.

The acmite along the coarse-grained patches has developed prismatic crystals towards the latter, the acmite of the brown zones occurs in aggregates of equidimensional grains. In the natrolite-analcime zone between vein and naujaite there are small crystals of ægirine. The presence of acmite in the central parts of the veins may be taken as evidence of a higher partial oxygen pressure at this place than in the marginal parts of the vein where ægirine was formed.

3. The Analcime-Natrolite Veins: These veins closely resemble the analcime-natrolite patches of the acmitic veins and some of the coarse-grained inclusions in the lujavrite. They are composed of analcime, prisms and fine-grained masses of natrolite, yellow sodalite, deformed grains of nepheline and microcline of naujaitic type, and minor amounts of acmite, arfvedsonite, steenstrupine, igdloite, pyrochlore, schizolite, britholite, sphalerite and chkalovite. There may be traces of border zones composed of acmite, arfvedsonite and steenstrupine and these veins are therefore considered to be special cases of the acmitic veins described above.

4. The Albitite at Tuĝtup aĝtakôrfia: This vein is, as discussed in the lujavrite chapter, younger than the lujavrite. It is, in addition to the albite with few twin lamellae, composed of scattered grains of microcline, large grains of yellow sodalite, round grains of analcime and the accessories: lepidolite, schizolite, epistolite, acmite, acmitized arfvedsonite, sphalerite, igdloite and steenstrupine.

The border zones of the vein are composed of acmite, analcime, sodalite, microcline, arfvedsonite, steenstrupine, schizolite, epistolite, ussingite, eudialyte pseudomorphs, astrophyllite(?), lepidolite, sphalerite and fibres of natrolite and the natrolite-like mineral. The adjacent naujaite contains albite, analcime and natrolite.

In the upper horizontal part of the vein there are large crystals of analcime, chkalovite and beryllium sodalite.

It is a remarkable fact that albite only occurs in the albitite and in the naujaite adjacent to the vein. It has not been observed in the apophysis of lujavrite in the lower part of the albitite-bearing fracture or in the small inclusions of lujavrite. The lujavrites contain microcline, analcime and sodalite (the latter mineral in grains which, as to shape and size, recall the nepheline of the normal lujavrite). The parts of the albitite adjacent to the lujavrite are also free from albite and rich in analcime, sodalite and microcline.

The steenstrupine of the albitite occurs in well-developed crystals with few inclusions. The steenstrupine occurring in the lujavrite forms grains of irregular shape and it is rich in inclusions (cf. plate 12, fig. 1 and plate 16, fig. 1).

The albite of the vein closely resembles that of the replacement bodies of the naujaite pegmatites.

The high concentration of analcime around the lujavrite of the albititic vein might be interpreted as a result of a later formation of the lujavrite which had modified a pre-existing albitite. This view is, however, in disagreement with the field observations which rather clearly indicate that the albitite is formed later than the lujavrite. This problem will be further discussed later in this chapter.

5. Comparison with Other Regions: Veins containing fibres and needles of ægirine have been described from a number of alkaline complexes in different parts of the world. A few of these are briefly mentioned below.

In Khibina (Fersman, 1929 and Chirvinsky, 1939) the acicular ægirine III occurs in hydrothermal veins with "spreustein", natrolite, analcime, astrophyllite, neptunite, biotite, ramsayite, lamprophyllite, zircon, sulphides, chalcedony as well as rare ussingite and schizolite. According to Afanasyev (1937, p. 117) there is, in the lovchorrite zone of Khibina, a succession of veins. Oldest are veins of ægirine-nepheline syenite, followed by pegmatites with ægirine, feldspar, rinkolite and lovchorrite, then ægirine-albite veins containing eudialyte, loparite and lovchorrite, and finally natrolite-sulphide veins. Ramsay and Hackman (1894) stated that the latest formations of Khibina and Lovozero were zones of felted ægirine and according to Vlasov et al. (1959), ægirine III occurs in Lovozero in rocks exposed to alkalinization and in brecciated areas of ægirine II in the ægirine-feldspar zones of the pegmatites.

Acmite is rather rare in Lovozero (Vlasov et al., 1959). It only occurs in a few pegmatites where it is associated with natrolite and analcime.

Fracture fillings containing acicular ægirine have also been described from Libby, Montana (Goranson, 1927, Larsen and Pardee, 1929), the Bearpaw Mountains, Montana (Pecora, 1942), the Highwood Mountains, Montana (Larsen, et al., 1939), Iron Hill, Colorado (Larsen, 1941), the Manitou Island complex, Ontario (Rowe, 1958) and Nemuro, Japan (Suzuki, 1938). The ægirine in these occurrences is generally associated with albite, zeolites, carbonates, micas, fluorite and sulphides. Eucolite has been described from the veins in the Bearpaw Mountains in association with lamprophyllite, sodalite, katapleite and elpidite (?). The ægirine is generally one of the first formed minerals of the fractures and occurs as crusts on the walls, as radiating groups of needles, as felt-like masses and as needles normal to the walls of the fractures. The carbonates and sulphides generally occupy the central parts of the veins and are clearly later than the ægirine.

It should also be pointed out that ægirine is a common constituent of fenites around alkaline complexes and that ægirine and acmite occur in low metamorphic rocks in orogenic zones, for instance in the Alps (e. g. Fischer and Nothaft, 1954) where the ægirine-bearing rocks show gradual transitions into phyllites and are believed to be formed by alkali-penetration of the latter. Ægirine may also occur in glaucophane schist complexes.

The albitite of Tugtup agtakôrfia may be compared with some albite-rich pegmatites in Khibina (Fersman, 1929). These veins, however, contain eucolite and furthermore nepheline, corroded microcline, astrophyllite, ægirine, arfvedsonite, sphene, ilmenite and zeolites.

It is a remarkable fact that the veins considered in this chapter correspond closely to the rocks formed in the later stages of development of the fully differentiated pegmatites of Lovozero (Vlasov et al., 1959). The minerals formed here are albite, natrolite, analcime, ussingite and minor amounts of rare minerals of the type found in the Ilímaussaq rocks. This similarity persists even to the latest stages of development where amygdules containing chalcedony, chkalovite and beryllium sodalite are formed. The most pronounced difference between the two complexes is the rarity of titanium-bearing minerals in Ilímaussaq, whereas titanium is of great importance in Lovozero. It should, however, be mentioned that the titanium-rich murmanite of Lovozero appears to be substituted by the related titanium-poor mineral epistolite in Ilímaussaq (DANØ and SØRENSEN, 1959, p. 33).

From the Manitou Island Complex ROWE (1958) has described disseminated uranium-pyrochlore in metasomatized and recrystallized deformation zones in fenite surrounding an alkaline complex. It is accompanied by apatite, magnetite, iron sulphides, biotite, hematite, soda hornblende and soda pyroxene II.

In Poços de Caldas in Brazil (FRANCO and LOEWENSTEIN, 1948), there is a hydrothermal deposition of zircon and baddeleyite (*caldasite*) in fractures in zeolitized nepheline syenites containing eudialyte, rosenbuschite and other zirconium-bearing minerals. The zirconium minerals in the fractures are considered to have been formed at the expense of zirconium leached out of the zeolitized nepheline syenites. The caldasite contains small amounts of uranium, rare earths, niobium, thorium, calcium and lead (GUIMARAES et al., 1953). It should be mentioned that the ore contains 0.2–2.93 % U_3O_8 and 1.85 % $(Y, Yb)_2O_3$ and only traces of cerium and thorium.

FRONDEL and MERWIN (1959) have described zones of alteration in the phonolites and nepheline syenites of Poços de Caldas containing allanite, bastnaesite, thorogummite and secondary cerianite. The $Ce(OH)_3$ is easily oxidized in the alkaline solutions and may in this way be separated from the other rare earth metals.

LOUCHITSKI (1947) has suggested that zirconium dissolved in alkaline rocks by sodium metasomatism is deposited by hydrothermal processes elsewhere in the complexes. It is tempting to apply this view on the above-mentioned occurrences in Poços de Caldas and to consider the rare earth-thorium veins as formed in deeper levels than the caldasite veins, but the available literature does not allow such a correlation.

From Werner Bjerge in East Greenland BEARTH (1959) has described a late phase of hydrothermal alteration in an alkaline complex. Diffuse zones of decomposition and fracture fillings were formed during this alteration. The primary mafic minerals of the diffuse zones were replaced by a zirconium-bearing limonite with some pyrite; the fracture fillings contain hematite, Mn-limonite, pyrite, calcite, quartz, siderite, strontianite, baryte (?), fluorite and crusts of black manganese ores. The mineralized zones often follow the dykes cutting the complex and they also cut post-syenitic basalts so that a considerable interval of time has elapsed between the formation of the syenite-nepheline syenite complex and the post magmatic mineralization. The mineralized zones are enriched in Fe, Mn, Ti, Zr and Nb; the Zr-limonite also contains rare earths and Th. These elements are believed to be set free by decomposition of the mafics of the alkaline rocks. This mineralization may also be explained by the leaching hypothesis of LOUCHITSKI (op. cit.).

MACKIN and INGERSON (1960) have discussed leaching processes in order to explain the formation of some types of iron ores in limestones around plutonic complexes. The dark minerals of the plutonic rocks are believed to be dissolved by deuteric processes and their iron and other elements are transported to the enclosing rocks.

An ingenious leaching hypothesis has been advanced by KORZHINSKY (e. g. 1959 and 1960). According to this hypothesis the post-magmatic solutions from granitic magmas become increasingly acid during the later stages of crystallization. These circulating acid solutions leach the bases out of a large volume of already crystallized rocks. In this stage the potash feldspar is albitized or muscovitized, the hornblende is biotitized and a silicification also takes place. By subsequent cooling the solutions become progressively more alkaline and the bases are redeposited, especially in fractures in the leached rocks. The weak bases such as Al and Fe are deposited before the stronger bases. The changing alkalinity-acidity of the solutions is not caused by fractionation in the magma, but by a filtration effect, the acid components (CO_2, HCl, H_2S, etc.) migrating faster than the remaining components. One may therefore speak of an "advancing wave of acidic components". The increasing acidity in the first stages is also caused by condensation of supercritical fluids. If this hypothesis was applied on the veins of Ilímaussaq one might explain the early separation of the ægirine/acmite (containing the weak base Fe) and the later separation of albite and zeolites. It should, however, be mentioned that REKHARSKI (1957) has described zones of alteration around hydrothermal veins containing sericite and quartz closest to the vein and albite and carbonates further away.

Finally, the veins described in this paper should be compared with the rare earth-thorium veins occurring in shear zones around alkaline complexes in a number of localities in the United States (e. g. Mountain Pass, California (OLSON et al., 1954), Powderhorn, Colorado (OLSON and WALLACE, 1956), Lemhi Pass, Idaho (ANDERSON, 1961) and Bearpaw Mountains, Montana (PECORA and KERR, 1953)). These veins are generally rich in carbonates and sulphides and further contain bastnaesite and other rare earth carbonates, thorite, allanite, monazite, cerite, baryte, micas, chlorite, zeolites, albite, potash feldspar, ægirine, apatite, quartz, iron ores and others. In the Lemhi Pass area the radioactive veins are partly located in older copper-bearing veins.

Similar veins have been found to the east of the Ilímaussaq complex. A few specimens have been studied in a preliminary way by JOHN HANSEN and the writer and a more detailed study is now being undertaken by JOHN HANSEN. Some of the rocks of these veins are of lujavritic type containing ægirine, acmite, microcline of the Ilímaussaq type, subordinate arfvedsonite and pigmentary material. Most veins, however, are albitized and there may be rather large amounts of carbonates and chlorite. Further components are schizolite, white mica (lithium-bearing?), biotite, quartz, iron ore, pyrite, sphalerite, limonite, fluorite, apatite, monazite, thorite (?), steenstrupine (?), bastnaesite and zircon. The analcime and natrolite, which are such characteristic components of the veins inside Ilímaussaq, have not been observed in the veins occurring around the Ilímaussaq massif.

6. Discussion and conclusions: The rocks discussed in this section may be divided into four main groups: a. green veins; b. acmite and analcime/natrolite veins; c. albitite and d. coarse-grained rocks of the veins.

a. The green veins closely resemble the veins of ægirine III of Khibina and Lovozero which are considered to be of hydrothermal origin. There is also a certain resemblance to some of the occurrences mentioned from other regions.

As mentioned on earlier pages the green veins of Qeqertaussaq and the head of Kangerdluarssuk are closely associated with black rocks of lujavritic appearance in joints orientated around N-S and E-W. At Igdlúnguaq there is also a rather close association of green veins and lujavrite, green felt-like rocks being present in the marginal zones of some of the lujavrite veins.

As already mentioned the green veins appear to be older than the black lujavrite. No evidence supporting the opposite age relationship has been found. The formation of the green veins may then be connected either with the last weak activities of the naujaite, or with the emplacement of the lujavrite. The fact that the green rocks are partly formed by crushing of the naujaite minerals in the fractures, along which the emplacement of the lujavrite occurred, is, in the writer's opinion, in best agreement with the last-named view.

In fractures, which were not completely sealed by the lujavrite, there was a later introduction of albite, natrolite, analcime, etc. (see further below).

b. The brown acmitic veins differ from the just mentioned green veins in the almost complete absence of microcline. Instead analcime and natrolite occur. Albite is very rare in the veins studied in this paper. There is, in places, a weak development of ægirine felt in the border between the veins and the naujaite, this ægirine being apparently older than the acmite. The acmite of the veins is mainly formed at the expense of the dark minerals of the naujaite in zones of crushing.

The brown veins may be contiguous with veins of lujavrite but are, in places, cut by lujavrite veins. At Igdlúnguaq they are also cut by a green vein at **G. 3-4** of plate 1. One brown vein is, at this place, cut by the green vein under geometrical conditions corresponding to dilation. In one case, a brown vein may be traced across the green rock by means of small crystals of steenstrupine in lines continuous with the vein.

The brown veins occur in joints parallel to the lujavrite veins, but also in fractures more or less diagonal to the latter. The diagonal fractures may contain short veins of lujavrite as on the west coast of Igdlúnguaq.

According to these observations some of the brown veins are older than the lujavrite, whereas others are simultaneous with or later than that rock. In the first case the veins may be simultaneous with the green veins, but formed under different physical and chemical conditions, perhaps a lower temperature and higher partial water and oxygen pressures. They then represent a more advanced leaching than the green veins. It is, however, also possible that they are younger than the lujavrite and the green veins, but formed in fractures which are partly older than these rocks. In that case they have been formed in connection with adjustment processes accompanying and succeeding the formation of the lujavrite. In this connection it should be pointed out that the brown veins penetrated by the green vein at **G. 3-4** if older than that rock, should have been displaced along the vein in the same way as the white band in the naujaite at **G-H. 3** which is not the case. The fact that the brown veins do not cut the lujavrite veins, but are themself cut by the latter rocks may be explained by assuming that the fractures in which they occur, were permeable for late magmatic fluids during the formation of the lujavrite and that the veins of the latter rock have caused local sealing of these fractures.

The formation of the acmite in some fractures was succeeded by the formation of the coarse-grained analcime-natrolite patches and veins. This feature recalls some of the above-mentioned veins from localities in the United States where ægirine occurs along the margins, and carbonates, zeolites, sulphides and other hydrothermal minerals in the central parts. Pecora (1948) has emphasized this type of "xenothermal telescoping" from the Bearpaw Mountains.

Additional information about the mode of origin of the brown veins is obtained in the albite-bearing naujaite adjacent to thin lujavrite veins at Igdlúnguaq (p. 48). The naujaite here contains deformed naujaite minerals, polysynthetically twinned grains of albite, analcime, acmitized arfvedsonite, eudialyte crystals of lujavritic type, abundant lepidolite, britholite, schizolite, neptunite, fluorite and steenstrupine. This albitization (and acmitization) is younger than the formation of the black border zone of the lujavrite vein since this zone is deformed and partly acmitized. In a groundmass of analcime this lujavrite contains laths of microcline, corroded and crushed grains of nepheline, eudialyte crystals, acmite, arfvedsonite, sodalite and minor lepidolite, astrophyllite, biotite and neptunite. The eudialyte has brown, steenstrupine-like patches. The acmite of the lujavrite is in part enclosed in arfvedsonite. It appears as if a type of "lujavritization" has expired and has been succeeded by the albitization, etc. and it is clearly seen that the acmitization here is later than the lujavrite.

This albitized naujaite should be seen in connection with the thin diffuse steenstrupine-bearing zones which occur here and there in the naujaite of Igdlúnguaq (p. 67). The steenstrupine is associated with analcime, small round grains of albite (with few twin lamellae), lepidolite, britholite and acmite. The albite penetrates the naujaitic sodalite and can have a thin network of natrolite.

c. **The albitite at Tugtup agtakôrfia** has, as the brown veins, borders rich in acmite. It is later than a lujavritic vein occurring in the same fracture in the naujaite. The lujavrite is strongly acmitized adjacent to the albitite as it has also been described above from the albite-acmite zone at Igdlúnguaq. As in that locality the border of the lujavrite is rich in analcime and microcline and free from albite. Thus, in these two localities there is a zone of albitization and acmitization in continuation of microcline-, sodalite- and analcime-rich lujavrite veins. On the west coast of Igdlúnguaq veins of analcime and natrolite occur in the same way and are probably formed at a lower temperature and a higher partial water pressure than the albitite (see further p. 184).

The formation of these albite-, analcime- and natrolite-bearing veins may be explained in at least two ways:

i. The lujavrite magma was water-saturated. A pressure relief might then result in the expulsion of a water-rich phase (cf. NEUMANN, 1948, SMITH, 1948, TUTTLE and FRIEDMAN, 1948, and FRIEDMAN, 1950). The pressure relief may be caused by tectonic processes, but there may also have been local empty spaces when fracture systems in the naujaite have not been completely filled up by the lujavrite magma. The presence of microcline (and not albite) in the lujavrites associated with the albititic rocks at Tugtup agtakôrfia and Igdlúnguaq indicates that the sodium-rich rest liquid was expelled from these rocks. Veins containing albite, etc. were then formed at the places where these sodium-rich fluids were trapped, the temperature, the chemical composition, the water content and the pressure determining whether albite or analcime-natrolite were formed. If the water of the system was allowed to disappear, an albititic rock might for instance be formed. The occurrence of the largest amount of analcime vugs in the upper part of the albitite at Tugtup agtakôrfia may be due to an especially high concentration of water at this place.

The last-named conclusion is apparently in disagreement with the fact that the albitite, in contact with the lujavrite of the lowermost part of the vein, is very rich in analcime. However, the analcime rock has, in places, a rather distinct relic naujaite texture and its analcime may therefore have been formed prior to the albitite. As stated by COOMBS et al. (1959, p. 83) analcime may form in a rock and albite in a fracture in the rock if the partial water pressure in the rock is equal to the rock pressure and the partial water pressure in the fracture is lower than that value.

ii. The albititic rocks discussed here and some of the analcime-natrolite veins are clearly later than the lujavrite and also later than the dark border zones of that rock. The lujavrites and naujaites adjacent to the veins are furthermore rich in analcime and natrolite. It may therefore be assumed that the veins were formed from late, perhaps deuteric fluids which also have effected the analcitization of the lujavrite and naujaite. The veins then represent the latest manifestations of these processes and occur where the late, more or less contaminated, fluids have been squeezed out from the lujavrite and into solution cavities and fractures.

Some of the round grains of analcime in the albitite at Tugtup agtakôrfia appear to be enclosed in the albite and there are undoubted inclusions of analcime-rich lujavrite. This may indicate that analcime was formed in an early stage of the alteration processes and that it was later substituted by albite. As it will be further discussed in the chapter on the alkali-aluminium silicates, the albite may have crystallized at almost the same temperature as the analcime, but at a lower water pressure or a higher content of silica.

A combination of the above-mentioned two ways of formation of the veins may also have been in operation. In that case, the water dissolved in the water-saturated lujavrite magma effected the analcitization of the lujavrite and the adjoining naujaite in the last stages of crystallization of the magma and it was also responsible for the formation of the black border zones. The water-rich phase expelled at an earlier stage, when the magma became saturated with water, was trapped at suitable places and crystallized at lower temperature under reaction with the already crystallized rocks.

d. The coarse-grained rocks of the thin veins: The late mineralization of the thin veins resembles the replacement bodies of the naujaite pegmatites very much. It is therefore tempting to consider the veins as late formations in pegmatitic rocks and the coarse-grained components of some of the veins might then be regarded as remnants of the original pegmatites.

One might interprete the albitite at Tugtup agtakôrfia as having been formed by total replacement of a naujaite pegmatite. But it appears from the discussion above that this is most unlikely, since the rock is considered to be younger than the lujavrite and since no traces of a eudialyte pegmatite have been observed. The scattered grains of microcline and acmitized arfvedsonite in the albitite are most probably remnants of the naujaite which once occupied the zone in which the albitite occurs.

The large grains of arfvedsonite, microcline and natrolite which occur along the margins of some of the thin veins might be regarded as remnants of pegmatites in the same fractures. These large grains have a very irregular distribution. The microcline may be of naujaitic origin or formed in connection with the green veins, the arfvedsonite may also be a naujaitic mineral or formed in early stages of the development of the fillings of these fractures, apparently later than some acmite and ægirine, but earlier than the latest development of acmite. The natrolite grains are clearly formed in connection with the thin veins. One might suggest that the development of the thin veins commenced at pegmatitic conditions, but there is no evidence in support of the view that these pegmatites are connected with the naujaite, on the contrary they appear to be considerably younger than that rock.

The coarse-grained rocks found along the borders of vein no. 3 at the head of Kangerdluarssuk might also be regarded as a type of naujaite pegmatite being partially replaced by steenstrupine-bearing rocks. The prisms of arfvedsonite normal to the walls of the vein could support such a view recalling the "*comb structure*" found along the margins of some granite pegmatites and similar features observed in some of the Lovozero pegmatites. The coarse-grained rocks might then be regarded as cross-cutting naujaite pegmatites differing in development from the sill-like pegmatites described in the present paper. In this case the replacement bodies are restricted to the pegmatites.

However, the veins contain, in their central parts, inclusions of naujaite of coarser grain size than the vein rock. The author is, therefore, more inclined to think that the coarse-grained vein rocks represent off-shoots from a magma lying below the naujaite. As discussed in an earlier paper (1958, p. 32), the naujaite crystallized in the upper part of the agpaitic magma chamber of Ilímaussaq at the same time as the kakortokite was formed at lower levels. There may have been transitional stages between these two rock types (op. cit., p. 33). Inclusions of naujaite in the kakortokite indicate that the naujaite was consolidated slightly earlier than the kakortokite. It is therefore suggested that the marginal parts of vein no. 3 are derived from a magma underlying the naujaite and that they are coarse-grained because the naujaite along the fractures was still warm at the moment of injection. In this connection it should be mentioned that coarse-grained rocks similar to the ones mentioned here have been found as inclusions in the green lujavrite to the south of Lilleelv.

During the phase of deformation which accompanied the *mise en place* of the lujavrite, the coarse-grained veins acted as zones of discontinuity along which release of strain occurred and the fine-grained rocks were then formed in the zones of deformation in the veins. This recalls the common situation of mylonites in and along basic dykes in orogenic regions. Analcitization of the earlier rocks took place together with the formation of the fine-grained rocks.

The coarse-grained patches of vein no. 4 are clearly of a type differing from the coarse-grained rocks of vein no. 3. Two ways of interpretation seem to be possible:

i. The ussingite-bearing rocks recall in many respects some types of replacement bodies described from Lovozero pegmatites (VLASOV et al., 1959). One might accordingly interprete the ussingite patches as remnants of a strongly replaced naujaite pegmatite and the green rocks could then have been formed in a later stage of deformation. The small grains of steenstrupine and lovozerite should, according to this interpretation, be rolled-out remnants of larger grains from the replacement bodies. It is, however, difficult to see how the crushed steenstrupine could occur in such well-developed crystals and it is also difficult to explain that the ussingite of the fine-grained rock, even when crowded with small ægirine needles, could have almost the same optical orientation over large areas. For these reasons the writer cannot accept this view.

ii. The large grains of microcline, sodalite, ægirine and eucolite occurring in the coarse-grained patches of the vein may be remnants of naujaite minerals enclosed in a green zone composed mainly of ægirine needles, microcline and small altered grains of eudialyte, that is, a composition corresponding to that of some of the green rocks of vein no. 3.

The large grains of the coarse-grained patches are partly of the poikilitic type occurring in the naujaite, but they are always strongly deformed. The eucolite grains can be of a poikilitic development recalling that of the naujaitic eudialyte, but the poikilitic inclusions are composed of ussingite (with small inclusions of sodalite), microcline and albite instead of sodalite. The eudialyte of the naujaite adjacent to the vein is partially altered into eucolite. It appears therefore to be permissible to conclude that the eudialyte of the coarse-grained patches has been transformed into eucolite, perhaps in connection with the formation of the green veins. This conclusion is supported by the presence of small grains of eucolite in green veins elsewhere in Ilímaussaq and by the eucolite in the mobilized naujaite of the southeast point of Igdlúnguaq.

In a late phase, this vein, just like a number of other green veins in Ilímaussaq, was permeated by sodium-rich fluids which effected an albitization of the vein. In this stage the steenstrupine, the lovozerite and perhaps some of the large grains of ægirine were formed and the sodalite and microcline of the pre-existing rock were replaced by ussingite. The lovozerite was most probably formed at the expense of the small remnants of eudialyte occurring in the rock and it is most probably simultaneous with the ussingite since these two minerals are often associated in Ilímaussaq. The steenstrupine, which encloses numerous small grains of lovozerite, is apparently later than that mineral and it occurs where the concentration of eucolite and lovozerite is especially high.

The age relation of the ussingite and albite has not been determined with any certainty. "Veins" composed of "wall-to-wall" grains of albite apparently cut the ussingite indicating a later formation of the albite.

But one may also assume that there was first an albitization of the microcline-bearing rock so that the zones of albite have penetrated the original microcline and sodalite. In a later stage ussingite replaced the last-named two minerals leaving most of the albite unaltered. This interpretation is in best agreement with that of the evolution of the other green veins in Ilímaussaq and, according to this, ussingite has been formed in a late stage at special conditions (see further p. 185). According to this view the areas of chkalovite may be regarded as partly preserved amygdules from the original albitic vein. The latest minerals to be formed in vein no. 4 were fine-grained natrolite and a fine-grained carbonate-like mineral.

e. Conclusions: As a result of the discussion on the preceding pages it may be concluded that the thin veins considered here are associated with the *mise en place* of the black lujavrite. Earlier than that rock are veins composed of ægirine and microcline, approximately contemporaneous with the lujavrite are the acmitic veins and later than the lujavrite are the veins and parts of veins containing albite and/or analcime-natrolite. The last-named minerals are accompanied by steenstrupine, lepidolite and other rare minerals.

To the east of Ilímaussaq there are carbonate- and chlorite-bearing veins which also contain ægirine, albite and rare minerals. If these veins are formed simultaneously with the veins inside Ilímaussaq, the conditions of formation have apparently differed considerably inside and outside the alkaline rocks and in such a way that the most pronounced low temperature minerals occur outside the alkaline rocks. Carbon dioxide is thus almost totally expelled from the alkaline rocks into the colder country rocks.

The thin veins considered in this chapter are composed of crushed and partly recrystallized naujaite minerals and of minerals formed at the expense of introduced substances. The latter were, as discussed above, transported in solution either by a water-rich phase expelled from a water-saturated lujavrite magma during the crystallization of the latter, or by late, mainly deuteric, fluids squeezed out of the lujavrite. These interpretations are based on the study of the thin veins alone. But the veins may also be compared with the light coloured, coarse-grained inclusions in the lujavrite and with the analcime veins associated with some of these rocks, which, on earlier pages, have been considered to be recrystallized and partly mobilized naujaite inclusions in the lujavrite. It is therefore possible that mobilized naujaitic material has contributed to the vein-forming fluids. Leaching processes may also have taken place along the naujaite fractures.

The fact that the thin veins often contain the highest concentrations of steenstrupine, etc. at the places of intersection with eudialyte-rich rocks (cf. pp. 24 and 48) might indicate that the veins were formed by some type of "*lateral secretion*", for instance a partial leaching of the rock adjacent to a fracture with a high water content and a low pressure (cf. RAMBERG, 1961). The dark borders might then be regarded as "basic behinds", perhaps formed because of a difference in pressure around the fracture. The mobile components Na and K were concentrated in the fracture, the basic components being left in marginal minerals of low mol volumes (REITAN, 1960). The writer, however, prefers a somewhat different interpretation of the influence of the adjacent rock on the composition of the vein.

Whatever of the above-mentioned hydrothermal hypotheses on the formation of the albite and analcime-natrolite veins is preferred, the veins have always been formed in fracture zones in the naujaite and have thus replaced the crushed naujaite minerals there. The dark minerals of the naujaite may, in a crushed state, be concentrated along the borders of the veins, the remaining naujaite minerals have been substituted for by the minerals of the veins. For instance, eudialyte is a very rare mineral in the veins, but eudialyte pseudomorphs are common. At places where the naujaite of the fracture zones was rich in altered fragments of eudialyte these remnants may have increased the concentration of rare earths, thorium, niobium, etc. in their immediate surroundings so that a precipitation of a part of the content of these elements in the mineralizing fluids could occur. The fragments may also have acted as nuclei which have facilitated the crystallization of steenstrupine, this mineral often being associated with altered eudialyte (see further p. 197).

The almost total disappearance of eudialyte in the mineralized zones and the almost complete absence of zirconium minerals in these zones indicate that a considerable amount of zirconium has been removed during the replacement processes. Instead minerals rich in rare earths, thorium, niobium and phosphorus have been formed. A spectrographical examination of ten samples of acmitic veins from Igdlúnguaq gave from 600 ppm to more than 1 % Zr, 100 ppm to higher than 1 % La, 60 ppm to about 1 % Y, and 2000–5000 ppm Ti. There was about 10 ppm Be (100 ppm in one sample), and V, Ni and Co were not detected. The samples were taken in the acmite-arfvedsonite-rich parts of the veins. According to spectrographical analyses the steenstrupine contains more than 1 % Zr. Two samples of naujaite analyzed by USSING (1911, p. 369) contain 0.38 % and 0.27 % ZrO_2 but, as mentioned above, the highest concentrations of rare minerals in the veins occur at the intersection of eudialyte-rich rocks. Eudialyte contains about 14 % ZrO_2 and it is therefore evident that zirconium has been removed during the mineralization of the fracture zone. One might then expect, that larger concentrations of zirconium ore, corresponding to the *caldasite* of Poços de Caldas, occur in higher levels in Ilímaussaq, but such occurrences have not yet been found.

f. On the formation of the replacement bodies of the naujaite pegmatites: The similarity of the replacement bodies in the naujaite pegmatites and the thin veins discussed in this chapter has been hinted at on earlier pages. It has therefore been concluded that the replacement bodies of the pegmatites were formed from fluids derived from sources external to the pegmatites. This is in strong contrast to the prevailing hypotheses among students of granite pegmatites, as it has been mentioned on p. 138. It is tempting to conclude this section by a brief consideration of the difference in interpretation of these two groups of pegmatites.

The rare elements of the naujaite and lujavrite are mainly present in eudialyte and in the naujaite also in rinkite and a few other minerals. Some rare elements are also taken up by the rock-forming minerals (such as ægirine and arfvedsonite) by *camouflage*, *capture* and *admittance* according to the rules of V. M. GOLDSCHMIDT. This is in agreement with the statements of VLASOV et al. (1959) that the eudialyte-rich rocks in Lovozero are poor in other minerals containing the rare earth metals, Nb, Ti, etc., these elements being present in eudialyte, ægirine and other rock-forming minerals.

NEUMANN (1948, p. 83) has suggested "that the bulk of the (late) fluid phase will stay back in the magma chamber and deposit *in situ* the compounds dissolved in it, as a fine, invisible dust on the surface of the rock-building minerals, and thus, as a rule, a smaller part only of the fluid phase will find its way into fissures as hydrothermal solutions, giving rise to mineral deposits". In this connection reference should be made to the common existence of interstitial, easily leachable, uranium in many granites.

The fluids responsible for the formation of the mineralized zones in Ilímaussaq, whatever their origin, have permeated fracture zones in the naujaite and have dissolved the rare elements present in eudialyte, in ægirine, etc., and in interstitial dust. The introduced and the dissolved material was redeposited at places where the concentration of rare elements was especially high and where "germ" crystals were present. This may, as discussed above, take place where the fracture zones were rich in remnants of eudialyte, that is, where the veins intersect eudialyte-rich rocks. Eudialyte is widespread in Ilímaussaq and the concentration of rare elements in the alkaline rocks of that massif is exceptionally high. It is therefore evident that the precipitation of the rare elements can take place, not only in the naujaite pegmatites, but also at favourable places in the naujaite. The carbonate-bearing pegmatites and the carbonate veins in the Bearpaw Mts. (PECORA, 1942 and PECORA and KERR, 1953) may be similar features.

In contrast to this, most granites are very poor in rare minerals. Higher concentrations of rare elements are, according to RINGWOOD (1955), only found in granite pegmatites when a large quantity of volatiles in the granite magma has prevented the rare elements from an early separation in zircon, xenotime and other minerals. High concentrations of volatiles are specially found in the apical and marginal parts of the granite massifs (cf. KENNEDY, 1955). A part of the rare elements of the granite magma is, at these conditions, concentrated in the volatile-rich residual liquids from which zoned pegmatites, containing rare minerals, are formed. Another part of the rare elements is held back in the granite as interstitial dust in the way outlined by NEUMANN (op. cit.), or it may be taken up by the rock-forming minerals by *camouflage*, etc. The rare elements dispersed in the granite in that way are partly dissolved by deuteric and other fluids migrating through the granite and its country rocks. The concentration of the rare elements in these fluids is so low that precipitation generally cannot take place. Only where the fluids migrate through rocks having a sufficiently high concentration of rare elements, that is, the pegmatites, can the rare elements be deposited in the recrystallized parts of the pegmatites. This revival of the hypothesis of SCHALLER has the drawback that it does not explain the large amount of albite in the replacement bodies of granite pegmatites, but it may be assumed that the precipitation of the sodium-aluminium silicates of the migrating phase has resulted in the formation of barren quartz-feldspar veins outside the pegmatites, or perhaps that the rare elements of the migrating phase were dissolved as sodium complexes so that sodium minerals were separated simultaneously with the rare minerals. This way of interpretation explains that the composition of the pegmatites generally depends on the composition of the country rocks. It also explains that the primary minerals of many granite pegmatites have been crushed before the replacement processes took place, a feature which is in strong disagreement with a formation of the replacement bodies in a closed pegmatite system.

The Ross-Adams uranium ore in Alaska (MACKEVETT, 1958) may be a granitic equivalent to the steenstrupine veins of Ilímaussaq.

The Ross-Adams alkali granite is abnormally enriched in U, Th and rare earths. Accessories in the granite are uranothorite, zircon, pyrite, fluorite and magnetite. These minerals also occur in pegmatites. In a restricted area in the granite there are numerous veinlets containing uranothorite, uranothorianite, coffinite, hematite, calcite, fluorite, pyrite, galena, quartz and chlorite. Potassium is lacking in these veinlets. The granite between the veinlets contains disseminated uranium- and thorium minerals. Similar features may be expected in the pyrochlore- and columbite-bearing granites of Nigeria and Uganda.

The Alkali-Aluminium Silicates.

The light coloured minerals of the rocks studied in this paper are listed in the table below:

		SiO_2	Al_2O_3	Na_2O	K_2O	H_2O	Cl
nepheline....	$(Na,K)\ AlSiO_4$	42	36	16	6	–	–
sodalite	$Na_8Cl_2\ (AlSiO_4)_6$	37	32	26	–	–	7
albite	$NaAlSi_3O_8$	69	19	12	–	–	–
microcline ...	$KAlSi_3O_8$	65	18	–	17	–	–
analcime	$NaAlSi_2O_6.H_2O$	55	23	14	–	8	–
natrolite	$Na_2Al_2Si_3O_{10}.2H_2O$	47	27	16	–	10	–
ussingite	$Na_2AlSi_3O_8\ (OH)$	60	17	20	–	3	–

The chemical compositions given in the table are calculated from the formulae, except in the case of the nepheline where the determinations of p. 227 are used. With the exception of nepheline all the other light coloured minerals of the rocks studied here are very pure Na- or K-silicates. A very pronounced fractionation of the alkalies has thus taken place.

Nepheline in lujavrite and naujaite.

Only the nepheline of the naujaite and naujaite pegmatites has been examined and it is clearly of direct magmatic origin. The nepheline of the lujavrite appears in some rocks to be derived from assimilated naujaite, but in most cases it probably separated directly from the magma. The nepheline found in some of the analcime-natrolite veins is most probably derived from the adjoining naujaite.

According to SAND et al. (1957) nepheline is formed at temperatures higher than 460°C at a water pressure of ca. 1000 atm. According to WYART and CHRISTOPHE-MICHEL LÉVY (1955) nepheline, in strongly alkaline liquids, is replaced by hydrosodalite, hydrocancrinite and other minerals at temperatures of 400–600°C.

Feldspars in lujavrite and naujaite.

The feldspar of the naujaite (and kakortokite) is, according to USSING (1911), generally developed as a perthite. In the naujaites examined in the present paper no perthites have been observed and albite is only exceptionally found. Analcime and natrolite are, however, often present. These naujaites are of a rather bleached appearance and the samples described here all come from inclusions of naujaite in lujavrite. As long as it is not known whether the perthites found elsewhere in the naujaite are exsolution features, a primary structure as suggested by USSING, or a result of late albitization, the lack of perthites in the naujaites studied may be explained in at least two ways: 1. The samples examined were collected in the "breccia zone" that is in the lowermost part of the naujaite mass of Ilímaussaq. It might then be suggested that the feldspar of these lower naujaites was originally non-perthitic and that there was a transition to the feldspars of the lujavrite (see below). 2. The naujaite samples were collected in inclusions in lujavrite. If the feldspar of these inclusions was originally perthitic, a recrystallization has apparently taken place in connection with the *mise en place* of the lujavrite. The sodium released may have contributed to the late sodium-"metasomatism".

Perthites are never developed in the feldspars of the lujavrites as emphasized by USSING (1911). Albite and microcline appear to have been formed in mutual equilibrium, but the proportion of the two minerals vary considerably from place to place: from microcline rocks free from albite to albite rocks free from microcline. No regularity in the distribution of the two feldspars has been established so far. In many cases, but far from always, the albite-free rocks have interstitial analcime between the microcline laths and it may be suggested that the albite here has been substituted by analcime.

As mentioned in the mineralogical chapter the albite and microcline of the rocks examined are of low temperature type with a pronounced resemblance to authigenic feldspars. This speaks in favour of a low temperature of crystallization.

WYART and SABATIER (1956 a) found that albite and orthoclase can only co-exist as microperthite in equilibrium with solutions with a Na/K ratio of about 6. If this ratio were higher or lower, albite or microcline were formed. ORVILLE (1959, p. 118) found in the system albite-orthoclase-alkali halides, at 600°C and 2000 bars (i. e., below the feldspar solvus), that at the albite and orthoclase ends one feldspar was formed in equilibrium with liquid. From intermediate compositions two feldspars were formed in equilibrium with a liquid of fixed composition (0.236 mole per cent K/(Na+K)). At lower temperature the liquid became progressively poorer in K and correspondingly richer in Na, at 400°C the ratio was 0.163. No analcime or other minerals were formed down to 400°C. These experiments may explain that some lujavrites contain two feldspars, others only one, namely by assuming variations in magma composition or in temperature of crystallization. At a certain temperature a liquid of a fixed Na/K-ratio will occur in equilibrium with the feldspars so that differences in the original composition are counterbalanced by the proportion of the two feldspars.

FERGUSON (1960) has indicated that at low temperature and a surplus of Na^+, a maximum microcline is formed together with low albite, whereas orthoclase is formed when Na^+ is low.

All these observations indicate that the crystallization of the lujavrite took place at a very low temperature. The feldspars of the lujavrite have not been analyzed but correspond so closely in optical properties to the ones studied chemically and by X-ray methods that they may well be very near the pure end members. Their temperature of formation should then, according to BARTH (1956), be around 400° or perhaps as low as 300° C (see p. 225).

Analcime in lujavrite and naujaite.

Most samples of naujaite and lujavrite examined contain some analcime.

POVARENNYKH (1954) distinguishes autohydrolytic zeolitization in the last stages of magma crystallization and post magmatic hydrothermal zeolitization. According to CHAYES (1950) late magmatic minerals may be distinguished from post magmatic ones by means of statistical methods. The late magmatic processes take place while the residuum is distributed, in a homogeneous way, in the partly crystallized magma and the amount of reaction products should then be approximately proportional to the amount of primary minerals. In the case of post magmatic processes the amount of reaction products depends on local features and the time of reaction and it should therefore vary from place to place. However, the residuum may, in the late stages of crystallization, be concentrated in restricted parts of the magma chamber.

The analcime of the naujaite is distributed in a rather irregular way and is most common adjacent to the late veins. The analcime in the inclusions of green lujavrite in black lujavrite is also distributed in an irregular way. The analcime of the late veins has a patchy distribution. In the individual specimens of lujavrite the analcime is distributed in a very regular way, all transitions being found from rocks with thin interstitial films between nepheline, feldspars, etc. to rocks in which the dark minerals are enclosed in a matrix of analcime which may be very coarse-grained. In some lujavrites all traces of albite have disappeared, instead analcime occupies the spaces between the nepheline, microcline, etc. and may occur in lath-shaped areas.

These features are in best agreement with the view that the analcime of the lujavrite is late magmatic, whereas in the naujaite and green lujavrites, it is post magmatic. In the "dense" analcime rocks the analcime may either have been formed by complete recrystallization of zones of crushing in the naujaite or by magmatic immiscibility processes in connection with the emplacement of the lujavrite, as it has been discussed on earlier pages. The patchy distribution of the analcime in some of the "dense" rocks favours the first-named view, but does not exclude the last-named since these rocks in any case are older than the final consolidation of the lujavrite.

The origin of the analcime of the lujavrites may be explained in at least three ways or by a combination of these:

i. In the areas studied by the writer analcime occurs especially in the thin lujavrite veins and in lujavrites adjacent to naujaite. The lujavrite magma might then have been modified by an assimilation of naujaitic material. In this connection it is worth mentioning that the mobilized naujaitic material has given rise to analcime veins. The "dense" analcime rock may, according to this explanation, be interpreted as an intermediate stage between naujaite and lujavrite.

ii. In the late stages of crystallization a high content of water in combination with a sufficiently low temperature (see further below) may have allowed the substitution of albite by analcime. This is in agreement with the observation that analcime in some lujavrites partially replaces the albite, whereas the microcline is unaltered. In later stages microcline and nepheline may also be replaced by the analcime. As mentioned above, Orville has demonstrated that the liquid in equilibrium with two feldspars becomes progressively richer in Na with decreasing temperature. If, at the same time, there is an increase in water pressure, one may well explain that the primary minerals are replaced by the analcime. This explanation is also in agreement with the development of analcime in lujavrite veins and in lujavrite adjacent to naujaite. The veins are formed in thin fractures in naujaite where a concentration of water and other volatiles may easily occur and the concentration in the marginal areas may be due to a slightly lower temperature there (cf. Barth, 1952 and Kennedy, 1955). The concentration of analcime in the lujavrite adjacent to recrystallized inclusions of naujaite may be explained in a similar way, an alkali-rich water phase having migrated towards the cold xenoliths in order to re-establish equilibrium in the magma. According to this explanation the lujavrite magma has, at least locally, been water-saturated.

iii. The analcitization may be deuteric being caused by late fluids migrating through the meshwork of crystals of earlier formation.

All three types of processes have, in the opinion of the writer, contributed to the analcitization of the lujavrite. In connection with the crystallization of the analcime there was also a crystallization of needles and prisms of arfvedsonite which are often arranged in star-shaped groups. Such groups also occur in the black border zones of the lujavrite which, accordingly, are most probably of the same age. The prisms of arfvedsonite growing on inclusions in the lujavrite and along the borders of the veins of that rock may then be compared with the prisms of amphibole or pyroxene growing on xenoliths in gabbro and other basic rocks. This means that there also has been a diffusion of iron towards the walls on the cooler rocks.

Apart from some late veins of albitite and analcime-natrolite, no traces of formations post magmatic in proportion to the lujavrite have been observed in the areas studied by the writer, but such phenomenae occur elsewhere in Ilímaussaq.

If the analcime crystallized during the latest stages of the lujavrite formation it is rather unlikely that resurgent boiling took place since the vapour pressure is then relieved by changes in the relative proportion of crystals, liquid and vapour (cf. YODER, 1958).

The stability relations of albite and analcime are fairly well known from experimental work.

Albite is, according to SAND et al. (1957), formed at temperatures higher than 290°C at ca. 1000 atm. water pressure. According to MOREY and INGERSON (1937) it is formed most readily by hydrothermal synthesis if there is more SiO_2 than required by the formula of albite. At lower temperatures analcime is formed from mixtures of albitic composition. COOMBS et al. (1959) found that analcime is stable up to 570°C at 2000 bars water pressure in the absence of free silica. Analcime has a great nucleation energy and is formed readily in the experiments. It may grow metastably in the stability field of albite. The temperature of alteration of analcime into albite increases with increasing pressure. Analcime and albite may co-exist at low temperatures (SAND et al., op. cit.). MOREY and CHEN (1955) found that at 350°C and about 300 atm. albite and potash feldspar are dissolved stoichiometrically in water and that some analcime is formed at the expense of the albite.

These data indicate that the substitution of albite by analcime in the late stages of crystallization of the lujavrite may be a result of a decrease in temperature, an increase in partial water pressure, or a combination of these two factors. The chemical composition also plays an important role.

A late magmatic crystallization of analcime has been described from a number of occurrences of basic alkaline lavas and shallow intrusions, e. g. teschenite sills. Silica-poor zeolites are formed in these rocks. Analcime often forms the matrix and is considered to be of direct magmatic formation. Evidence of a high water content of these magmas is the presence of zeolite-rich pegmatoids (see for instance SHAND, 1949 and TURNER and VERHOOGEN, 1960). A few examples will be mentioned here.

TILLEY (1958) suggested that icositetrahedrons of analcime in lujavrites from Ilímaussaq described by USSING (1911) may be primary components of the rock.

WILKINSON (1958) considered the analcime of a teschenite sill of Tasmania to have been formed over a range of conditions. First analcime crystallized in the interstitial areas of the other minerals. The analcime encloses grains of apatite, biotite, iron ore and analcitized feldspar. Then the feldspars were replaced along cracks and, finally, a formation of analcime took place in veins and in vugs. The analcime is thus magmatic, deuteric, and perhaps post magmatic.

In tinguaites from Toror Hills, Uganda (HYTÖNEN, 1959) the groundmass may be composed of analcime and/or natrolite. The feldspars of these rocks are alkali feldspar, $Or_{88}Ab_{12}$ and low albite $Ab_{95}An_5$, that is, feldspars corresponding closely to those of the lujavrite in respect to composition. The cores of the alkali feldspar grains may be replaced by natrolite, the margins of the grains being unaltered. The natrolite-bearing rocks have no nepheline in the groundmass, whereas analcime and nepheline may co-exist. The analcime and natrolite are considered by HYTÖNEN to be formed by magmatic or at least deuteric crystallization.

It may also be of some interest to note that analcime may be formed as an authigenic mineral in sediments. A prominent example is the Green River formation in the United States (see for instance MILTON et al., 1960). Here a series of sediments, in part of saline type, has been subjected to a Na-H-CO_3-"metasomatism" during which a number of minerals, such as carbonates, analcime, albite, acmite, magnesian riebeckite, sodium boron silicates, leucosphenite, quartz, fluor-apatite and others were formed. Quartz and analcime may have been formed in equilibrium.

These few examples also support the view that a part of the analcime of the lujavrite may be of direct magmatic crystallization, whereas another part may have been formed by replacement of the primary light coloured minerals in a late stage when the concentration of sodium and water in the magma was very high, or in a slightly later stage when deuteric fluids penetrated the meshwork of crystals in the partly crystallized magma.

The analcime of the naujaite and of the green lujavrite enclosed in black lujavrite is clearly post magmatic in respect to these rocks. The analcitization is very probably caused by fluids expelled from the crystallizing lujavrite.

The coarse grain size of the analcime in many lujavrites and late veins may be due to a very rapid growth of this mineral, possibly from a gel-like interstitial phase.

Natrolite in lujavrite and naujaite.

Natrolite in some lujavrites may occur in a way recalling the late and secondary analcime. In the naujaite it has a rather patchy distribution. It often forms fine-grained aggregates around the nepheline grains of naujaite and lujavrite. Fracture fillings of fine-grained natrolite occur in these rocks and a part of the natrolite may therefore be of post magmatic hydrothermal origin. However, the mode of occurrence of the natrolite indicates that in many rocks it is formed in the same way as the analcime, perhaps a little later than that mineral. A part of the natrolite is therefore very probably late magmatic.

Natrolite has not been synthesized. It disintegrates at 290°C at ca. 1000 atm. (SAND et al., 1957). KAIZUMI and KIRIYAMA (1957) have undertaken hydrothermal heating of amorphous, dehydrated natrolite powder. Natrolite was formed below 200°C; above 250°C analcime was obtained. At Plombières thermal water at a temperature of 70°C precipitates natrolite, chalcedony and other minerals.

These few data indicate that natrolite crystallized at a rather low temperature, most probably lower than the temperature of formation of analcime.

The light coloured minerals of the late veins.

The light coloured minerals of the thin veins and of the replacement bodies of the naujaite pegmatites will be treated together.

In the green veins **microcline** is the first light coloured mineral to be formed. It may be succeeded and substituted by one or all of the minerals albite, analcime, natrolite, and in rare cases also by ussingite.

In the replacement bodies of the naujaite pegmatites and in the remaining types of thin veins there may be scattered grains of microcline. They may be large as the grains of the naujaite and its pegmatites, or small lath-shaped of the type found in the green veins and in the lujavrites. The microcline grains have the appearance of inclusions in the albite, analcime and natrolite and they are most probably remnants of naujaitic microcline, but there may, occasionally, have been an early formation of microcline, as in the green veins.

The green veins are apparently older than the lujavrite; the other vein types are contemporaneous with or slightly younger than that rock.

The relationship between **albite** and **analcime** in the veins is probably comparable to that in the lujavrite. The albite is thus formed at higher temperature, more dry conditions and low pressure; the analcime at lower temperature and a higher water pressure. Besides the amount of silica present may have played a role, analcime being formed in a silica-poor environment, perhaps at alkaline conditions. **Natrolite** may then have been formed at still lower temperatures and more alkaline conditions.

The yellow sodalite (hackmanite) is often associated with analcime and natrolite and is probably formed at similar conditions when S and Cl occur.

Ussingite occurs, in addition to the veins, also in lujavrites. In the lujavrite of Tuperssuatsiaq described in an earlier paper (Buchwald and Sørensen, 1961, p. 16) ussingite replaces microcline. In some of the lujavrites described in the present paper ussingite clearly replaces that mineral. At Tugtup agtakôrfia ussingite occurs in the white rims around nodules in the lujavrite. This ussingite is clearly secondary after microcline and is associated with analcime and natrolite. Ussingite-bearing off-shoots from these white rims penetrate the enclosing albite-rich lujavrite. The relation between ussingite and albite in the lujavrites is uncertain. No certain cases of one replacing the other have been noted and where the two minerals are closely associated the ussingite may have replaced pre-existing microcline.

In the veins ussingite replaces microcline and sodalite and is apparently later than the albite, although, as mentioned on p. 173, this question is not quite clearly solved.

Ussingite may in chemical respect be termed a NaOH-bearing albite. Its specific gravity is slightly lower than that of albite, 2.46–2.49 against 2.5–2.6. The water content combined with the lower density may indicate that the ussingite is stable at slightly lower temperature than the albite. Ussingite differs from analcime and natrolite in higher contents of SiO_2 and Na_2O and lower Al_2O_3 and H_2O. It may therefore be suggested that ussingite is formed in slightly alkaline solutions at rather low temperatures and water pressures. At higher water pressures and a higher alkalinity analcime and/or natrolite would be formed. Ussingite may, as demonstrated by Bondam and Ferguson (1962), contain vugs of villiaumite.

Microcline is apparently unstable in all veins except those containing ægirine felt. The lack of microcline in the veins rich in albite, analcime and natrolite may be a result of the high concentration of sodium in the fluids responsible for the formation of these veins.

As demonstrated by Wyart and Sabatier (1956 b) potash feldspar is easily transformed into albite by NaCl-solutions in experiments carried out in an autoclave (just as albite is transformed by KCl into adularia or microcline). According to Morey (1957), KCl is more soluble than NaCl in supercritical fluids. On the basis of these experiments it may be suggested that the microcline of the green veins, which is older than the albite, analcime and natrolite, is formed at the expense of K released at deeper levels in connection with the interaction of sodium-rich fluids and the pre-existing rocks. This is in agreement with the results of experiments carried out by Orville (1960, p. 107) according to which K moves to the low temperature and Na to the high temperature part of a rock mass, if the alkali ions are free to migrate between these parts via a vapour phase. "The result will be continued replacement of K-rich feldspar by Na-rich feldspar at the higher temperature and replacement of Na-rich feldspar by K-rich feldspar at the lower temperature". An increase in pressure, according to these experiments, shifts the ion-exchange equilibrium in the same direction as a decrease in temperature. In this connection it should be mentioned that AMES (1958) has demonstrated, by means of fluid inclusions in the minerals of a pegmatite at Portales, New Mexico, that there is a progressive enrichment in K in proportion to Na with decreasing temperature.

These features should be compared with the zonal distribution observed at Wairakei, New Zealand (cf. COOMBS, et al., 1959) where thermal NaCl-water penetrates rhyolitic rocks. The ascending water is rich in silica which is precipitated at all levels. Near the surface there is an acid zone of leaching, with increasing depth succeeding zones of zeolites, albite and adularia are developed. At the deepest levels examined sericite replaces the primary feldspars and there is a leaching of alkalies. Albite is especially precipitated from $NaHCO_3$-water, adularia from more alkaline NaCl-water. That K is precipitated at deeper levels than Na is most probably a result of the chemical composition of the solutions and the country rocks which may be so different from those of Ilímaussaq that the inverse order of separation may be explained. According to COOMBS (1960) the zeolites of Wairakei co-exist with water so rich in CO_2 that it is weakly acid in relation to pure water at the same temperature. Obsidian has been recrystallized into zeolites in this water.

The formation of microcline in the green veins may be influenced by the acidity-alkalinity of the fluids. HEMLEY (1959) has formed potash feldspar hydrothermally in weakly acid liquid and found, that with increasing temperature, the liquid should be more acid in order to form potash feldspar (see, however, p. 187).

Acidity-alkalinity.

It is difficult to estimate **the acidity-alkalinity** of the fluids in question. As stated by BARNES and ERNST (1960, p. 63) and by FRANCK (1956) the ionization of the inorganic solutions studied experimentally decreases, with the single exception of pure water, with increasing temperature near or above the critical point of water. The decrease of ionization of acids is greater than that of bases. In addition the increased ionization of water with increasing temperature will favour the hydrolysis of salts. Thus hydrolysis of NaCl and KCl at high temperature may make solutions of these salts weakly alkaline which can explain the ready mobility of silica in nature. For these reasons HCl may be a very weak acid at high temperatures.

As stated by FRANCK (op. cit., p. 192): "KCl ist bei Lösungsdichten unter 0.7 g/cm^3 nur ein mittelstarker oder sogar schwacher Elektrolyt ..... Man kann vermuten dass ein Teil des Chlorid unter diesen Bedingungen hydrolysiert".

As stated by WHITE (1957) thermal waters are often rich in NaCl. HCl is scarce and occurs only near the surface. The NaCl waters are weakly acid to alkaline when examined at room temperature. The NaCl is considered by WHITE to be of magmatic origin and is not a result of leaching of the country rocks. At high pressure and temperature below the critical temperature of the fluids one phase is present; at lower pressure a liquid phase and a vapour phase co-exist, the latter being richest in the volatile components.

It is commonly found that liquid inclusions in minerals of pegmatites and ore veins are saturated with alkali halides to the extent that crystals of NaCl and NaF may be precipitated. According to SMITH (1954) there are also CO_2-rich and siliceous fluid inclusions. The enclosed fluids have higher densities than the critical density of water and are assumed to have had high solvent properties.

Fluorine is scarce in thermal waters. This is probably a result of hydrolysis of NaF at high temperatures (cf. FYFE, et al. 1958, p. 144) releasing HF which reacts with the country rocks at lower temperature. However, gases given off by cooling lavas may be rich in HF as demonstrated by NABOKO (1957) and by the well known features observed in Valley of the Ten Thousand Smokes.

NaCl-waters have, according to the examination of thermal waters and of fluid inclusions in pegmatite and ore minerals, been of great importance in the formation of pegmatites and ore veins. The original chlorine has disappeared entirely from these systems during the crystallization of the minerals. In Ilímaussaq chlorine is an important component of sodalite and eudialyte and is released during the disintegration of these minerals. It is therefore reasonable to assume that the fluids responsible for the formation of the late veins have contained NaCl. The presence of late villiaumite also indicates that NaF has contributed to these fluids. In addition, alkali silicates are, at high temperature, more soluble in aqueous liquids than the other rock-forming minerals, the solubility decreasing with decreasing pressure. Water-rich fluids at high temperature and pressure may therefore have dissolved alkalies at deep levels and deposited the dissolved material at higher levels when the pressure is relieved.

KORZHINSKY (1956 and 1959) has suggested that magmatic solutions are neutral or weakly alkaline at high temperature. At lower temperatures they become acid because of the condensation of the volatile phase and because of oxidation and reactions. When these acid solutions react with the country rocks weak bases replace the stronger ones, for instance Na replaces K during albitization. At still lower temperatures the solutions again become alkaline. This hypothesis may suggest that, in the thin veins of Ilímaussaq, there is primarily a formation of microcline at neutral or weakly alkaline conditions. This is in disagreement with the above-mentioned experiments of HEMLEY (1959), but it should be pointed out, as it has been done by BARNES and ERNST (1960, p. 67), that HCl is relatively weakly ionized at the high temperatures of these experiments so that the experimental conditions were not so strongly acidic as was formerly assumed. Many authors, for instance KORZHINSKY, consider potash feldspar to be formed under alkaline conditions.

The first alkaline or neutral stage may then have been succeeded by an acid stage during which the albitization took place. In the concluding alkaline stage analcime and natrolite were formed. They are poorer in SiO_2 than the albite which is in excellent agreement with the common observation of the high solubility of silica in alkaline solutions.

CO_2 may have a considerable influence on the development of pegmatites and ore veins, but the activity of that component in Ilímaussaq must have been very low since carbonates are practically lacking. However, carbonates are more prominent in the veins around Ilímaussaq. The lack of carbonates may be due to the poverty in Ca and Mg in the alkaline rocks of Ilímaussaq, but siderite and rhodochrosite should, if CO_2 was of any importance, have been formed, at least locally. BEUS (1958) has demonstrated that fluid inclusions in the first formed beryl crystals in a pegmatite contain $F^{\div}$, $Cl^{\div}$ and crystals of alkali halides, whereas inclusions in the last-formed crystals are rich in CO_2. This may indicate that halides play the most important role in the early stages, and that the importance of CO_2 increases with decreasing temperature and time. This may be caused by the low solubility of Na_2CO_3 at temperatures around the critical temperature of water and by the observation that "the salts of weaker acids, such as carbonates and sulphides, probably suffer less from hydrolysis than the halides and sulphates". (FYFE, et al., 1958, pp. 138 and 145). It is also possible that CO_2 and H_2S, which may have been insoluble in the magma, have been released earlier than the more soluble gases rich in alkali halides. The latter are therefore concentrated within and the former around the massif (cf. KRAUSKOPF (1948)). The presence of sulphur in the vein-forming fluids is proved by the occurrence of hackmanite and sphalerite.

It may then be concluded that the veins were formed from fluids rich in sodium, chlorine and fluorine. These fluids were most probably alkaline. The albite may, as mentioned above, have been formed under weakly acid conditions, otherwise minerals such as gibbsite, pyrophyllite, kaolinite and diaspore, indicating a more acid environment, are lacking (see however p. 229).

The physical state of the late fluids should be briefly discussed. The feldspars of the lujavrite indicate that the consolidation of that rock took place around 400° C or at lower temperatures, that is, parts of the fluids were expelled at temperatures above the critical temperature of pure water. Now, solutions containing alkali halides and alkali silicates do not show a critical end point, that is, the salt shows an increasing solubility through the critical point of the solvent. Concentrated solutions may therefore not show critical phenomenae (cf. Fyfe, et al., 1958, p. 138).

The upper part of the Ilímaussaq massif is in contact with volcanic surface rocks which probably belong to the period of igneous activity responsible for the formation of the alkaline rocks of Ilímaussaq (Ussing, 1911, p. 306). It may therefore be concluded that these rocks consolidated at a depth of few kilometres. At a depth of 6–7 kilometres the load pressure will be around 2000 atm., besides, the vapour pressure of the magma has been considerable, even if the salinity of the solution depresses the latter. It is therefore reasonable to assume that the consolidation of the lujavrite took place at a pressure of a few thousand atmospheres. According to Turner and Verhoogen (1960, p. 405) the density of water "vapour" at 400° C and 2000 bars is 0.75 g/cm³. The fluids expelled from the crystallizing lujavrite have therefore been very dense with very pronounced solvent properties. At these high pressures only a liquid phase exists below the critical point. With decreasing pressure a vapour phase is formed in equilibrium with the liquid phase and the dissolved material is distributed between the two phases so that the most volatile compounds are concentrated in the vapour phase. At temperatures around 400° C the vapour phase contains an appreciable concentration of sodium chloride (cf. Fyfe, et al., 1958, p. 138).

A possible mechanism of precipitation of the light coloured minerals of the veins is then, that albite and analcime and their associated rare minerals (see below) were precipitated as a result of decreasing solubility in connection with a decrease in pressure. Some of the albite, ussingite and perhaps natrolite of the veins may have been precipitated from a liquid formed by partial condensation of the vapour phase. The halides, sulphur and CO_2 have been partly or entirely removed from the system in the vapour phase. It should also be pointed out that the solubility of Na_2CO_3 increases with decreasing temperature (Fyfe, et al., op. cit., p. 138).

The fact that albite, and not analcime or natrolite, occurs in the veins around Ilímaussaq may be due to a lower partial water pressure in these places. However, the number of specimens examined from these veins is too small to permit a conclusive discussion of this problem.

The Ægirine/Acmite and Arfvedsonite.

Oxidation-Reduction Processes.

The soda pyroxenes and arfvedsonite co-exist in some of the rocks studied in this paper, in others they appear to substitute each other.

In the naujaites of the areas examined ægirine is predominant; arfvedsonite, when present, may be slightly later than the ægirine, having inclusions of that mineral. Ægirine, as well as arfvedsonite, are replaced by acmite.

In the naujaite pegmatites arfvedsonite appears to be earlier than ægirine, the latter mineral being especially present in the coarse-grained ægirine patches.

The lujavrites studied are rich in arfvedsonite. Acmite and ægirine, when present, are mainly confined to patches which appear to be enclosed in the arfvedsonite rock. The rims of the nodules mentioned on p. 152 are also rich in acmite. In the late stages of analcime crystallization in the lujavrite, arfvedsonite is formed, often as groups of radiating needles and prisms. There is often a black border zone rich in arfvedsonite (and acmite) between lujavrite and naujaite.

The ægirine of some green veins is partially substituted by arfvedsonite during a type of "lujavritization".

In the brown veins, relations are less clear. A part of the acmite of these veins is formed by crushing of acmitized ægirine and arfvedsonite(?) of the adjacent naujaite. In places this acmite may be substituted by arfvedsonite which may then be the latest formed mafic mineral. In other places the arfvedsonite is partially replaced by fibrous acmite and biotite. Locally, ægirine is a late constituent of these veins (see p. 120).

In the green, black and multiple veins of Qeqertaussaq, arfvedsonite is never replaced by acmite.

The veins at the head of Kangerdluarssuk have ægirine substituted by arfvedsonite in many cases. Streaks composed of ægirine/acmite and arfvedsonite may have been formed by out-rolling of acmitized arfvedsonite, but some of the arfvedsonite may have grown at the expense of the pyroxenes.

In the albite-bearing veins at Igdlúnguaq and Tugtup agtakôrfia, arfvedsonite is always replaced by acmite.

The age relation of pyroxene and arfvedsonite has been determined by petrographical methods and is therefore in many cases rather uncertain. The borders between the two minerals are often highly irregular so that "thin section effects" may be the cause of the common existence of inclusions of the two minerals in each other. Rims of one mineral on the other may be due to a later formation of the rims, but also to a replacement of the core so that the opposite age relation is obtained. Inclusions of one mineral in the other may also be due to a simultaneous growth of the two minerals so that the one with the slowest growth rate is enclosed in the one having the fastest growth.

The aggregates of acmite often have interstitial grains of arfvedsonite which appear to penetrate the acmite along the grain boundaries and along cleavages. The arfvedsonite should then be the last-formed mineral. But many definite cases of acmite replacing arfvedsonite exist in which the large grains of arfvedsonite are pseudomorphed by aggregates of rather irregular acmite grains with interstitial arfvedsonite. The arfvedsonite here, however, does not penetrate the acmite cleavages.

Cases of fibrous acmite occurring along the margins, cracks and cleavages of arfvedsonite grains are the most unambiguous evidence of a later formation of acmite than of arfvedsonite.

Even if the age relation between pyroxenes and arfvedsonite is ambiguous in many cases a few general conclusions may be drawn. Most evidence is in favour of the view that the ægirine/acmite is slightly earlier than or simultaneous with the *mise en place* of the black lujavrite. The late stage of analcitization of the lujavrite was accompanied by a crystallization of arfvedsonite. In a succeeding stage there was a local formation of acmite.

As mentioned in the mineralogical chapter, USSING (1894) interpreted the acmitization of the arfvedsonite as a result of oxidation processes. The brown mica associated with the acmite may then be formed at the expense of the small amount of magnesium in the arfvedsonite.

BRØGGER (1890) described the replacement of barkevikite by ægirine and lepidomelane (*pterolite*). Similar features have been described by BURRI (1928) from Alter Pedroso, Portugal, where the soda amphibole osannite is surrounded by ægirine. This ægirine encloses protoclastic feldspar and is thus later than the deformation.

In Lovozero arfvedsonite is generally later than ægirine II, and arfvedsonite pseudomorphs after ægirine are common. In the pegmatites arfvedsonite is formed earlier than the ægirine II.

STRAUSS and TRUTER (1950) have described, from Spitzkop, the replacement of ægirine augite by soda amphibole so that only the outer rims of green pyroxene are left. In the Manitou Island Complex, soda pyroxene is replaced totally by soda hornblende (ROWE, 1958).

YAGI (1953) has from Sakhalin described sheets, etc. of dolerite with monzonitic and syenitic differentiates. During this evolution the diopsidic augite is substituted by Ti-augite and ægirine augite. As the magma becomes enriched in water, arfvedsonite substitutes the ægirine augite. In a still later stage with a high concentration of sodium, ægirine replaces the arfvedsonite.

CHRISTOPHE-MICHEL LÉVY (1954) and WYART (1954) have produced ægirine hydrothermally in the temperature interval 250–500° C. At 450° C ægirine is formed when the mixture contains more than 6 % Na, at 400° C only 3 % Na is needed. Ægirine was not formed below 200–250° C.

ERNST (1959) has demonstrated experimentally that at high partial oxygen pressures and low temperatures blue riebeckite ($Na_2Fe^2{}_3Fe^3{}_2Si_8O_{22}(OH)_2$) is formed; at lower P_{O_2} and higher temperature, quartz and green amphibole occur. The green amphibole is believed to be a mixture of riebeckite and arfvedsonite. The riebeckite and arfvedsonite are, at increasing partial oxygen pressure, substituted by acmite: the higher oxygen pressure, the lower temperature of transformation of amphibole into acmite. As an example, the Quincy granite, Mass. is mentioned. The granite contains arfvedsonite and magnetite, the late pegmatites riebeckite and hematite, that is, "ferrous iron probably maintained P_{O_2} at a moderate low value; in the highly aqueous pegmatite stage the predominance of H_2O over iron oxide would tend to elevate partial oxygen pressure" (op. cit., p. 123).

The role of oxygen in plutonic petrology has been discussed recently by OSBORN (1959), MUELLER (1960), and EUGSTER (1957). Oxidation processes go on most readily in water-rich environments. Changes in the partial oxygen pressure are generally caused by large volumes of a water phase introducing H_2, $H_2O + H_2$, or $H_2O + O_2$. The composition of the water phase determines whether oxidation or reduction take place (EUGSTER, op. cit., p. 424).

Ægirine-acmite and arfvedsonite are connected by equations of the following type:

$$\underset{\text{(acmite)}}{5\,NaFe^3Si_2O_6} + H_2O = \underset{\text{(arfvedsonite)}}{Na_3Fe^2{}_4Fe^3Si_8O_{22}(OH)_2} + Na_2O + 2\,SiO_2 + O_2$$

$$5\,NaFe^3Si_2O_6 + 2\,H_2 = Na_3Fe^2{}_4Fe^3Si_8O_{22}(OH)_2 + Na_2O + 2\,SiO_2 + H_2O$$

It should be remembered that the ægirine contains a slight amount of Fe^{2+} and that the ratio Fe^{2+}/Fe^{3+} of the arfvedsonite may vary.

Chemical analyses of arfvedsonite and ægirine/acmite

	Arfvedsonite Narssârssuk. BØGGILD (1953, p. 293)	Arfvedsonite Nunarssuatsiaq. BØGGILD (1953, p. 293)	Acmite no. 21070, Brown lujavrite North coast of Tunugdliarfik. Anal. Me MOURITZEN	Ægirine no. 18453, Ægirine felt in pegmatite, South coast of Qeqertaussaq. Anal. B. I. BORGEN
SiO_2	43.52	49.11	53.07	52.12
TiO_2	1.73	0.78	0.39	0.70
ZrO_2	0.84	–	0.08	0.02
Al_2O_3	5.30	1.16	1.44	1.56
Fe_2O_3	11.12	9.23	31.92	30.34
FeO	22.39	25.50	0.10	1.17
MnO	1.13	1.13	0.37	0.19
MgO	1.09	0.18	0.09	0.07
CaO	2.21	0.77	0.23	0.31
Na_2O	7.39	8.01	12.24	13.30
K_2O	1.83	2.89	0.04	0.05
$H_2O\pm$	1.20	1.12	0.03	0.09
F_2	0.88	0.29	–	–
P_2O_5	–	–	tr.	0.01
	100.63	100.17	100.00	99.93
$-O=F_2$	0.37	0.12		
	100.26	100.05	100.00	99.93

The analyses of ægirine and acmite have kindly been placed at my disposal by OLE LARSEN who is now studying these minerals in Ilímaussaq.

The pair acmite-arfvedsonite may, just like hematite-magnetite in non-alkaline rocks, buffer the system so that a rather constant partial oxygen pressure is maintained. However, the formation of ægirine/acmite at the expense of arfvedsonite is, in addition to a rather high partial oxygen pressure, favoured by a high temperature and richness in SiO_2 and Na_2O and poverty in H_2O. A high partial water pressure favours the formation of arfvedsonite, but if it is combined with a high partial oxygen pressure the formation of acmite/ægirine is favoured. Acmite may thus substitute for arfvedsonite at a high temperature, rather dry conditions and a fairly low partial oxygen pressure; or at low temperature, rather wet conditions and a higher partial oxygen pressure. Besides the alkalinity plays a role.

It appears from this discussion that the relation between ægirine and arfvedsonite is determined by so many variables that it is very difficult to arrive at a definite conclusion regarding the conditions of formation of these minerals. However, a few tentative suggestions may be advanced.

In the arfvedsonite lujavrite the partial oxygen pressure must have been low, since soda pyroxenes and other minerals rich in Fe^{3+} are generally lacking. The analcime- and acmite-bearing rims around the nodules described on p. 152 may, as mentioned on earlier pages, be remnants of ægirine-bearing rocks enclosed in the black rock. The nodules may also have been formed from a water-rich phase immiscible with the lujavrite magma. The cores of the nodules contain arfvedsonite, whereas acmite predominates in the rims. The small patches of immiscible magma may then have had a higher partial oxygen pressure in their marginal parts than in the cores, or, because of a higher water content and more alkaline conditions, oxidation goes on more easily in the analcime-bearing white rims than in the enclosing albite-bearing lujavrite. The content of SiO_2 may also have played a role (see p. 153).

The ægirine and acmite of the thin late veins may have been formed at rather varying combinations of temperature, alkalinity and partial oxygen pressure. The association ægirine-microcline in the green veins may indicate weakly alkaline conditions, a rather high temperature and a rather high partial oxygen pressure. The association acmite-albite has been formed at a similar temperature, neutral or weakly acid conditions and a higher partial oxygen pressure. The association acmite-analcime may indicate a lower temperature, a higher alkalinity and a rather high partial oxygen pressure.

The arfvedsonite of the thin veins has most probably been formed at a lower temperature than the soda pyroxenes, and at alkaline conditions and a very low partial oxygen pressure. The association analcime-arfvedsonite is very widespread.

The natrolite of the thin veins is generally younger than the mafic minerals and it may therefore occur in contact with acmite as well as with ægirine and arfvedsonite.

The presence of ægirine and acmite as early constituents of the late veins may indicate that the first "emanations" expelled from the lujavrite magma were enriched in oxygen.

In the discussion above, only the partial oxygen pressure has been considered. It should, however, also be remembered that H_2 has a great influence on the redox conditions. The presence of some Fe^{3+} in all rocks examined indicates that the partial hydrogen pressure has not been very significant in the formation of the rocks considered here.

The lack of late acmite in the veins of Qeqertaussaq is rather easily explained, since these veins contain large amounts of astrophyllite, a mineral rich in FeO and MnO, indicating that the partial oxygen pressure was very low.

It is a well-known fact that Fe^{2+} is oxidized much more easily than Mn^{2+}. This is clearly seen in the rocks of Ilímaussaq where MnO-bearing minerals are widespread. Thus schizolite and neptunite are very common in the lujavrites and thin veins and they are associated with ægirine-acmite as well as with arfvedsonite. In cases the schizolite is replaced by a brownish black powder of manganese oxides, this is especially the case in strongly weathered samples. The schizolite of fresh samples is practically unaltered.

Eudialyte is richer in FeO than in Fe_2O_3. It is formed in equilibrium with ægirine in the naujaite and with arfvedsonite in the lujavrite. Eudialyte is altered in the strongly oxidized rocks and acmite-ægirine are often associated with the eudialyte pseudomorphs.

Cerium-bearing minerals are widespread in Ilímaussaq. Unfortunately the existing chemical data does not allow a discussion of the oxidation state of that element, but Ce^{3+} appears to be most prominent (monazite, britholite). The CeO_2 recorded in the old analyses of steenstrupine (see p. 230) should be regarded with some reservation.

The steenstrupine is of great interest when the redox processes are discussed. As described in a previous paper (BUCHWALD and SØRENSEN, 1961, p. 32), the anisotropic marginal zones of the steenstrupine crystals are generally less radioactive than the cores. The marginal zones have a stronger brown colour than the cores, most probably because of the oxidation of the iron. As suggested in the quoted paper there may, in the marginal parts of the crystals, have been an oxidation of Fe^{2+} and U^{4+}. The UO_2^{2+} formed in this way may have been removed by leaching which is in accordance with the common observation that the most fractured crystals and parts of crystals are most anisotropic. This oxidation and leaching hypothesis is supported by a number of observations made since the publication of the above-mentioned paper. The birefringent and weakly radioactive steenstrupine crystals are very commonly found in association with acmite/ægirine; adjacent arfvedsonite grains and inclusions of that mineral often having developed rims of acmite in contact with the steenstrupine. Metamict steenstrupine is, on the other hand, often found in contact with arfvedsonite and there may be arfvedsonite rims on adjacent acmite grains. These observations indicate that the marginal anisotropic zones may well have been formed by oxidation and leaching. It should be pointed out that there are many exceptions to the above-mentioned associations of steenstrupine with acmite and arfvedsonite. However, steenstrupine is often formed later than these minerals and, consequently, equilibrium cannot always be expected. In old analyses of steenstrupine (see the table p. 230) contents of CeO_2 and Mn_2O_3 are recorded indicating a very strong oxidation of the altered steenstrupine. The unaltered mineral contains Ce_2O_3 and MnO. In weathered specimens the steenstrupine may be replaced by a brownish black powder and in some samples of metamict steenstrupine there are small grains of thorianite which may have a certain content of Ce^{4+}. It is thus possible that CeO_2 and Mn_2O_3 really occur in the altered steenstrupine, but the author does not wish to discuss this point as long as no modern analyses of the mineral are available. The fact that steenstrupine generally is associated with unaltered schizolite and neptunite indicates that no strong oxidation of the Mn^{2+} of these minerals has taken place. At Tugtup agtakôrfia there is an incipient formation of brownish black alteration products in the schizolite associated with anisotropic steenstrupine.

It may then be concluded that the Fe^{2+} and U^{4+} of the steenstrupine are oxidized more easily than the Mn^{2+}. This is in agreement with the data published by GARRELS (1960).

As it will be apparent from the discussion above there are still many uncertainties in the interpretation of the oxidation-reduction processes in the rocks described in this paper. However, when more chemical data is available, it should be possible to study these processes in much more detail.

The Steenstrupine and Other Rare Minerals.

The alteration of the eudialyte: In the naujaite and lujavrite, eudialyte, often with "flames" of mesodialyte, is the most prominent rare metal mineral. It is most spectacularly developed in the naujaite pegmatites.

In the altered naujaite and lujavrite, eudialyte is, to varying extent, replaced by katapleite, neptunite, pigmentary material, monazite and other minerals. This is especially the case in rocks in which the feldspars, nepheline and sodalite are substituted by analcime and/or natrolite. There are, however, many cases cf unaltered eudialyte occurring in analcime rocks, as for instance, some lujavrites and the "dense" banded analcime rocks. The last-named rocks are, as discussed above, associated with the *mise en place* of the lujavrite.

Chemical analyses of Eudialyte, Mesodialyte, Eucolite, Katapleite and Lovozerite

	Eudialyte Kangerdluarssuk. BØGGILD (1953, p. 249)	Mesodialyte Lovozero. VLASOV, et al. (1959, p. 306)	Eucolite Khibina. KOSTYLEVA (1929)	Katapleite Narssârssuk BØGGILD (1953, p. 253)	Lovozerite Lovozero. VLASOV et al., (1959, p. 317)
SiO_2	49.62	49.95	48.22	44.70	52.12
TiO_2	–	0.90	0.27	–	1.02
ZrO_2	14.12	13.15	12.05	30.85	16.54
Al_2O_3	–	–	–	–	0.40
Nb_2O_5	–	0.93	–	–	–
$(Ce,La)_2O_3$	2.50	0.81	2.27	–	0.56
Y_2O_3	–	–	0.58	–	–
Fe_2O_3	–	0.90	–	–	0.72
FeO	7.16	2.78	5.33	–	–
MnO	1.34	1.75	3.00	–	3.46
MgO	–	0.22	0.32	–	0.76
(Ca,Sr,Ba) O	9.66	12.38	10.33	0.71	3.40
Na_2O	13.24	12.33	13.24	14.09	3.74
K_2O		0.84	0.51	–	1.90
H_2O	–	1.60	1.32	9.07	15.03
Cl_2	1.36	1.43	1.35	–	–
S	–	–	0.04	–	–
	99.00	99.97	98.83	99.42	99.65
$-O=Cl_2$	0.30	0.32	0.30		
	98.70	99.65	98.53	99.42	99.65

In the most zeolitized naujaite and lujavrite, in the replacement bodies of the naujaite pegmatites and in the late veins, eudialyte is entirely altered; instead pseudomorphs after eudialyte, and steenstrupine occur.

In the first stages of alteration of the eudialyte, katapleite is formed. The eudialyte contains about 14 $^0/_0$ ZrO_2, the katapleite about 30 $^0/_0$ (cf. the table p. 196). It thus appears as if the zirconium of the eudialyte is at first taken up by katapleite, which makes up a varying part of the eudialyte pseudomorphs. In some ussingite-bearing rocks lovozerite (with about 16 $^0/_0$ ZrO_2) is formed. Otherwise, secondary zirconium minerals are lacking. Neither the zircon mentioned by Ussing nor the elpidite mentioned by Bøggild have been observed. The amorphous mineral zirfesite, which replaces the eudialyte of Lovozero, may be present, but has not been identified. The minerals vlasovite and seidoserite described from Lovozero and giannetite and pennaite mentioned from Poços de Caldas have not been found.

In some green ægirine-microcline veins eucolite occurs, probably formed at the expense of naujaitic eudialyte (cf. p. 173). The eucolite is, according to the analytical evidence (the table p. 196), slightly poorer in zirconium than the eudialyte. A part of the zirconium released during this alteration may, in vein no. 4 at the head of Kangerdluarssuk, have been taken up by the lovozerite co-existing with the eucolite, but as mentioned on p. 173, the lovozerite may be later than that mineral.

Steenstrupine often occurs in association with eudialyte pseudomorphs and may even form rims on altered grains of eudialyte (and eucolite). According to Machatschki (1931) and spectrographic analyses carried out in connection with the present study, steenstrupine contains 1 $^0/_0$ Zr, or more. A part of the zirconium released during the break down of the eudialyte is thus fixed in the steenstrupine (and in ægirine and arfvedsonite). Steenstrupine and eudialyte are related crystallographically, but as emphasized by Lorenzen (1881) and Machatschki (1931), the steenstrupine cannot be regarded as a direct pseudomorph after eudialyte. In this connection it should also be mentioned that the optical axes of eudialyte and its rim of steenstrupine are approximately at right angles. The eudialyte is generally completely replaced by katapleite, etc. before the "steenstrupinization" takes place. The small, partly diluted fragments of eudialyte of these pseudomorphs may have served as nuclei for the crystallization of the steenstrupine. It is therefore not strange that many grains of steenstrupine grow in a crystal skeleton- or glomeroblast-like way. Some grains of steenstrupine have an internal aggregate structure recalling the structure of adjacent eudialyte pseudomorphs.

Even if a part of the zirconium of the eudialyte is held back by the steenstrupine, a considerable part must have been set free during the alteration (see p. 206).

In addition to the zirconium, eudialyte contains traces of Ti, Nb, rare earth metals, Th and U. The eudialyte pseudomorphs, therefore, are often accompanied by minerals such as monazite, britholite, pyrochlore, neptunite, and of course also steenstrupine.

Steenstrupine occurs in a number of rock types, namely lujavrite, replacement bodies in naujaite pegmatites, recrystallized naujaite and a number of thin veins. The naujaite and lujavrite adjacent to the latter may also contain steenstrupine.

Steenstrupine in lujavrite: In the lujavrites three types of steenstrupine may be distinguished:

i. As mentioned by BUCHWALD and SØRENSEN (1961, p. 16) there are in the lujavrites of Tuperssuatsiaq small crystals of steenstrupine in the aggregates of arfvedsonite which are interstitial to the laths of albite and microcline and to the crystals of nepheline and sodalite. Ussingite may partially replace the microcline, sodalite the nepheline and analcime may replace the albite. Unaltered eudialyte is not present but small pseudomorphs occur. There are also scattered grains of the "green mineral" mentioned on p. 222. Analcime and natrolite are scarce in most lujavrite samples examined from this locality. The steenstrupine of these rocks occurs either in small crystals with few inclusions, or also in larger, more irregular grains with inclusions of arfvedsonite and altered eudialyte.

Similar rocks, but richer in analcime, have also been found at Kvanefjeld (op. cit., p. 18) and in the mountain wall on the north coast of Tunugdliarfik.

The mode of occurrence of the steenstrupine crystals in these lujavrites indicates that the steenstrupine is a primary precipitate from the magma. The altered grains of eudialyte clearly show that there was first a crystallization of eudialyte and that this mineral was unstable in the later stages of crystallization. It is therefore reasonable to assume that the eudialyte is stable at higher temperature than the steenstrupine.

Two factors have most probably determined the late crystallization of steenstrupine in these analcime-poor lujavrites:

a. In the latest stages of crystallization of the lujavrite there was a sufficiently high content of P, Nb, Th and rare earths to make the crystallization of steenstrupine possible. This means that a part of the rest liquid from the crystallization was held back in the interprecipitate arfvedsonite phase. The withdrawal of SiO_2 from the magma during the early precipitation of feldspars may also have favoured the formation of the silica-poor steenstrupine. That the rest elements played a role is seen from the presence of lepidolite, schizolite, sphalerite and neptunite.

b. In this locality eudialyte is unstable and steenstrupine stable in albite-rich and analcime-poor lujavrites. In other areas steenstrupine is especially present in analcime-rich lujavrites, but there are, as mentioned above, lujavrites rich in analcime and also rich in unaltered eudialyte. As discussed in a previous chapter analcime and albite may be stable at the same temperature, but at different partial water pressures. In the rocks discussed here albite is partially replaced by analcime, and microcline by ussingite. It may therefore be suggested that the stability fields of eudialyte and steenstrupine are determined by temperature rather than by pressure, so that eudialyte is stable at the highest temperature and that the two minerals may be formed over a rather wide range of pressures. If this is the case the steenstrupine in this locality is formed at a temperature below the stability field of eudialyte and at a rather low partial water pressure. In this connection it should be noted that the nepheline of these rocks is accompanied by sodalite which, according to experimental work by WYART and CHRISTOPHE-MICHEL LÉVY (1955), substitutes nepheline at low temperatures.

In some of the black veins of Qeqertaussaq (which are eudialyte-free) there are small steenstrupine crystals similar to the ones discussed above.

In other areas in Ilímaussaq (cf. BUCHWALD and SØRENSEN, 1961, p. 17) there are lujavrites very rich in analcime and secondary arfvedsonite. Eudialyte is lacking, but small pseudomorphs occur. Besides, there are small crystals of steenstrupine of the size and shape of the above-mentioned grains, but apparently in a strongly altered state. These analcime-rich lujavrites may have been formed by deuteric alteration of the albite-rich type of rock found at Tuperssuatsiaq, but it is also possible that a part of the steenstrupine crystallized simultaneously with the analcime.

ii. In the green and brown lujavrites of the north coast of Tunugdliarfik there are horizons containing large poikilitic steenstrupine grains of irregular shape. The inclusions in the steenstrupine grains are: ægirine, arfvedsonite, microcline, lath-shaped analcime, nepheline (sometimes surrounded by natrolite), schizolite, ussingite, lovozerite, altered eudialyte, sphalerite and natrolite. In a few cases there are inclusions of arfvedsonite in the steenstrupine of the green, arfvedsonite-free rocks. The inclusions in the steenstrupine are orientated as in the surrounding rock, but they generally occur in smaller grains than those in the matrix.

In some cases, arfvedsonite is lacking in the central parts of the steenstrupine grains, but occurs in the marginal parts. The inclusions may then be of the size of the arfvedsonite grains of the adjacent rock and may, as the latter, be associated with ægirine.

The steenstrupine in these rocks is always associated with analcime and is connected by gradual transition with poikilitic pigmentary areas, which may be altered steenstrupine or perhaps represent an early stage of formation of that mineral.

Accessories in these steenstrupine-bearing lujavrites are schizolite, sphalerite, lepidolite, neptunite, britholite, igdloite, epistolite and astrophyllite. The schizolite occurs in large poikilitic grains in which the enclosed minerals are more fine-grained than in the surrounding rock. Small crystals of eudialyte may occur.

The fact that the inclusions of ægirine, etc. in the steenstrupine are in smaller grains than in the surrounding rock might support the view that the crystallization of the steenstrupine commenced at such an early stage that the ægirine, etc. only occurred in small grains. However, the orientation of the enclosed grains in conformity with those of the lujavrite indicates that the steenstrupine grew *in situ*. The inward decrease in grain size of the inclusions is then a result of a more advanced replacement in the central parts of the steenstrupine grains.

In the inclusions of green lujavrite in black lujavrite there is often a late formation of small arfvedsonite rims on the ægirine needles. The steenstrupine grains then contain inclusions of arfvedsonite, especially in their marginal parts, indicating that the crystallization of the steenstrupine commenced slightly before that of the arfvedsonite and continued during the growth of that mineral. The black lujavrite enclosing the green rock is often completely analcitized, whereas the green inclusions have patchy analcime. It is therefore natural to connect the crystallization of the steenstrupine with the analcitization of the black lujavrite during which process fluids penetrated into the inclusions. The poikilitic schizolite and the other accessories were formed at the same time.

The green and black components of the multiple veins of Qeqertaussaq and the head of Kangerdluarssuk, the lujavrite associated with the albitite at Tugtup agtakôrfia and the arfvedsonite-bearing "dense" analcime rocks of Igdlúnguaq contain steenstrupine grains of the same type and probably formed in a similar way during the albitization and analcitization of these rocks.

The larger grains of steenstrupine in the above-mentioned lujavrites at Tuperssuatsiaq may represent a continuation of the growth of the primary steenstrupine crystals during the analcitization of these rocks.

Light coloured patches rich in steenstrupine occur in the steenstrupine-bearing lujavrite. The matrix of these rocks, as that of the adjacent lujavrite, is rich in analcime and/or natrolite. The inclusions in the steenstrupine may be in a better preserved state than in the surrounding white rock. These patches may be regarded as magma pockets rich in rest elements separated from a water-rich lujavrite magma. They have apparently been formed in equilibrium with the latter. Thus the occurrence at the east end of Tugtup agtakôrfia is rich in nepheline and steenstrupine, the surrounding lujavrite rich in nepheline and eudialyte. That is, in the first stages of crystallization nepheline is formed in both rock types; in the later stages eudialyte is formed in the lujavrite, and steenstrupine at lower temperature in the "pockets". In this connection it is interesting to note that this eudialyte is the most radioactive eudialyte found so far in Ilímaussaq (cf. Buchwald and Sørensen, 1961).

iii. Adjacent to recrystallized inclusions of naujaite the lujavrite contains poikilitic grains of steenstrupine in many places. Further away from the inclusions there are black nodules.

The black nodules are microscopically seen to be poikilitic areas in which the host is composed of pigmentary material with remnants of eudialyte and small patches of steenstrupine. Enclosed in this material are katapleite, arfvedsonite, acmite, neptunite, analcime, natrolite, schizolite, monazite, microcline and other minerals.

Steenstrupine occurs in poikilitic grains with inclusions of the minerals of the surrounding lujavrite having preserved their original orientation and size. The inclusions are arfvedsonite, microcline, altered eudialyte, acmite, britholite and lath-shaped analcime. In some acmite-bearing rocks there are no inclusions of that mineral, only arfvedsonite being present. The steenstrupine has apparently grown in between the primary minerals of the lujavrite. The groundmass of these lujavrites is rich in analcime and in addition can contain natrolite. Star-shaped groups of arfvedsonite are common. The steenstrupine-bearing rocks are rich in schizolite and also contain britholite, monazite and sphalerite.

Similar poikilitic grains of steenstrupine occur in the coarse-grained inclusions in the lujavrite, in thin lujavrite veins, and partly in the lujavrite associated with, and enclosed in the albitite at Tugtup agtakôrfia.

The formation of steenstrupine in these rocks is probably connected with their analcitization and with the formation of arfvedsonite, schizolite, etc. The black nodules may represent the first stages of formation of the steenstrupine and the latter mineral is then mainly formed at the expense of the altered eudialyte whereas the other primary minerals are enclosed with size and shape preserved. A spectrographic examination of black nodules and steenstrupine from no. 21051 have shown that the nodules contain ca. 1 % Zr, 8000 ppm La, 2000 ppm Y and 800 ppm Ti and that the steenstrupine contains ca. 1 % Zr, > 1 % La, 3000 ppm Y and 500 ppm Ti. The steenstrupine, in some cases, is clearly formed where the lujavrite magma has been contaminated by naujaitic material (e. g. eudialyte) and steenstrupine therefore occurs nearer to the naujaite than the black nodules. A higher content of volatiles in these marginal parts of the lujavrite magma may also have been of importance.

It appears from the discussion above that the steenstrupine of the lujavrites is formed during late magmatic, in part deuteric processes.

Steenstrupine in the late veins, etc.: The steenstrupine of these occurrences differs from that of the lujavrites in having well-developed crystal faces and in being poor in, or free from inclusions. It is associated with albite and/or analcime-natrolite, and furthermore with lepidolite, schizolite, sphalerite, britholite, epistolite, pyrochlore, neptunite and other accessory minerals. It is commonly later or partly later than the associated ægirine, acmite and arfvedsonite.

In some naujaites and recrystallized naujaites the steenstrupine occurs in crystal skeleton-like grains growing in between the naujaitic minerals. These grains are, via a glomeroblastic stage, transformed into homogeneous crystals.

In the green rocks of veins nos. 3 and 4 at the head of Kangerdluarssuk, the steenstrupine crystals are poor in inclusions and they may be "wrapped" by ægirine needles. The rare inclusions of microcline, ægirine, etc. may be arranged parallel to the faces of the crystals.

In vein no. 4 steenstrupine occurs in the parts of the vein richest in small grains of lovozerite and it may also grow on eucolite.

In the albitite at Tugtup agtakôrfia the steenstrupine crystals of the central part of the vein are free from inclusions, those of the border zones have inclusions of eudialyte pseudomorphs, lovozerite, acmite and arfvedsonite (with acmite rims). The steenstrupine of the associated lujavrite is rich in inclusions of arfvedsonite, acmite, etc. (see above).

The occurrences of steenstrupine discussed here, as has been outlined in the preceding chapters, have been formed from mobilized or leached naujaite and from fluids expelled from the lujavrite magma. This steenstrupine is thus simultaneous with the steenstrupine of the above-mentioned black lujavrites. The steenstrupine of the black lujavrites was formed during the crystallization and partial recrystallization of these rocks; the steenstrupine of the late veins during replacement of naujaite or in crush zones in that rock. In the last-named cases steenstrupine is formed through reactions between pre-existing minerals and material introduced into fractures in these minerals. The steenstrupine is especially associated with light coloured minerals towards which crystal faces are developed. Where the steenstrupine borders on the marginal arfvedsonite and acmite of these occurrences crystal faces are generally lacking. The occurrence of ægirine needles, etc. enveloping the steenstrupine of some veins indicates that the steenstrupine here has exerted an outward directed pressure during its growth. The steenstrupine of the black lujavrites, on the contrary, has not been able to push aside the pre-existing minerals which are consequently enclosed in the poikilitic steenstrupine grains. There is thus a characteristic difference between the steenstrupine of the "mother rock" and that of the fractures in older rocks into which material has been introduced. The steenstrupine of the green and brown inclusions in black lujavrite then represents an intermediate stage between these two types of development. In the green and brown rocks steenstrupine was formed by replacement processes in solid rocks into which rest elements from the black-lujavrite magma were introduced.

The steenstrupine of the veins, etc. is often surrounded by radiating fractures formed in connection with the metamictization of that mineral. Such fractures have been observed in albite, microcline, analcime, ussingite, ægirine and sodalite, but they have not yet been seen in natrolite. Furthermore, the steenstrupine of the natrolite-bearing rocks has often an irregular colour distribution and an irregular aggregate extinction. The natrolite is, therefore, considered to be younger than the steenstrupine.

Conditions of formation of the steenstrupine: As mentioned above, the steenstrupine of the black lujavrite is formed instead of eudialyte as a result of decreasing temperature and a change in the chemical environment caused by an accumulation of rest elements such as Th, Nb, P, Mn, H_2O, F and rare earths.

In the late veins, etc., steenstrupine has most probably been formed at a temperature similar to that prevailing during the crystallization of the lujavritic steenstrupine. The fluids responsible for the formation of the vein steenstrupine were expelled from the lujavrite and thus contained a certain amount of the rest elements mentioned above. The fluids have been modified by mobilized naujaitic material and by leaching taking place along the fractures in the naujaite through which the fluids percolated. The eudialyte in the naujaite was unstable in contact with these fluids and it was therefore pseudomorphed by katapleite, etc. The steenstrupine of the veins, etc. is often associated with pseudomorphs after eudialyte and it therefore appears that the Th, rare earths, Mn and Nb released during the alteration of the eudialyte have favoured the precipitation of steenstrupine. The ratio between introduced and released elements cannot be estimated with any certainty. The common association of steenstrupine, monazite, britholite, etc. with the eudialyte pseudomorphs shows that released material must have played a role, but the high content of P in the just mentioned late minerals compared with the almost complete lack of P in the naujaite clearly shows that there has also been an introduction of material.

The late stage mineralization of the veins is geochemically characterized as follows: P and rare earths are concentrated in steenstrupine, monazite and britholite; Nb in pyrochlore, igdloite and epistolite; Mn in schizolite, neptunite, astrophyllite and steenstrupine; Ti in astrophyllite and neptunite; Th and U in steenstrupine and thorianite (the monazite, britholite, pyrochlore, etc. being weakly radioactive as demonstrated by BUCHWALD and SØRENSEN, 1961); F in steenstrupine and lepidolite; and Li in lepidolite (cf. p. 140).

Experimental data on the stability of eudialyte: According to MAURICE (1949) zircon is unstable in alkaline solutions, but stable in acid solutions at 400° C and 900 atm. In alkaline solutions baddeleyite and zirconosilicates (as for instance $Na_2O \cdot ZrO_2 \cdot 1{\cdot}5SiO_2$, which is uniaxial negative with nE = 1.692, nO = 1.715 and specific gravity = 2.88) are stable.

KOSTYLEVA (1937), RINGWOOD (1955) and MURTHY (1958) state that zirconium in acid magma occurs as Zr^{4+}. In water-rich magmas at lower temperature zirconium forms complexes such as ZrO_4^{4-}, $(Zr(OH)_6)^{2-}$ or $(Zr(OH)_8)^{4-}$, so that early separation of zirconium is prevented. In acid solutions these complexes disintegrate forming zircon; in alkaline solutions sodium-rare earth-zirconium minerals which also contain volatiles are formed (e. g. eudialyte and rinkite).

CHRISTOPHE-MICHEL LÉVY (1961) has formed eudialyte at temperatures higher than 440° C from solutions containing more than 5 % Na_2CO_3. In less alkaline environments zircon is formed. Katapleite was formed at 410–530° C and elpidite below 380° C. The water pressure at which the experiments were carried out varied from 85–700 kg/cm².

The results of CHRISTOPHE-MICHEL LÉVY are in excellent agreement with the crystallization temperature of the lujavrite estimated from the feldspars of that rock. It is therefore assumed that the steenstrupine was formed at temperatures lower than 400° C. It may furthermore be assumed, as discussed on p. 189, that the fluids present during the latest stages of crystallization of the lujavrite and expelled from that rock to form veins, etc. were at such high pressures that they may be regarded as very dense, condensed water- and volatile-rich phases.

Occurrences of steenstrupine and related minerals are, as mentioned in the mineralogical chapter, very rare. In Lovozero steenstrupine is associated with the late natrolite, albite, ussingite, etc. of the pegmatites and it has apparently been formed at conditions similar to those at which the Ilímaussaq steenstrupine was formed. The tritomite, etc. of the Langesundfjord pegmatites may have been formed at rather similar conditions.

The evolution of the steenstrupine occurrences of Ilímaussaq may also be compared with the rare earth carbonate—thorium veins, which have especially been described from the United States (see p. 167). These veins occur in shear zones in and around bodies of alkaline rocks and have marginal zones composed of ægirine and feldspar, and central zones composed of carbonates, quartz, sulphides and other hydrothermal minerals. The rare earth—thorium minerals occur between the margin and core or as stringers in the core. KOSTERIN (1959) has discussed the evolution of such veins. They are chemically characterized by strong bases such as Na and K and by anions of weak and intermediate acids such as H_2CO_3 and HF. The fact that the veins contain carbonates indicates that they were formed from alkaline solutions. In the American occurrences mentioned by KOSTERIN there is an increase of rare earths and $CO_3^{\div\div}$ and a decrease of $F^{\div}$ in the successively formed rare earth carbonates. The rare earths are believed to have been transported as carbonate complexes and, in rocks rich in Al, Fe^{3+} and Zr, also as fluor-complexes. The "Y"-carbonate complexes are more stable than the "Ce"-carbonate complexes which explains the earlier precipitation of "Ce" minerals. The carbonate complexes disintegrate at decreasing pressure and increasing hydrogen ion concentration.

Zirconium and the other rare elements of the steenstrupine occurrences form sodium complexes with a number of anions. When the anion concentration is lowered, the rare elements are precipitated by reaction or by hydrolysis.

The importance of fluorine complexes has been demonstrated in extraction experiments by KAPLAN and USPENSKAYA (1958). It was found that the alkaline decomposition of monazite was improved markedly by the addition of fluorine compounds to the charge to be sintered. Zircon has been decomposed in a similar way. That $Cl^{\div}$ and $F^{\div}$ complexes may have played a role in the early stages of vein formation is illustrated by the example given by BEUS (1958) and quoted on p. 188. In later stages carbonate complexes may have been more important.

If the fluids, as assumed, have been alkaline, the amphoteric oxides may have been transported in solution, for instance as zirconates. These metals should then be precipitated with decreasing alkalinity. This may explain the common association of lovozerite and ussingite.

It may then be suggested, as a working hypothesis for further studies, that the fluids expelled from the lujavrite magma at temperatures lower than the stability field of eudialyte contained in solution elements such as Zr, Ti, Nb, rare earths, Th, U, Li, Mn, Na, Cl, F and P. The fluids were so dense that a certain ionization of the halides took place, so that the rare elements could form sodium halide complexes in the alkali halide fluids. (This follows because the dielectric constant of water increases with increasing density of the solution at constant temperature, but decreases with increasing temperature at constant density, as demonstrated by FRANCK, 1956). Complexes with other anions may also be possible.

As the pressure on the fluids decreased, the alkalinity was changed and reactions took place. The complexes became successively unstable and the rare elements were precipitated as phosphates, silico-phosphates, silicates and niobates. A part of this precipitation was probably caused by hydrolysis as a result of pressure relief. HCl and HF released during this process may have left the system entirely, but at low temperatures villiaumite was occasionally formed (cf. BONDAM and FERGUSON, 1962).

The zirconium complexes are apparently more stable than the complexes of Th, Nb and rare earths, possibly because of the amphoteric nature of the zirconium oxide or because of strong fluorine complexes. The phosphate precipitation (which has apparently played an important role in the precipitation of Th and rare earths) and hydrolysis (which may have been most important in the precipitation of Nb), may then have been prevented and the fluids have been able to dissolve zirconium from the altered eudialyte along the fractures. Considerable amounts of zirconium may thus have been deposited at higher levels. Spectrographic examinations of some rocks from Ilímaussaq and of a few steenstrupine samples have indicated that the yttrium group of rare earths is present in much smaller amounts than the cerium group. Furthermore, uranium is relatively scarce in the rocks and veins studied in the present paper. It may therefore be assumed that Zr, "Y" and U have been transported to higher levels (cf. Poços de Caldas, p. 166).

If carbonate complexes have been active in the transportation of the rare elements, large amounts of CO_2 must have been released and could perhaps, in addition to the carbonate-bearing veins to the east of Ilímaussaq, also have formed carbonatites in volcanic vents closer to the surface. U and "Y" are according to SHCHERBINA (1957) very mobile in carbonate solutions.

The order of formation of the minerals of the steenstrupine occurrences is not always easy to establish. It is certain that the steenstrupine is formed later than the alteration products of the eudialyte (first of all katapleite, neptunite, eucolite and lovozerite) and that it is also later than the ægirine/acmite. It is partly later than the arfvedsonite.

The steenstrupine is generally associated with schizolite, lepidolite and sphalerite and is most probably formed simultaneously with these minerals.

Epistolite, igdloite, pyrochlore and astrophyllite are generally later than the steenstrupine.

The relation to britholite and monazite is less clear. These two minerals often occur in altered eudialyte in the lujavrite and the late veins. They may be associated with or enclosed in steenstrupine and should, accordingly, be older than or crystallize simultaneously with that mineral. All three minerals are apparently formed in the late period of analcitization, etc., but most probably at different physical and chemical conditions.

The light coloured minerals of the steenstrupine occurrences have generally crystallized later than the steenstrupine and may corrode that mineral.

The steenstrupine and its accompanying minerals are only exceptionally deformed and are thus later than the tectonic processes during which the lujavrite was formed.

The occurrences described in the present paper are examples of hydrothermal high temperature and high pressure precipitation of rare elements from saline waters. An example of a low temperature and low pressure precipitation from similar waters is the diagenetic mineralization of the Green River formation (see p. 183). At these conditions minerals such as elpidite, labuntsovite, fluor apatite, leucosphenite and cryolite are formed. They are associated with analcime, sodium carbonates and other minerals. That is, at these temperatures sodium carbonates have played an important role.

VII. SUMMARY AND CONCLUSIONS

During the first phase of crystallization of the agpaitic magma naujaite was formed in the upper part of the Ilímaussaq complex, while the banded kakortokite was deposited in the lower part. The naujaite crystallized from the top downwards and pegmatites were developed from magma pockets enriched in volatiles. When this took place in irregularities in the lower surface of the downward crystallizing naujaite, almost horizontal pegmatites were formed having an upper zone rich in microcline, arfvedsonite, etc.; an intermediate ægirine zone; and a lower eudialyte zone. The intermediate zone was the last part of the pegmatite to crystallize and contains rinkite, albite, molybdenite and other late minerals.

During the cooling of the naujaite an orthogonal joint system and diagonal joints were formed.

Coarse-grained veins rich in zoned crystals of eudialyte occur in some of the joints in the naujaite. They are considered to be off-shoots from the underlying still liquid agpaitic magma, the coarse grain size being due to injection into a warm naujaite.

The second phase of agpaitic magma activity was initiated by the formation of green felted ægirine in some of the joints in the naujaite, mainly in N-S and E-W joints. The formation of these green veins was accompanied by small displacements along the fractures in question. Green veins were also formed in some of the coarse-grained veins mentioned above which behaved as zones of discontinuity in the naujaite. The felted ægirine of the green veins was accompanied by microcline and sometimes by eucolite.

The formation of the green veins was succeeded by the main phase of emplacement of the black, arfvedsonite-rich lujavrite. The intrusion of the lujavrite was guided by the N-S and E-W joints in the naujaite and black rocks succeeded the green felted rocks in some of these joints.

The lujavrite intruded into the lower part of the naujaite and inclusions of that rock in the lujavrite were rotated and tilted.

The lujavrite is laminated and also banded in some cases. The lamination is most probably a result of movements occurring during the crystallization of the lujavrite, this rock being emplaced during a period of subsidence of parts of the earlier rocks. The banding of the lujavrite is most probably due to crystallization differentiation.

Inclusions of green lujavrite in the black lujavrite indicate that the formation of the black rock was preceded by a formation of green lujavrite. The inclusions are, to various extent, digested by the black rock.

In the black lujavrite there are spheroids with white rims. The cores of these spheroids are rich in analcime and arfvedsonite and poor in feldspars, nepheline and sodalite. The rims are rich in analcime and acmite. Inclusions of green lujavrite in the black rock may show transitions into similar rocks. The spheroids may therefore be strongly recrystallized inclusions. The spheroids may also have been formed from magma patches enriched in assimilated naujaitic material. A third possibility is that a water-rich lujavrite magma consolidated at such a low temperature that it separated into two immiscible liquids of which the water-rich phase gave rise to the spheroids. In the first stages of crystallization, the same rock forming minerals were formed in the two immiscible liquids at equilibrium conditions, the only difference being that acmite was formed in the rims of the spheroids, perhaps because of a higher partial oxygen pressure there (combined with a higher content of silica). The last-named feature recalls the above-mentioned evolution of the lujavrites, green rocks being formed earlier than the black ones. The crystallization of the water-rich spheroids concluded at lower temperature than that of the main lujavrite. Therefore analcime substitutes for the light coloured minerals in the spheroids and steenstrupine may be formed instead of eudialyte.

"Dense" rocks with a fairly high concentration of eudialyte and nepheline are, in places, associated with lujavrite veins. The "dense" rocks are generally rich in analcime and they might be regarded as further stages of evolution of the spheroids mentioned above, that is, rocks formed from a water-rich liquid immiscible with and squeezed out from the main lujavrite magma. The "dense" rocks might also be regarded as urtitic lujavrite separated from the melanocratic lujavrite as a result of deformation during crystallization. However, the "dense" rocks are older than the lujavrite and show transitional stages into deformed naujaite. The writer therefore favours the view that they were formed in zones of deformation in the naujaite in connection with the emplacement of the lujavrite. The zones were recrystallized and their material may have been mobilized. The zones should then be regarded as naujaitic mylonites. Arfvedsonite and steenstrupine were locally developed during the analcitization of the zones.

Two types of processes have thus taken place in connection with the emplacement of the lujavrite, namely the formation of green ægirine felt along activated joints and the formation of "dense" rocks in the mylonite zones.

The inclusions of naujaite in lujavrite are often strongly recrystallized into rocks rich in analcime, natrolite and yellow sodalite. Steenstrupine and other rare minerals also occur indicating that rest fluids derived from the lujavrite took part in the process. The lujavrite adjacent to the inclusions is more coarse-grained than elsewhere and rich in arfvedsonite and analcime. Steenstrupine, etc. is locally present. This lujavrite has been contaminated by naujaitic material and is enriched in volatiles.

The later stages of formation of the black lujavrite: Eudialyte is the only common lujavrite mineral containing appreciable amounts of rare elements. This mineral crystallized approximately simultaneously with the feldspars of the rock. The co-existence, in many cases, of an almost pure maximum microcline with a low albite indicates that the temperature of crystallization of the lujavrite was very low, possibly about 400° C or lower. In experiments by CRISTOPHE-MICHEL LÉVY (1961) eudialyte was not formed below 440° C.

In some lujavrites albite is partially substituted by analcime, in others, all the light coloured minerals are replaced by analcime and, in cases, also by natrolite. Simultaneous with this process is a formation of needles of arfvedsonite.

The crystallization of analcime instead of albite, according to experimental work, is caused by a lower temperature, a higher partial water pressure, a lower silica content, or a combination of these factors.

In many analcime-rich lujavrites the eudialyte crystals have been pseudomorphed by katapleite, neptunite and pigmentary material. These rocks often contain small crystals of steenstrupine. Similar small steenstrupine crystals have also been found in albite-rich lujavrites which are poor in analcime, but with an incipient development of that mineral.

The features enumerated above indicate that the albite and other light coloured minerals of the lujavrite were substituted by analcime during late-magmatic or deuteric processes. At the same time eudialyte became unstable in many rocks and was succeeded by steenstrupine.

The crystallization of the latter mineral took place in a magma considerably enriched in rest elements such as P, Th, rare earths, Nb and Mn. It was accompanied by schizolite, lepidolite and sphalerite.

The formation of analcime (and natrolite) in many lujavrites shows that the consolidation of these rocks took place in a very water-rich environment. If the partial water pressure of the magma exceeded the load pressure, or a relief of pressure took place in connection with tectonic processes, a water phase may have been expelled. Therefore veins of albite, analcime and natrolite are often associated with lujavrite. It is not unlikely that there has been a release of water pressure at several stages of the consolidation of the lujavrite, the last stage being the squeezing out of the rest liquid remaining after the crystallization of the rock. The expelled water phases will, in proportion to the lujavrite magma, be enriched in the most volatile components which explains that steenstrupine, lepidolite, epistolite and other rare metal minerals may occur in the albite-, analcime- and natrolite veins.

The release of a water-rich phase should be compared with the above-mentioned immiscibility processes. The water-rich phase may be the vapour phase in equilibrium with the two immiscible liquids or it may have been formed at a later stage. In the author's opinion the common association of analcime lujavrites and late veins favours the latter possibility. The spheroids should then have been formed at a higher temperature and a higher external pressure than the veins. The latter rocks were most probably formed from fluids expelled from a water-saturated lujavrite magma as a result of a pressure relief. This relief could have been produced by tectonic processes or by the existence of fracture systems which were only partially filled with the water-saturated lujavrite magma.

The above-mentioned analcitization of the lujavrite is partly a late magmatic crystallization of "primary" analcime, partly a deuteric alteration caused by late fluids migrating through the crystal meshwork of the almost entirely consolidated magma. During this late stage there was a formation of arfvedsonite needles (in part in star-like groups). The black borders between lujavrite and naujaite and poikilitic grains of steenstrupine and schizolite are simultaneous with this analcitization.

The late fluids of the lujavrite were, in places, expelled causing analcitization of the enclosed fragments of naujaite and green lujavrite. During this process the eudialyte of these rocks was broken down, and it was eventually substituted by steenstrupine. The altered naujaite was mobilized in places giving rise to steenstrupine-bearing analcime veins which penetrate the enclosing lujavrite.

The fluids expelled during and after the crystallization of the lujavrite could migrate through fractures in the naujaite reacting with that rock. These processes resulted in the formation of veins containing albite, analcime, natrolite, ussingite, yellow sodalite, steenstrupine, schizolite, lepidolite, igdloite, pyrochlore and other minerals. This mineralization could take place in the preexisting ægirine-bearing veins and it could also result in the formation of replacement bodies in the naujaite pegmatites. The steenstrupine was especially formed where the fractures contained remnants of altered eudialyte. It appears as if the precipitation of the rare elements of the migrating fluids has been facilitated by the presence of eudialyte remnants in the fractures, perhaps because of a higher concentration of the rare elements in these places.

In some late veins there was an early formation of acmite and arfvedsonite, succeeded by the formation of steenstrupine, other rare minerals, and sodium-aluminium silicates. These veins are in many cases diagonal to the joint system through which the emplacement of the lujavrite took place. Small displacements along the veins are most probably due to adjustments during the emplacement of the lujavrite. The acmite of the veins was partly formed at the expense of the ægirine and arfvedsonite(?) of the naujaite, the other minerals of that rock were dissolved, but, as mentioned above, the fractures were later mineralized by the fluids expelled from the lujavrite.

The occurrences of the last-named acmite and the ægirine of the green veins, mentioned above, indicate that the emplacement of the lujavrite was preceded by a wave of emanations richer in oxygen than the liquids from which the subsequent lujavrite and late veins were formed.

The late fluids were very probably expelled from the crystallizing or almost consolidated lujavrite at temperatures around or lower than 400° C and at a high combined load and vapour pressure. The fluids were sodium-halide-bearing with a certain amount of rest elements such as P, Th, rare earths, Nb, Li and Mn. CO_2 or carbonates may have been present but have disappeared from the system without leaving traces. The fluids may have been so concentrated that they, even at temperatures around 400° C, have shown no critical phenomenae. It may then be assumed that the fluids, when expelled from the lujavrite, have been condensed phases with high solvent power. The rare elements were present as sodium halide (and perhaps carbonate) complexes. As the temperature and pressure decreased the dissolved material was precipitated as phosphates, silicates and by hydrolysis. At the same time HCl, HF and perhaps CO_2 were released and they were concentrated in the vapour phase developing when the pressure became sufficiently low. This vapour also contained a certain amount of sodium-aluminium silicates and rare elements and it may have been responsible for the formation of some natrolite veins in Ilímaussaq and of the carbonate-bearing veins to the east of the complex.

As mentioned above eudialyte was unstable in contact with the late fluids and zirconium-bearing minerals do not occur in the late veins with the exception of steenstrupine containing about 1 $^0/_0$ Zr (and ægirine and arfvedsonite with traces of Zr). This means that there has been a continuous removal of zirconium. Zircon has been found in some of the carbonate veins to the east of Ilímaussaq, but one might expect that higher concentrations may have been formed at higher levels corresponding to the *caldasite* of Poços de Caldas. U, Ta, and the yttrium group of rare earths may have accompanied this Zr.

It is then concluded that the steenstrupine formation is closely associated with the late phase of crystallization of the lujavrite being formed during late processes in that rock and from fluids expelled from the crystallizing lujavrite.

The mineralogical composition of the black lujavrite indicates, as mentioned above, that this rock crystallized at very low temperatures, perhaps of the order of 400° C. The rock is thus formed at hydrothermal or metasomatic temperatures. It is therefore tempting to examine if metasomatic processes, rather than magmatic, could have been responsible for the formation of the black lujavrite. This problem has been discussed on pp. 148–155 and it was concluded that, although some features are not incompatible with a metasomatic origin, most evidence available is in favour of a magmatic origin of the black lujavrite. At these low temperatures it should be expected that there has been an interplay of magmatic and hydrothermal processes as it has been demonstrated in the case of the analcitization of the lujavrite. It may therefore, in cases, be difficult to distinguish between the relative importance of magmatic and hydrothermal processes. But it is, in the writer's opinion, clearly established that magmatic crystallization may take place at about 400° C in a magma enriched in sodium and volatiles.

The rocks studied in the present paper are of considerable economic interest since the radioactive minerals and rocks of Ilímaussaq are potential sources of uranium and thorium. Only a few selected occurrences have been treated during this study, but, in the author's opinion, they are representative of the steenstrupine-bearing rocks in Ilímaussaq and the conclusions arrived at should therefore, if correct, be valid for the whole Ilímaussaq Intrusion.

In addition, the interplay of magmatic and hydrothermal processes in the formation of the lujavrite is of general petrologic interest since these processes, although taking place in a magma of a rather uncommon composition, may be compared with those of more common igneous rocks. The study of the well exposed occurrences in Ilímaussaq may therefore throw new light on the transitional stages between magmatic crystallization and hydrothermal mineralization. It is therefore to be hoped that further field studies and detailed geochemical work may be carried out simultaneously with the mineralogical examination of steenstrupine and other rare minerals.

Postscript.

After the printing of the paper the author's attention has been drawn to the works by L. VAN WAMBEKE on the tonalites of Helle and Lammersdorf: a. Les processus pegmatito-pneumatolytiques dans les granites (Bull. Soc. belge de Géol., de Paléont. et d'Hydrol. t. LXII, 1953, pp. 110–115); b. La minéralisation des tonalites de la Helle et de Lammersdorf et leurs relations avec les autres minéralisations (ibid. t. LXIV, 1956, pp. 534–581). In these papers an excellent discussion of disseminated and veinlet mineralization of plutonic rocks is given.

APPENDIX 1

Mineralogy.

Mineralogical textbooks contain many references to the Ilímaussaq complex, however, the latter area is generally referred to as the Kangerdluarssuk region, since the first visiting mineralogists were especially attracted by this impressive fiord. A number of minerals were first discovered in Ilímaussaq, namely eudialyte, steenstrupine, rinkite, ussingite, arfvedsonite, sodalite, epistolite, ænigmatite, schizolite, britholite and naujakasite. These, and the other minerals found in the Ilímaussaq massif up to 1953, are described in the comprehensive memoir: The Mineralogy of Greenland by O. B. Bøggild (1953). This book also contains a rather complete bibliography of the minerals of the region.

In this chapter, the minerals found in the areas studied by the writer will be mentioned. Since many of the minerals referred to are being currently studied, only data of importance for the petrological treatment of the rocks will be given. Further information can be obtained from Bøggild's memoir and from a few other papers to which references will be made.

The minerals will be listed in alphabetical order. At the head of each description, the chemical formula, unless stated, is taken from Strunz (1957), and a reference to the page in Bøggild's memoir is also given.

The minerals have been identified by a combination of the immersion method, X-ray powder diagrams and spectrographical analyses. Some of the minerals have been examined by means of a Leitz four-axes universal stage.

It should be emphasized that, in addition to the minerals described here, there are a number of other minerals in Ilímaussaq and that there also are other types of pyroxenes, potash feldspars, etc. elsewhere in the complex.

Acmite/Ægirine: $NaFe^{3}Si_2O_6$ (Bøggild, 1953, p. 273).

In this paper the distinction between acmite and ægirine follows the principles used by Ussing (1894, p. 198), Sabine (1950) and Schüller (1958). The soda pyroxene is accordingly termed acmite when it is brown to colourless in thin section, and ægirine when it is green to colourless. The green colour of the ægirine, according to SCHÜLLER (op. cit.) and others, is caused by a small amount of Fe^{2+} substituting some of the Fe^{3+} of the acmite. The acmite thus represents a higher stage of oxidation than the ægirine (cf. the table p. 192).

No ægirine-augite has been observed in the rocks studied in this paper.

Ægirine has, during the present study, been observed as: 1) tiny needles and microlites enclosed in the sodalite of the naujaite; 2) large anhedra with poikilitic inclusions of sodalite in the naujaite; 3) large prismatic crystals and radiating groups of needles in the naujaite pegmatites; 4) felt-like masses composed of small needles, from less than 0.1 to a few millimetres long, in thin green veins cutting the naujaite; 5) small needles in green lujavrites.

The ægirine often has an irregular distribution of the green colouration with bleached zones along the margins of the crystals and along fractures in the latter (cf. USSING, 1894, p. 182).

Acmite occurs as: an alteration product of the ægirine and arfvedsonite from naujaite and albititic veins; fracture fillings (brown veins) in naujaite; the predominant mafic mineral in some brown lujavrites; small patches in arfvedsonite lujavrites.

A detailed study of some soda pyroxenes from Ilímaussaq is being undertaken by O. LARSEN.

In Khibina and Lovozero three phases of ægirine formation are distinguished: ægirine I (magmatic), ægirine II (late magmatic) and ægirine III (hydrothermal) (VLASOV et al., 1959). The content of vanadium is decreasing from I to III (SHCHERBINA, 1960). Ægirine I corresponds, in Ilímaussaq, most probably to the ægirine enclosed in the sodalite and to some of the large grains of ægirine in the naujaite and naujaite pegmatites. Ægirine II may be equivalent to most of the large grains in the naujaite and naujaite pegmatites and to the radiating needles of the latter rocks. Ægirine III would then correspond to the green felted veins in the naujaite. It should be mentioned that the ægirine from the latter occurrences only has traces of vanadium according to the spectrographic examination.

Ænigmatite: (Na, Ca) $(Fe^2, Ti, Al, Fe^3)_5$ $(O_3Si_4O_{11})$ (?). (BØGGILD, 1953, p .307).

This mineral occurs as reddish brown to black grains in naujaite and naujaite pegmatites, but is rare in the rocks described in this paper.

Albite: $NaAlSi_3O_8$. (BØGGILD, 1953, p. 380).

The albite occurs, in the areas studied by the writer, as thin laths, up to a few millimetres long, in the lujavrites; and more rarely in naujaite (especially close to steenstrupine-bearing rocks). The laths are polysynthetically twinned according to the albite law. Karlsbad and complex albite-Karlsbad twinning have also been observed.

In the naujaite pegmatites there are large grains, polysynthetically twinned according to the albite law.

The albititic parts of the naujaite pegmatites, the albitites and the green veins, contain cleavelanditic and sugary-grained albite. These albites are twinned according to the albite, Karlsbad and complex albite-Karlsbad laws. The sugary-grained albite is often untwinned. In some green veins there are albite grains composed of three twin lamellae, the middle one is wedge-shaped (plate 5, fig. 1). The latter forms albite and Karlsbad twins with the two marginal lamellae, which accordingly are in a mutual position corresponding to the complex albite-Karlsbad law (i. e. the so-called *Roc-Tourné* law).

According to GORAI (1951) the combination of albite, Karlsbad and complex albite-Karlsbad twinning is characteristic of igneous rocks. It should, however, be pointed out that these three twin laws are also found in authigenic albites where the *Roc-Tourné* twinning is stated to be very characteristic (MOORE, 1952 and BASKIN, 1956). The multiple Karlsbad twinning described from Rockall (SABINE, 1960) is probably of the same type.

The twin laws have been determined on the universal stage by means of the method indicated by REINHARD (1931).

The composition of the albites was determined on the universal stage by the REINHARD method. A content of 0 to 8 % anorthite was found, the highest values in the poorest measurements. BØGGILD (op. cit.) reports an analysis of albite from Kangerdluarssuk (most probably from the pegmatite to the north of Lilleelv) which gave 0.00 % CaO, 0.00 % K_2O and 11,86 % Na_2O. A partial analysis of the albite from Tugtup agtakôrfia gave 0.0 % CaO, 0.1 % K_2O and 11.1 % Na_2O. The albite is therefore most probably very poor in anorthite and the high values obtained are probably due to inaccurate measurements.

The albite shows low temperature optics according to the curves in TRÖGER, (1956, p. 103).

The determination of the optic axial angle on the universal stage gave values from (+) 72 to (+) 88°. More than 80 % of the 52 measurements gave values between 74 and 80°. For comparison it should be mentioned that the axial angle of the albite from Lovozero varies from (+) 70 to 80° and that the albite from Rockall has an axial angle of (+) 75 to 83° (VLASOV, et al., 1959 and SABINE, 1960, respectively). The axial angle of the authigenic albites varies from (+) 85–88° (STRAKHOV, 1957) to (—) 70° (BASKIN, 1956).

It has not been possible to demonstrate any systematic variation in the chemical composition and the optic axial angle of the albites from the different rock types.

The laths of albite are flattened parallel to (010) and have the (001) and (010) cleavages developed.

Analcime: $NaAlSi_2O_6 \cdot H_2O$. (BØGGILD, 1953, p. 359).

Analcime is very widespread in Ilímaussaq and occurs in all rock types. In the naujaite and lujavrite it may substitute all other light coloured minerals and many lujavrites are composed of mafic minerals set in a groundmass of analcime. Also the pegmatites and vein rocks are rich in analcime and have vugs of very beautiful icositetrahedrons of that mineral.

The analcime often forms very large individuals, also in the lujavrites where the mafic minerals are enclosed in large analcime grains which may occupy a whole thin section. The largest individual observed so far was found in the albitite at Tugtup agtakôrfia and measured 20 centimetres in diameter. The large grain size of analcime should be compared with the ease of formation of that compound in experimental studies.

The analcime of Ilímaussaq is of the variety termed *eudnophite* and is thus birefringent with an intricate polysynthetic penetration twinning developed (cf. COOMBS, 1955). The cubic cleavage is very distinct. (—) 2V varies at least from 46 to 88°. Three partial analyses of analcime, taken from the coarse-grained analcime inclusions in the lujavrite and from analcime-bearing veins, gave the result: 0–0.1 % K_2O, 0.0 % CaO and 13.5 to 17.1 % Na_2O.

Some grains of analcime contain small isotropic patches with an index of refraction similar to those of the analcime. Some of these patches are undoubtedly sodalite; the presence of isotropic analcime has not yet been established.

Most occurrences of analcime have patches of well-developed twinning associated with analcime of a more "gritty" internal structure. This is especially seen in deformed rocks, the latter structure is therefore believed to have been formed by deformation of the twinned grains (plate 3, fig. 1).

Apatite: $(Ca, RE)_5 (PO_4)_3 \cdot (Cl, F)$*) (BØGGILD, 1953, p. 178).

The rarity of apatite in the Ilímaussaq agpaites is in striking contrast to the abundance of this mineral in the agpaitic rocks of Khibina and Lovozero in Kola.

In the areas described in the present paper, apatite has been observed as small grey prisms in the pegmatite on the south coast of Qeqertaussaq, as small brownish grains along some acmitic veins in naujaite, and as blue prisms and rounded grains in the lujavrites and their enclosed coarse-grained rocks. Some of the brown and blue grains appear to be connected by transitional stages with the britholite mentioned below. BØGGILD (1953, p. 180) has described dahllite associated with natrolite from cavities in the naujaite.

It is planned to treat the members of the apatite group in more detail at a later date.

Arfvedsonite: $NaNa_2(Mg,Fe^2)_4Fe^3Si_8O_{22}(OH,F)_2$ (BOYD, 1959). (BØGGILD, 1959, p. 291).

Arfvedsonite occurs as: small needles enclosed in the sodalite of the naujaite, large grains in naujaite and naujaite pegmatites, small prisms along brown veins in the naujaite, and small needles in lujavrite and brown veins. The arfvedsonite of the analcime-rich rocks is often arranged in star-shaped groups.

The arfvedsonite is, in thin section, of a bluish green colour and displays the anomalous interference colours described by SAHAMA (1956). The arfvedsonite of the various rock types is of a rather constant appearance; so far no attempts have been made to distinguish the several types of soda amphibole found in the agpaitic rocks of Ilímaussaq.

The arfvedsonite of the naujaite and the albititic veins is often altered into aggregates of needles of acmite which may be arranged parallel to the c-axis of the arfvedsonite (cf. USSING, 1894, p. 198). The alteration progresses in from the margins and fractures of the arfvedsonite. The secondary acmite is often associated with small scales of a brown mica. The alteration causes an increase of $Fe^{3}+$, Na and Si and a decrease in H_2O, MgO, CaO and Al_2O_3. The magnesium released may be partly fixed by the biotite.

Astrophyllite: $(K_2,Na_2,Ca)\ (Fe^2,Mn)_4(Ti,Zr)\ ((OH)Si_2O_7)_2$. (BØGGILD, 1953, p. 238).

The mineral occurs as small bronze-coloured flakes in some of the thin veins in the naujaite and in some lujavrites, especially in albite- and analcime-rich rocks. This mineral is easily identified in thin section because of its pleochroism, the strongest absorption being seen when the long direction of the flakes is orientated normal to the plane of vibration of the polarizer. This identification has been checked by X-ray powder diagrams, but no closer study of the astrophyllite has been undertaken. Lamprophyllite, which is of a similar appearance to the astrophyllite, has been looked for, but not found.

There are often brown rims around radioactive inclusions in the astrophyllite.

Beryllium Sodalite: $Na_8Be_2Al_2Si_8O_{24}(Cl_2,S)$.

This mineral has been described in a preliminary way in a paper presented at the International geological Congress in Norden, 1960 (SØRENSEN, 1960 b). At

*) RE = rare earth metals.

the time of going into print, no chemical analysis of the mineral was available, but at the oral presentation of the paper, a chemical analysis, undertaken by Miss Me MOURITZEN, was given. It is printed below:

SiO_2	51.58
Al_2O_3	11.15
BeO	5.40
Fe_2O_3	tr
MgO	0.20
Na_2O	25.52
K_2O	0.12
H_2O-	0.03
S	0.33
Cl	7.28
	101.61
$-O=Cl$	1.64
	99.97

The mineral is uniaxial positive, $nO=1.496$, $nE=1.502$, $nE—nO=0.006$ According to the X-ray data the mineral is tetragonal, with $a=8.583$ Å and $c=8.817$ Å. The grains show an intricate penetration twinning.

The beryllium sodalite occurs as thin zones and streaks in vugs in albite-rich veins, as at Tugtup agtakôrfia and Qeqertaussaq. It is white on fresh surfaces, but turns pink when exposed to strong sunshine. The zones and streaks, which are composed of small interlocking grains, are secondary after chkalovite and most often envelope and cut rounded grains of the latter.

At the oral presentation of the mineral, it was suggested that it should be termed *tugtupite*, because it clearly differs from sodalite in composition and crystallography. The name is derived from the locality Tugtup agtakôrfia. It should, however, be pointed out that SEMENOV and BYKOVA (1960) have described a similar mineral from Lovozero which they have termed *beryllo sodalite*. The chemical analyses of the two minerals are almost identical, but the Ilímaussaq mineral appears to deviate more from cubic symmetry than the Lovozero one. A detailed description of the two beryllium minerals, beryllium sodalite and chkalovite is being prepared and the concluding discussion of the nomenclature of the beryllium sodalite will be reserved for that paper.

Biotite:

Small flakes of a lepidomelane-like biotite occur in the acmite pseudomorphs after arfvedsonite and in some of the acmite veins in the naujaite. In the last-named places the flakes are elongated along the c-axis, so that the cleavages are normal to the elongation of the grains. The mineral is optically negative and practically uniaxial, but no closer examination has been undertaken because of the small grain size (0.1 millimetre).

Britholite: $(Na,Ce,Ca)_5F(SiO_4,PO_4)_3$. (BØGGILD, 1953, p. 179).

The occurrences of this mineral have been described recently by DANØ and SØRENSEN (1959, p. 18). The britholite is uniaxial negative or with a small axial angle. The refractive indices given by BARTH and BERMAN (1930) are: $nX=1.772$, $nY=1.775$ and $nZ=1.777$ for a biaxial britholite. The specific gravity is 4.446. From this apatite mineral very rich in rare earths there are apparently transitions into more common apatite, as it has been mentioned on p. 218.

The britholite occurs as small prisms and round grains in and along veins of felted ægirine and acmite and also in lujavrites rich in analcime. The britholite may be associated with pseudomorphs after eudialyte (see the table p. 230).

Carbonates:

Carbonate minerals are practically lacking in Ilímaussaq, but, in thin fracture fillings in the green ægirine veins in the naujaite, there may be very small grains, less than 0.1 millimetre, of a carbonate-like mineral.

Cancrinite has been looked for, but not found.

Chalcedony: SiO_2.

In some of the albite-rich thin veins in the naujaite there are small rounded amygdule-like areas, up to one millimetre across, composed of tiny length fast fibres with low birefringence and refractive indices close to those of albite. The mineral is most probably chalcedony. Similar occurrences have been reported by VLASOV, et al. (1959, p. 480) from Lovozero where the chalcedony is associated with albite and ægirine III and supposed to be formed in a late hydrothermal phase of replacement in the central parts of the pegmatites.

Chkalovite: $Na_2BeSi_2O_6$.

The occurrence of this mineral in Ilímaussaq has been preliminarily described by SØRENSEN (1960b). It occurs in amygdules in albititic rocks and in veins composed of analcime and natrolite. It is generally partially replaced by beryllium sodalite. In drill cores from Kvanefjeld it is associated with analcime and villiaumite.

The chkalovite is colourless, transparent, biaxial positive with 2V varying from 78 to 84°. $nX = 1.548$ and $nZ = 1.552$. $nZ—nX = 0.004$. Since the printing of the paper referred to above, a chemical analysis has been carried out by Miss Me MOURITZEN with the following result:

SiO_2	57.78
BeO	12.56
Fe_2O_3	tr
MgO	0.16
Na_2O	29.20
K_2O	0.09
H_2O-	0.02
S	0.17
Cl	0.14
	100.12
$-O=Cl$	0.03
	100.09

This analysis corresponds very closely to that of the chkalovite from the type locality in Lovozero. The occurrences of the mineral in Lovozero and Ilímaussaq are also very similar, the chkalovite being restricted to amygdules, etc. and being formed in a late stage of the development of the pegmatites and hydrothermal veins.

Elpidite: $Na_2ZrSi_6O_{15} \cdot 3\,H_2O$. (BØGGILD, 1953, p. 250).

According to BØGGILD, elpidite has been found in pseudomorphs after eudialyte in the Kangerdluarssuk region. The mineral has been looked for, but not found during the present examination.

Epistolite: (Na,Ca) (Nb,Ti,Mg,Fe,Mn) (OH) SiO_4. (Bøggild, 1953, p. 227).

Flakes of epistolite occur in the albititic rocks and also in some lujavrites. There may be transitions into murmanite as suggested by Danø and Sørensen (1959, p. 31). Murmanite has the composition NaTi(OH)SiO_4 and occurs in Lovozero under similar conditions as the epistolite of Ilímaussaq.

Erikite, see monazite.

Eudialyte-Eucolite: $(Na,Ca,Fe)_6Zr(OH,Cl)(Si_3O_9)_2$. (Bøggild, 1953, p. 247).

A detailed description of the eudialyte from Ilímaussaq has been given by Ussing (1894, pp. 145–175).

In the naujaite eudialyte occurs in large poikilitic grains (with inclusions of sodalite) and in small well-developed crystals (which are up to a few millimetres across). The large grains are of irregular outlines, but generally have partial crystal faces developed. The large grains in the naujaite and naujaite pegmatites have closely spaced lines of dust and liquid inclusions, except in their marginal parts.

The eudialyte of the naujaite pegmatites generally occurs in well-developed crystals.

In the coarse-grained vein (no. three) at the head of Kangerdluarssuk there are crystals of eudialyte which show beautiful zoning parallel to the crystal faces (plate 3, fig. 2). The cores and margins of these grains are made up of eudialyte, the intermediate zones of eudialyte and mesodialyte (see below).

The eudialyte of the lujavrite occurs in perfect small flat crystals which are up to one millimetre across. They have irregular "flames" of mesodialyte and are free from dust and liquid inclusions (plate 11, fig. 1).

Unaltered eudialyte is very rare in the veins of ægirine, acmite, albite and analcime-natrolite.

Eucolite has been observed in rare cases. Adjacent to one of the green veins at the head of Kangerdluarssuk, the eudialyte of the naujaite is penetrated by thin zones of eucolite, the intergrowth being homoaxial. The green vein in this locality contains scattered grains of eucolite. Eucolite has also been observed in pseudomorphs after eudialyte.

According to Kostyleva (1929), the uniaxial positive mineral eudialyte is the (Na_2,K_2,H_2) member of an isomorphous series of which the uniaxial negative eucolite is the other end member, containing (Ca,Mn,Fe,Mg). Mesodialyte is an isotropic intermediate member of this series. The same view is taken by Vlasov et al. A survey of the available analyses of eudialyte and eucolite, indicates, however, that this distinction is somewhat simplified (cf. the table p. 196). The physical conditions of the formation may, in addition to the differences in chemical composition, have played an important role in determining whether eudialyte or eucolite have been formed. In this connection reference is made to heating experiments undertaken by Ussing (op. cit. p. 157) in which eudialyte by heating could be changed into isotropic and uniaxial negative substances.

The alteration of the eudialyte has been described in great detail by Ussing (op. cit.). As is the case in the eucolite of the pegmatites of the Langesundfjord area (Brøgger, 1890), the alteration products are, in the first stages of alteration, confined to small marginal patches, which are sharply demarcated from the unaltered mineral (cf. Danø and Sørensen, 1959, plate 2, fig. 1). In later stages of alteration the grains of eudialyte may be entirely pseudomorphed by secondary minerals (plate 14, fig. 1). It should, however, be mentioned, that entirely unaltered and altered grains may occur close together in the same thin section.

Secondary minerals are katapleite, neptunite, ægirine/acmite needles, analcime, eucolite, schizolite, britholite, monazite, white and brown mica, iron pigmentation, fluorite, natrolite and amorphous substances. The zirfesite of Lovozero has not yet been identified with any certainty. The white mica often occurs in a network composed of small spherulite-like "balls" (cf. BRØGGER, op. cit., p. 507). All of the above-mentioned secondary minerals are only exceptionally found all together; most pseudomorphs after eudialyte are only composed of a few of these minerals. Katapleite, neptunite, analcime and pigmentation are the most prominent. Alteration into zircon, as described by USSING from Sdr. Siorarssuit, has not been observed in the rocks studied by the writer.

Steenstrupine is often associated with the eudialyte pseudomorphs.

Fluorite: CaF_2. (BØGGILD, 1953, p. 69).

This mineral is rare and is especially seen in the eudialyte pseudomorphs. GORDON has mentioned crystal skeletons of white fluorite in a pegmatite from Kangerdluarssuk (BØGGILD, op. cit. p. 69). They may be secondary after dissolved villiaumite (?). The crystal skeletons mentioned by BØGGILD (op. cit. p. 392 may be of a similar origin).

Galena: PbS.

Rare small grains of galena have been found adjacent to veins containing ægirine felt and analcime.

Gonnardite: $(Ca,Na)_3((Al,Si)_5O_{10})_2 \cdot 6\ H_2O$.

At Tugtup agtakôrfia, a fibrous mineral occurs in the border zone of the albititic vein. It is associated with natrolite and ussingite. X-ray powder diagrams of the mineral are identical with diagrams of ranite from the Langesundfjord, which is demonstrated by MASON (1957) to be gonnardite.

No closer study of the mineral from Tugtup agtakôrfia has been undertaken so far.

"Green Mineral":

In thin sections of lujavrites from various localities in Ilímaussaq, scattered grains, up to one millimetre across, of an unidentified mineral have been observed, often in association with eudialyte. The mineral is colourless to faintly green in thin section. The shape of the grains recall that of the eudialyte crystals, the refractive indices are a little lower than those of eudialyte, the birefringence corresponds to that of katapleite or monazite and the mineral is biaxial negative with $2V_X = 26$—$30°$, $v > r$. The mineral is partly or entirely altered into an aggregate of a strongly birefringent mineral for which reason it has not yet been isolated for a more detailed study.

This mineral is most probably the olivine-like mineral mentioned by USSING (1911, p. 173) and it has also been mentioned by BUCHWALD and SØRENSEN (1961, p. 16).

The mineral should be compared with the karnasurtite ($(Ce,La,Th)(Ti,Nb)(Al,Fe)(Si,P)_2O_7(OH)_4 \cdot 3\ H_2O$) from Lovozero (VLASOV, et al., 1959, p. 423) which is uniaxial negative (or anomalously biaxial) with $nO = 1.617$, $nE = 1.595$ and $nO - nE = 0.022$. It is X-ray amorphous, but gives a monazite pattern when heated to 900° C.

Another possibility is nordite (VLASOV et al. 1959, p. 415) which has the formula $Na_3(Sr,Ca)(Mn,Mg,Fe)(Ce,La)(SiO_3)_6$. It has (—) $2V = 27$—$30°$, $nX = 1.619$—1.620, $nY = 1.630$—1.640 and $nZ = 1.642$—1.644.

The α-katapleite from Narssârssuk mentioned by GORDON (1924) is a third possibility.

Igdloite: $NaNbO_3$(?).

Under the name "white mineral" Danø and Sørensen (1959, p. 25) described white aggregates composed of very fine grains of a perovskite-like mineral associated with neptunite, epistolite and analcime. The X-ray powder diagram, the spectrographic analysis and comparison with synthetic $NaNbO_3$ indicated that the mineral might be almost pure $NaNbO_3$ and it was therefore proposed to call the mineral igdloite after the locality Igdlúnguaq. Since this paper was published the mineral has been analyzed by Miss Me Mouritzen with the following result:

SiO_2	13.88
Al_2O_3	1.33
Nb_2O_5	62.35
TiO_2	1.83
Na_2O	15.50
K_2O	0.58
CaO	1.29
BaO	0.13
Loss by ignition	*2.28*
	99.17

The powder separated did not suffice for further determinations.

The impurities in the powder were analcime, epistolite, neptunite and pyrochlore, but in so small amounts, that it was impossible to account for the 13.88 % SiO_2. It is then possible that the mineral contains some SiO_2, but we have decided to postpone the discussion of this problem until a new analysis has been made. The material available for such an analysis is unfortunately insufficent for which reason the further examination of the mineral depends on new collections of the mineral in Greenland.

Since the publication of the above-mentioned paper I have been informed by Dr. L. van Wambeke, Euratom, and Dr. A. Safiannikoff, Goma, that $NaNbO_3$ has been found in the Luesche carbonatite and described under the name *lueschite*. Dr. Safiannikoff kindly sent us some beautiful crystals of the mineral and the X-ray powder diagrams of lueschite and igdloite are practically identical. I have also been informed by Dr. T. Deans, London, that he has found $NaNbO_3$ in an African carbonatite. Until a new analysis of our niobium perovskite has been carried out I prefer to call the mineral igdloite, but it is very likely that the mineral is identical with lueschite.

The igdloite occurs in fractures in analcime-rich rocks with natrolite, neptunite, epistolite, pyrochlore and steenstrupine. It has also been found in albite-bearing veins.

The igdloite is easily distinguished from pyrochlore in thin section, being anisotropic.

According to Rowe (1958) niobium perovskite occurs in the Oka complex where nepheline has been altered into natrolite, thomsonite, white mica, analcime, etc.

Katapleite: $Na_2ZrSi_3O_9 \cdot H_2O$. (Bøggild, 1953, p. 253).

Small plates of katapleite, 0.01–0.1 millimetre across, are commonly found as a secondary mineral after eudialyte, as it has been described in great detail by Ussing (1894, p. 164).

Lithium Mica: (Bøggild, 1953, p. 338).

Large plates of lithium mica occur in the naujaite pegmatites and in the albititic rocks. In both cases the flakes have developed a star-shaped structure

(BØGGILD, op. cit., p. 337, fig. 68) and they may be intergrown with flakes of epistolite. The mica was termed polylithionite by LORENZEN, but we prefer to call it lepidolite on account of the X-ray data. Small flakes of a white mica are common in some lujavrites. Some of these flakes are undoubtedly lithium-mica; the fine-grained ones, which have only been studied in thin section, are mentioned under the name white mica, but they may well be lithium mica.

Lovozerite: $(H,Na,K)_2O \cdot (Ca,Mn,Mg)O \cdot (Zr,Ti)O_2 \cdot 6\,SiO_2 \cdot 3\,H_2O$.

The mineral was first described from Ilímaussaq by DANØ and SØRENSEN (1959). It occurs in small rather equidimensional grains and crystals, up to one millimetre across, in ussingite-bearing rocks and is most probably secondary after eudialyte. The mineral, in the unaltered state, is pink in thin section with polysynthetic twinning and it is uniaxial negative. It is generally strongly altered into micaceous and pigmentary alteration products; it has not yet been possible to isolate the mineral for a closer study. However, professor V. I. GERASSIMOVSKY, who first found and described the mineral in Lovozero, has seen thin sections of the lovozerite from Ilímaussaq and confirmed its identity (see the table p. 196).

Manganese Oxides: (BØGGILD, 1953, p. 129).

Black and brownish black powders are commonly found in fractures and cavities in rocks containing altered ægirine, schizolite and steenstrupine.

Microcline: $KAlSi_3O_8$. (BØGGILD, 1953, p. 376).

The microcline of the agpaitic rocks of Ilímaussaq was first described by USSING (1894). It differs from the microclines of granites, gneisses, syenites, etc. in lacking the cross-hatched twinning. Instead a chess board type of penetration twinning occurs.

The microclines of the rocks described in this paper have not developed any visible perthitic structure, but perthites are common elsewhere in the massif.

Large grains of microcline occur in the naujaite and in its pegmatites. Small lath-shaped grains occur in the lujavrites and in some of the thin veins of felted ægirine in the naujaite. The laths of microcline are flattened parallel to (010) and may be elongated parallel to the a-axis.

The colour of the microcline is white, grey or greenish. A distinct (001) cleavage is developed, the (010) cleavage is rather poor and (110) and $(1\bar{1}0)$ cleavages are rare.

In grains, with all cleavages developed, the relationship between the crystallographic axes and the axes of the indicatrix were determined on the universal stage with the following results: $a:X = 19°$, $b:Z = 19°$, $c:Y = 18°$, which corresponds closely to the stereogram of microcline published by TRÖGER (1956, p. 97). The angles between the crystallographic axes were found to be: α = about 91°, β = about 114° and γ = about 89°. The readings on the universal stage are, of course, somewhat inaccurate; the inaccuracy of the measurements are probably of the order of $\pm 2°$. But the measurements clearly indicate the high triclinity of the microcline. The triclinity has also been determined by means of the X-ray diffractometer according to the method by GOLDSMITH and LAVES (1954) where $\Delta = 12.5\,(d_{(131)} - d_{(1\bar{3}1)}) = 0.99$, that is the highest possible triclinity.

The penetration twinning was, on the universal stage, found to be according to the albite law, which was already stated by USSING. The angles between the twin axis (B) of the albite twins and the axes of the indicatrix were found to be: $B:X = 73°$, $B:Y = 83°$ and $B:Z = 19°$, all values with an accuracy of $\pm 2°$. This corresponds closely with the angles measured on similar microclines in Lovozero, namely 74, 82 and 18° (VLASOV, et al., 1959).

(—) 2V was, in 90 measurements, found to vary from 76 to 88° with most determinations falling in the interval 76–82°. The highest values were measured in grains with a slight undulatory extinction and are therefore regarded as rather inaccurate. In the microcline of Lovozero, (—) 2V is 72–84°; the microcline of Rockall has (—) 2V = 76.5—82° and the same type of twinning as in Ilímaussaq and Lovozero (SABINE, 1960).

The microclines of the rocks studied in the present paper only vary with respect to size and shape. They all have the same type of twinning and no systematic variation in 2V has been detected, the average values for the different rock types being: lujavrites (79°), naujaite (78°), naujaite pegmatite (81°), ægirine felted veins (80°), albitite (81°) and coarse-grained rocks in lujavrite (80°).

In deformed rocks the microcline first obtains an undulatory extinction, which is gradually changed into a peculiar spotted or "gritty" twin structure, the grains being made up of numerous small "spots" of two main optical orientations corresponding to the orientation of the twin lamellae of the original chess board twinning. (plate 3, fig. 3).

USSING (op. cit., p. 12) has published an analysis of microcline from a pegmatite containing 15.82 % K_2O and 0.53 % Na_2O. A few partial analyses have been carried out in connection with the present study giving 16.1–17.0 % K_2O, 0,3–0.5 % Na_2O and 0.0 % CaO. Two partial analyses of perthitic microcline from naujaite pegmatites elsewhere in Ilímaussaq gave 12.9 % K_2O, 3.7 % Na_2O and 0.0 % CaO.

There are, in the pegmatites of Lovozero (VLASOV, et al. 1959), two generations of microcline in the pegmatites, a first generation of large grains and a second generation of small grains, up to 0.3 millimetre long. The latter crystallized later than the prismatic natrolite of the pegmatites. The microclines of the rocks and pegmatites in Lovozero are rather similar, but the microclines of the pegmatites have the lowest content of sodium (0.69–3.56 % Na_2O).

Microcline of the type occurring in Ilímaussaq, Lovozero and Rockall is commonly found in agpaitic nepheline syenites and it has also been described from pegmatites in the Langesundfjord (BRØGGER, 1890, plate 22, fig. 6).

BARTH (1959) has described a similar microcline from Støa occurring in a low grade schist. Its composition is $Or_{97}Ab_3$ and Δ = 0.93. It shows a type of twinning recalling the chess board type described in this paper.

Finally it should be mentioned that authigenic microclines have properties which in many respects recall the "chess board microcline" mentioned above. Thus PERRENOUD (1952) has described an albite-twinned microcline with (—) 2V = 78—82°. BASKIN (1956) has described authigenic microcline with (—) 2V = 80° and a specific "four-ling twinning" according to the albite and pericline laws, that is, a twinning similar to the above.

BARTH (op. cit.) considered the peculiar microcline from Støa to have crystallized at such a low temperature (lower than 300°C) that a triclinic potash feldspar could form directly. At higher temperatures a disordered potash feldspar is first formed which, during cooling, inverts into a cross-hatched microcline.

The peculiar "chess board microcline", found in a number of occurrences of per-alkaline rocks, is then most probably formed at such low temperatures that the potash feldspar crystallized directly with maximum triclinic symmetry. This is in excellent agreement with the petrologic evolution of Ilímaussaq, since these rocks are very rich in sodium and have crystallized in the presence of large quantities of volatiles which could have lowered the temperature of crystallization considerably (cf. SØRENSEN, 1958 and 1960a).

Molybdenite: MoS_2. (BØGGILD, 1953, p. 63).

Rare small scales of this mineral have been found in the naujaite pegmatites.

Monazite: $Ce(PO_4)$.

Clusters of small angular grains of monazite are widespread in the lujavrites and in some of the thin black and green veins (DANØ and SØRENSEN, 1959, p. 12 and plate 1, fig. 1). The single small grains of monazite, up to about 0.1 millimetre across, are associated with altered eudialyte, britholite, steenstrupine, analcime, schizolite, eucolite, biotite, etc.

The mineral *erikite* was shown by DANØ and SØRENSEN (op. cit.) to be composed of very fine-grained aggregates of monazite which might be regarded as pseudomorphs after eudialyte.

A small amount of monazite separated from a lujavrite was partially analyzed by Mr. E. SØRENSEN, Risø who found 138 ppm U, 585 ppm Th, 28,4 % P_2O_5 and 6.1 % SiO_2. The erikite contains, according to BØGGILD (1953, p. 213), 15.12 % SiO_2 and 17.78 % P_2O_5. A part of this SiO_2 may be due to impurities since the erikite is a mixture of monazite and natrolite. The analysis of erikite also gives 9.28 % Al_2O_3, 5.63 % Na_2O, 1.81 % CaO and 6.28 % H_2O indicating that the natrolite has contributed considerably to the SiO_2 of the analysis.

The erikite described from Lovozero (VLASOV, et al., 1959, p. 425) is similar to that from Ilímaussaq, except for the slightly lower refractive indices. It contains 10.82 % SiO_2, 20.06 % P_2O_5 and the formula is given as $(La,Ce)PO_4 . H_2O$. It is considered to be a pseudomorph after a primary rare earth mineral.

There may then be a series of minerals including monazite, and erikite from Ilímaussaq and Lovozero and perhaps also the karnasurtite mentioned on p. 222. Material is being collected for a further discussion of this problem.

The monazite from Ilímaussaq also recalls the earthy monazite from Magnet Cove (ROSE, BLADE and ROSS, 1958) which is poor in thorium and is believed to have been formed by weathering of a rare earth apatite.

The monazite of Ilímaussaq is generally weakly radioactive as demonstrated by BUCHWALD and SØRENSEN (1961, p. 14).

Natrolite: $Na_2(Al_2Si_3O_{10}) . 2H_2O$. (BØGGILD, 1953, p. 399).

Natrolite is widespread in Ilímaussaq and occurs in a number of different forms.

In the naujaite fine-grained aggregates of natrolite replace nepheline and sodalite. The naujaite pegmatites contain stout prisms and fibrous crystals in cavities. The lujavrites may contain considerable amounts of fine-grained natrolite, especially secondary after nepheline. The matrix of the green felt-like veins is often composed of fine-grained, almost equidimensional natrolite. The brown, acmitic veins, the analcime-natrolite veins, and the recrystallized inclusions of naujaite in the lujavrite, contain several types of natrolite; namely, large prisms of bluish green colour, and white, grey and pink masses of dense, partly chalcedony-like natrolite with fibres less than 0.01 millimetre long. Chalcedony-like natrolite has also been described from Lovozero by KUZMENKO (1950).

The natrolite has developed (110) and (010) cleavages, (+) $2V = 54°—61°$ and the larger prisms may show a sort of penetration twinning with (110) as composition plane so that the external symmetry of the grains is nearly tetragonal.

A partial chemical analysis of a large natrolite prism from a coarse-grained analcime-natrolite inclusion in lujavrite at Igdlúnguaq gave: 16.0 % Na_2O, traces of K_2O and 0.0 % CaO.

The large prisms of natrolite often have undulatory extinction.

In the border zone of the albitite at Tugtup agtakôrfia, a white fibrous mineral forms rosettes and sheaf-like groups of thin fibres less than 0.1 millimetre long. The X-ray powder diagram resembles that of natrolite very closely, except for a few small deviations. The study of this mineral has not yet been concluded; as mentioned under gonnardite, this mineral resembles the ranite of the Langesundfjord.

Nepheline: $KNa_3(AlSiO_4)_4$ (Bøggild, 1953, p. 355).

The nepheline and its alteration has been described in great detail by Ussing (1894).

The nepheline of the naujaite is rather dusty and contains inclusions of small grains of sodalite. Besides it has, as has the nepheline of the naujaite pegmatites, small inclusions of microcline and arfvedsonite, up to 0.2 millimetre long, and vermicular inclusions of sodalite. The nepheline of the lujavrites is generally without inclusions and occurs in small stout prisms, up to half a centimetre long, which are generally corroded by analcime and/or natrolite.

An X-ray examination of a few samples of nepheline according to the method by Smith and Sahama (1954) gave the following results:

no. 21056. from naujaite, Igdlúnguaq:	18 mol % $KAlSiO_4$
no. 21084. – – – :	20 – –
no. 20 from pegmatite, Qeqertaussaq:	15 – –
no. 3. from natrolite-analcime vein, West Coast of Igdlúnguaq:	21 – –
no. 21035. white nepheline from coarse-grained analcime rock, east coast of Igdlúnguaq:	15 – –

The old analyses, undertaken by Lorenzen (Bøggild, p. 355), gave about 6 % K_2O, corresponding to 18 % $KAlSiO_4$. Three partial analyses of nos. 20, 21056 and 21084 gave 17.6–17.7 % Na_2O, 4.7–5.6 % K_2O, and 0.0 % or traces of CaO.

The various types of alteration of the nepheline are mentioned in the petrographic chapter. Secondary products are sodalite, analcime and natrolite. The latter may be uniaxial and is thus of the type to be called hydronepheline. Cancrinite has not been observed.

Neptunite: $Na_2FeTi(Si_4O_{12})$. (Bøggild, 1953, p. 256).

The red mineral neptunite, as mentioned by Danø and Sørensen (1959), is widespread in the altered rocks of Ilímaussaq. It is especially associated with altered grains of eudialyte, but is also found associated with ægirine, arfvedsonite and rinkite. It is most prominent in the analcime-rich rocks and is thus most probably of late origin. This corresponds well with the mode of occurrence of neptunite in Lovozero where it is formed at the expense of eudialyte, lomonosovite and lamprophyllite during hydrothermal alteration processes.

Niccolite: NiAs.

Niccolite, associated with galena, breithauptite, maucherite, löllingite, skutterudite and gudmundite, has been found adjacent to an acmitic vein at Igdlúnguaq. This association of ore minerals will be described in a paper by Oen Ing Soen and Sørensen (in press).

Pyrochlore: $(Na,Ca)_2(Nb,Ta,Ti)_2O_6(OH,F,O)$.

Ussing (1911, p. 171) mentioned the occurrence of small cubes of pyrochlore (?) in the arfvedsonite lujavrite. During the present examination pyrochlore has been found to be a rather common mineral in Ilímaussaq, especially in the analcime- and natrolite-rich rocks where it can occur in yellow fine-grained streaks and stringers up to a few centimetres long and one centimetre thick. It often occurs as fracture fillings in these rocks and may then be associated with igdloite.

The X-ray powder diagram shows greater resemblance to microlite than to pyrochlore (a = 10.39 Å), but Dr. L. van WAMBEKE (personal communication) has pointed out that this could be due to a content of strontium. This idea is supported by the spectrographic examination according to which the mineral contains 0.1–1.0 % Sr.

The pyrochlore is only weakly radioactive, this is in contrast to some Canadian occurrences of disseminated highly radioactive pyrochlore in nepheline syenites (ROWE, 1958).

Rinkite: $(Ca,Na,Ce)_{12}(Ti,Zr)_2Si_7O_{31}H_6F_4$ (SAHAMA and HYTÖNEN, 1957). (BØGGILD, 1959, p. 220).

Rinkite has, during this study, only been found in naujaite pegmatites and as rare grains in naujaite. It occurs as yellow prisms which are colourless to pale yellow in thin section. The prisms show polysynthetic twinning and are often altered into earthy brown and black substances, which have not yet been studied.

Schizolite: $(Ca,Mn)_2NaH(SiO_3)_3$. (BØGGILD, 1953, p. 241).

Prisms of schizolite are very widespread in the analcime- and albite-rich rocks. No systematic study of the variation of this mineral throughout the Ilímaussaq rocks has been undertaken so far; all grains of pectolitic appearance are termed schizolite. That the mineral is manganiferous is easily seen in the weathered rocks since the schizolite is then covered by a brownish black earthy alteration product. But other members of the pectolite-schizolite-serandite series may well be present (cf. SCHALLER, 1955).

Sodalite: $Na_8Cl_2(AlSiO_4)_6$. (BØGGILD, 1953, p. 390).

Three main types of sodalite may be distinguished in Ilímaussaq:

1. The green sodalite of the naujaite which is poikilitically enclosed in microcline, ægirine, etc. The grains are rounded or developed as rhombic dodecahedrons, but a prismatic development has also been observed. This sodalite is rich in microlites of ægirine and arfvedsonite from less than 0.01 to about 0.1 millimetre long. There are also liquid inclusions. The microlites are confined to the cores of the grains and may show some arrangement parallel to the faces of the rhombic dodecahedron (cf. USSING, 1894, p. 133). The microlites may be small crystals of ægirine and arfvedsonite caught during the growth of the sodalite or they may be products of exsolution of iron originally present in the sodalite lattice. This sodalite, according to LORENZEN, contains 0.25 % CaO, 0.18 % K_2O, 26.30 % Na_2O and 7.30 % Cl.

2. The nepheline of the naujaite and its pegmatites may contain vermicular inclusions of sodalite (USSING, 1894, plate 7, fig. 1) and may also be surrounded and corroded by sodalite, which is usually free of the dark microlites.

3. Large yellow grains of sodalite occur in the analcime- natrolite veins and in some of the recrystallized inclusions of naujaite in lujavrite. The grains are without dark microlites. This sodalite contains, according to a partial analysis, 0.4 % K_2O, 22.4 % Na_2O, 0.0 % CaO, 5.27 % Cl, 0.55 % S, 0.14 % SO_3 and 1.10 % H_2O. The mineral is thus related to the hackmanite of Lovozero.

The lujavrites contain, in places, small equidimensional grains of sodalite which may have dark microlites in their cores.

The rhombic dodecahedral cleavage is sometimes well-developed, especially in the deformed rocks and the mineral is then commonly penetrated by analcime and natrolite along the cleavages.

The sodalite of all rock types is, to varying extent, replaced by analcime and natrolite (partly developed as hydronepheline). In Lovozero the alteration of the sodalite into natrolite is accompanied by a release of Al_2O_3 so that gibbsite is formed. Neither this mineral, nor diaspore, have been observed during the present study, but flakes of a white mica are common in the natrolite pseudomorphs after sodalite. Ussing (1894, p. 141) has, however, mentioned scales of diaspore in altered sodalite.

Sphalerite: ZnS. (Bøggild, 1953, p. 44).

The naujaite pegmatites, the albitites and the veins containing felted ægirine and analcime-natrolite have large grains of sphalerite, up to three centimetres across. They are generally yellow to brown and contain, according to Kullerud (1953, p. 129), 5.40 mol per cent FeS (in a sample from Tugtup agtakôrfia). This should, by application of the ZnS-FeS thermometer, correspond to a temperature of formation of 170° C, but it should be pointed out that this sphalerite has not been formed in equilibrium with other iron-bearing minerals so that this temperature should be regarded with some reservation.

Small grains of sphalerite are quite common in the lujavrites, especially those rich in analcime.

In places, the sphalerite is partially altered into zones of sheaf-like and fine-grained hemimorphite.

Steenstrupine: $Na_2Ce(Mn,Ta,Fe^3)H_2((Si,P)O_4)_3$. (Bøggild, 1953, p. 227).

The steenstrupine described in the present paper occurs in lujavrites; in veins of albitite, felt-like ægirine, acmite and analcime-natrolite; and in naujaite, naujaite pegmatites and lujavrites adjacent to these veins. The steenstrupine in the veins generally occurs as well-developed crystals with few inclusions, whereas the steenstrupine of the adjacent rocks is found as grains of more irregular shape and richer in inclusions.

Bøggild (1899) distinguished three types of steenstrupine in Ilímaussaq. Type I forms isodiametrical rhombohedral crystals which are generally metamict, but sometimes with anisotropic margins. The grains are, microscopically, brownish yellow to brownish grey with darker coloured margins, and with a more or less pronounced zoning. The grains are often rather heterogeneous. The steenstrupine from Kangerdluarssuk belongs to this type.

Type II forms flat crystals which are brownish yellow to grey in thin section and with darker coloured margins. The crystals are often zoned with isotropic cores and anisotropic margins. The steenstrupine from Igdlúnguaq belongs to this type.

Type III is in isodiametrical crystals which are light-coloured to brownish yellow in thin section. The grains are often anisotropic throughout and may show a weak pleochroism with E yellowish brown and O lighter greyish brown. The cores of these crystals are occasionally isotropic (cf. Buchwald and Sørensen, 1961, p. 24). This type occurs especially at Tugtup agtakôrfia.

The anisotropic steenstrupine is uniaxial negative and has nO = 1.671, nE = 1.660 and nO–nE = 0.011. The metamict steenstrupine has lower indices of refraction. The specific gravity of the anisotropic steenstrupine is 3.51, that of the metamict variety about 3.40.

The steenstrupine of type III has developed a basal cleavage. This is only occasionally seen in the metamict grains.

Type III gives a distinct X-ray powder pattern. The metamict grains, when heated, recrystallize into a mixture of a $(Ce,Th)O_2$-compound and monazite. The metamictization of the steenstrupine has been discussed by BUCHWALD and SØRENSEN (op. cit.) in connection with an autoradiographic examination of this mineral.

BUCHWALD and SØRENSEN (op. cit.) distinguished five types of steenstrupine:

a. In lujavrites,
b. In recrystallized inclusions of naujaite in lujavrite and in veins of felt-like ægirine and analcime.
c. In albititic veins.
d. A reddish brown steenstrupine.
e. Less well defined steenstrupine.

Of these, a, b, and e fall in BØGGILD's types I and II, while c is identical with type III.

Chemical Analyses of Steenstrupine, Tritomite and Britholite

	Steenstrupine			Mangano-steenstrupine	Tritomite	Britholite
	Tugtup agtakôrfia. BØGGILD (1953, p. 229)	Kangerdluarssuk BØGGILD (1953, p. 229).	Lovozero VLASOV et al. (1959, p. 419).	Lovozero VLASOV et. al. (1959, p. 421).	Langesundfjord BRØGGER (1890, p. 484).	Naujakasik, BØGGILD (1953, p. 180).
SiO_2	26.72	20.61	32.10	21.36	13.59	16.77
TiO_2	–	–	–	1.49	–	–
ZrO_2				1.08	1.03	–
ThO_2	2.13	3.84	10.23	11.28	8.58	–
$(Nb,Ta)_2O_5$	4.37	1.58	2.13	–	1.11	–
CeO_2	–	17.85	–	–	11.26	–
$(Ce,La)_2O_3$	29.60	15.52	24.01	20.06	34.46	60.54
Y_2O_3	0.36	2.19	0.77	0.13	2.58	–
Al_2O_3	–	0.40	0.34	0.91	0.88	–
Fe_2O_3	2.67	5.18	1.81	1.99	1.55	0.43
Mn_2O_3	–	5.79	–	–	0.34	–
MnO	6.60	–	9.06	17.98	–	–
MgO	0.31	–	0.05	0.70	–	0.13
BeO	–	1.22	–	–	–	–
CaO	2.33	4.22	1.85	4.66	6.97	11.28
Na_2O	11.23	2.53	2.09	0.48	0.71	1.85
K_2O	–	–	–	0.24	–	–
H_2O	3.45	12.73	12.74	16.44	6.48	1.27
F_2	1.24	–	–	–	3.15	1.33
P_2O_5	8.19	4.53	3.74	0.65	–	6.48
PbO	–	1.02	–	0.10	–	–
B_2O_3	–	–	–	–	8.37	–
UO_2	–	–	–	0.20	–	–
	99.20	99.21	100.92	99.75	101.06	100.08
$—O = F_2$	0.52				1.33	0.56
	98.68	99.21	100.92	99.75	99.73	99.42

The reddish brown steenstrupine is brown to red in thin section. The crystals are often darkest in their central parts, and light-coloured along the margins. Many grains are anisotropic throughout and are then uniaxial negative, others have isotropic cores. This type of steenstrupine is best developed in vein no. 3 at the head of Kangerdluarssuk, but small grains have also been found in other localities associated with the more common type of steenstrupine or as independent grains.

The steenstrupine is often altered into brown and black materials of uncertain composition. There are also brown and black threads composed of numerous small rounded isotropic grains which are less than 0.01 millimetre across. These threads are especially developed in the marginal parts of the crystals, here they may be embedded in analcime. Similar alteration products have been described by VLASOV, et al. (1959) from Lovozero. Some of these are ill-defined, but one alteration product has been described under the name hydrocerite. It is composed $(La,Ce,Th)_2(Si,P)_2O_7.5H_2O$, and is yellow and isotropic in thin section with the index of refraction = 1.580. When heated to 900° it changes into cerite.

The steenstrupine of Ilímaussaq is of such a varied appearance, not only with regard to degree of metamictization and alteration, that it could be referred to as a group of minerals. In order to illustrate this, the steenstrupine of all the rocks mentioned in this paper are briefly described in the petrographical section of the paper. The variability of the steenstrupine of Ilímaussaq corresponds well with the statements found in VLASOV, et al. (1959) with respect to the steenstrupine of Lovozero which is considered as a mineral group with a rather variable chemical composition (see the table p. 230). The refractive index varies from 1.695 to 1.653 and the specific gravity is 3.1. A manganese-rich steenstrupine with refractive index higher than 1.80 and a specific gravity of 3.29 has been termed mangano steenstrupine. The steenstrupine in Lovozero is associated with ussingite, sodalite, natrolite, schizolite and erikite and occurs in the central zeolite zone of the fully differentiated pegmatites or in the zeolitized parts of the pegmatites. The mangano steenstrupine is associated with microcline, ægirine, hackmanite, nenadkevite and schizolite and occurs in the marginal parts of the pegmatites of the poikilitic sodalite syenites.

The rhombohedral steenstrupine crystals have a rather close resemblance to eudialyte crystals and LORENZEN (1881) and MACHATSCHKI (1931) have both considered and rejected the possibility that the steenstrupine was a pseudomorph after eudialyte. In the present paper, it will be demonstrated that steenstrupine often grows on altered eudialyte. According to the old analyses published by BØGGILD (op. cit.) zirconium is not present in the steenstrupine. However, MACHATSCHKI (op. cit.) stated that steenstrupine is richer in zirconium than in niobium in a sample examined spectrographically by him. According to BØGGILD there are up to 4.37 % Nb_2O_5 in the steenstrupine. Spectrographical examinations undertaken in connection with the present study have shown that steenstrupine contains from 500 ppm to more than one per cent Zr, and that "Ce" > "Y" (see also the table p. 230).

The minerals tritomite, melanocerite, karyocerite and cappelenite from the nepheline syenite pegmatites of the Langesundfjord (BRØGGER, 1890) have a rather close resemblance to steenstrupine with regard to mode of occurrence, crystal habit and chemical composition (see the table p. 230), but differ from that mineral in some respects, for instance, in higher refractive indices and in a rather high content of boron (7.83 % B_2O_3 in tritomite and 16.98 % in cappelenite). These minerals are uniaxial negative or metamict. According to NEUMANN, et al. (1957) the X-ray patterns of tritomite and steenstrupine are related.

The tritomite, etc. occur in pegmatites containing analcime, "spreustein", ægirine, sugary-grained albite, sulphides, astrophyllite and others. The cappelenite is associated with eucolite.

Small occurrences of melanocerite have been mentioned from Canada, but no descriptions of these occurrences have been available to the writer.

Thorianite: ThO_2.

Small crystals of this mineral have been found as inclusions in the steenstrupine of the veins composed of felt-like ægirine and analcime (BUCHWALD and SØRENSEN, 1961).

Ussingite: $Na_2AlSi_3O_8(OH)$. (BØGGILD, 1953, p. 396).

This mineral, which for many years was only known from a few boulders, has now been found in a number of localities in Ilímaussaq (DANØ and SØRENSEN, 1959). The mineral has been found as large grains in vein no. 4 at the head of Kangerdluarssuk, as small grains along the margins of the albitite at Tugtup agtakôrfia and as small grains in a number of lujavrites. Outside the areas treated in this paper, ussingite has been found in pegmatites and veins, for instance, associated with chkalovite, analcime and villiaumite in drill cores.

The ussingite has (+) $2V = 35°$, $nX = 1.508$, $nY = 1.512$ and $nZ =$ ca. 1.545. The mineral is easily identified in thin section because of the high interference colours and the fact that nZ is very close to the balsam while nX and nY are considerably lower. There is repeated twinning and the grains are often of a dusty appearance, at least along irregular cracks and fissures. The ussingite replaces sodalite and microcline and is associated with steenstrupine, ægirine, lovozerite, schizolite and sphalerite.

USSINGITE has also been found in Lovozero where it is formed in the hydrothermal stages of pegmatite formation in places where there is no natrolitization (VLASOV, et al., 1959).

White Mica:

Small scales and flakes of a white mica are found in eudialyte pseudomorphs, in altered sodalite, and also scattered through some altered lujavrites. Many of these flakes probably consist of lithium mica but this question must be left open at the moment because of the fine grain size of the flakes.

APPENDIX II

Volumetric analyses.

As stated on earlier pages it is most difficult to treat the rocks described in this paper in a quantitative way.

Many rocks are so coarse-grained and the variation in the proportion of their minerals is so pronounced that the common thin section methods of quantitative determinations cannot be used.

Only the lujavrites may be studied quantitatively and volumetric analyses have therefore been carried out on a number of samples of these rocks. It should be emphasized, however, that only a few small occurrences of lujavrite have been examined and that these rocks should most properly be treated on a regional scale. Thus, it is seen in table II that the lujavrite containing the spheroids is rich in albite and practically free from microcline, but that the rims of the spheroids contain some microcline. The banded lujavrites (table I) are richer in microcline and poorer in albite. This might indicate that the spheroids were formed in sodium-rich rocks and banding in more potash-rich rocks. Most evidence available to the author favours this view. The immiscibility processes discussed on p. 152 should then go on in an extremely sodium-rich environment. However, a microcline-bearing lujavrite at Igdlúnguaq (table I,3) contains white bands (table I,4) related to the rims of the spheroids (cf. p. 154) and it also contains spheroids (see fig. 12). It is therefore necessary, in the author's opinion, to leave the question of the distribution of albite and microcline in the lujavrites open until this problem has been regionally studied in Ilímaussaq. Consequently, the lujavrite discussion in chapter VI is restricted to the features of importance for the understanding of the formation of the steenstrupine.

The border zones between the lujavrite and naujaite, the "dense" analcime-rich rocks and the green and black veins of Qeqertaussaq and the head of Kangerdluarssuk have also been examined volumetrically. The mineralogical compositions of these rocks are, however, so variable, that the volumetric analyses given should only be regarded as examples of the make up of these rocks, other thin sections made of the same specimens would give quite different results.

The amount of steenstrupine present in the different rock types cannot be given with any accuracy except in a few lujavrites (for instance no. 13 in table IV) and green and black veins. In most cases single grains and clusters of many steenstrupine grains are scattered over the rock in such an irregular way that no true estimate is obtained from a study of a single thin section. The content of steenstrupine recorded in the tables is therefore an approximation only.

A SWIFT automatic point counter was used. The intervals between the counted points are 0.3 millimetre; about 800 points were counted per slide. Where the number of points is less than 600 it is indicated in the tables.

I. Banded lujavrites

	no. 21068 Tugtup agtakôrfia		no. 8–13/8 Southwest point of Igdlúnguaq	
	1. Dark band	2. White band	3. Dark band	4. White band
Arfvedsonite...	44	14	29	9
Acmite........	–	2	4	38
Microcline.....	28	1	19	7
Albite	–	–	18	1
Nepheline	9	28	8	8
Sodalite.......	11	–	–	–
Analcime......	5	33	13	29
Eudialyte	3	22	9	7
Green mineral .	–	–	–	1

II. Spheroidal lujavrite from Tugtup agtakôrfia (nos. 21099 and 21100)

	5. Lujavrite surrounding the spheroid	6. White rim of spheroid	7. Core of spheroid (only 266 points counted)
Arfvedsonite.........	34	11	31
Acmite..............	1	23	1
Microcline...........	1	4	–
Albite	45	2	–
Nepheline	8	2	–
Sodalite.............	<1	1	–
Analcime and natrolite	2	37	59
Ussingite............	<1	12	–
Eudialyte	7	6	7
Steenstrupine........	–	1	<1
Green mineral	<1	1	1
Arfvedsonite+acmite .	35	34	32
Light coloured minerals	56+	58	59

III. Lujavrites from the north coast of Tunugdliarfik

	no. 21106		no. 21115		no. 21073
	8. Black lujavrite	9. Green lujavrite	10. Black lujavrite	11. Green lujavrite	12. Brown lujavrite
Arfvedsonite	32	6	46	2	1
Acmite	–	–	–	–	38
Ægirine	2	50	–	45	–
Microcline	11	9	6	26	16
Albite	18	5	1	6	–
Nepheline	18	16	6	11	–
Sodalite	–	–	2	2	–
Natrolite	–	–	–	–	30
Analcime	7	5	32	5	–
Eudialyte and altered eudialyte	11	9	5	2	7
Steenstrupine	–	–	<1	<1	–
Green mineral	<1	–	1	–	–
Schizolite	–	–	–	–	<1
Lepidolite	–	–	–	–	7

IV. Special types of lujavritic rocks

	13. Lujavrite Tuperssuatsiaq (no. 17011)	14. Thin lujavrite vein. Southwest point of Igdlúnguaq (no. 21055 a)	15. Coarse-grained inclusion in no. 14 (no. 21055 b)	16. Black lujavrite adjacent to naujaite, Southwest point of Igdlúnguaq (no. 18499 b)
Arfvedsonite	44	41	32	75
Ægirine/acmite	1	14	6	1
Microcline	13	1	1	–
Albite	17	–	–	–
Nepheline	14	3	15	1
Sodalite	2	–	–	–
Analcime	–	36	27	16
Naujakasite	2	–	–	–
Eudialyte	–	4	15	–
Altered eudialyte	3	–	–	<1
Steenstrupine	4	[1]	4	6

[1]) Scattered grains of steenstrupine occur, but are distributed in such an irregular way that they could not be counted.

V. Lujavrites associated with the albitite at Tugtup agtakôrfia

	17. Apophysis below the albitite (no. 21110)	18. Border zone of the apophysis (no. 21110)	19. Inclusion in the albitite (no. 21063)
Arfvedsonite	35	13	<1
Ægirine/acmite	5	38	66
Microcline	33	9	4
Sodalite	16	20	–
Analcime	4	8	19
Eudialyte	4	4	–
Altered eudialyte	1	6	2
Steenstrupine	1	–	4
Schizolite	<1	<1	1
Igdloite	–	–	2
Lepidolite	–	<1	<1

VI. "Dense" analcime rocks from Igdlúnguaq

	20. Red band (no. 18–13/8)	21. White band (no. 18–13/8)	22. White rock (no. 21080)	23. Arfvedsonite-bearing rock (no. 21004)	24. White rock (no. 5)	25. Lujavrite adjacent to "dense" rock no. 5
Arfvedsonite	–	–	1	9	tr.	52
Acmite	1	3	tr.	2	–	1
Microcline	1	tr.	20	tr.	25	6
Nepheline	11	31	14	–	32	23
Analcime and sodalite	39	32	57	80	20	8
Eudialyte	48	34	8	9	14	10
Monazite	–	–	–	–	9	–

VII. Green and black veins, Qeqertaussaq

	26. Green rock (no. 21118)	27. Black rock with round analcime grains (no. 21120)	28. Dense black rock in no. 27.	29. Black rock (no. 21123)	30. Light coloured part of no. 29
Arfvedsonite . . .	–	43	43	48	18
Egirine	73	–	–	2	14
Microcline	19	10	39	8	2
Albite	4	15	2	35	62
Analcime	–	30	–	1	1
Natrolite	–	–	–		
Eudialyte	–	1	4	–	--
Steenstrupine . .	3	1	12	5	2
Schizolite	<1	–	–	<1	–
Astrophyllite . .	–	<1	–	–	<1

Only 95 points were counted in no. 28 and 380 were counted in no. 30.

VIII. Vein no. 2 and the fine-grained components of vein no. 4
The head of Kangerdluarssuk

	31. Vein no. 2 (no. 21154)	32. Vein no. 4 green rock (no. 21144b)	33. Vein no. 4 green rock between nodules. (no. 21144a)	34. Vein no. 4 Light coloured nodules in no. 33	35. Vein no. 4 Black rock (no. 21145)
Arfvedsonite . . .	35	<1	19	3	39
Egirine/acmite	15	29	25	8	8
Microcline	34	8	9	5	10
Albite	11	45	30	51	19
Sodalite	–	–	–	–	<1
Analcime	2	14	–	31	20
Ussingite	–	–	–	–	<1
Altered eudialyte	1	–	–	–	–
Steenstrupine . .	1	2	6	2	<1
Lovozerite	–	–	10	–	<1
Schizolite	–	<1	–	–	–
Britholite	–	<1	–	–	–
Igdloite	–	<1	–	–	–
Lepidolite	–	–	1	–	<1
Sphalerite	1	–	–	–	<1

449 points were counted in. no. 33, 404 points in no. 34.

IX. Some fine-grained components of vein no. 3
The head of Kangerdluarssuk

<table>
<tr><th></th><th>36. Analcime-rich rock (no. 18467a)</th><th>37. Dense green patches in 36.</th><th>38. Black rock (no. 21158)</th><th>39. Black rock (no. 21162)</th><th>40. Black rock (no. 21161)</th></tr>
<tr><td>Arfvedsonite...</td><td>30</td><td>37</td><td>26</td><td>37</td><td>34</td></tr>
<tr><td>Ægirine/acmite</td><td>26</td><td>40</td><td>12</td><td>4</td><td><1</td></tr>
<tr><td>Microcline .....</td><td>–</td><td>–</td><td>40</td><td>55</td><td><1</td></tr>
<tr><td>Nepheline .....</td><td>–</td><td>–</td><td>–</td><td>–</td><td>14</td></tr>
<tr><td>Analcime......</td><td>31</td><td>5</td><td>12</td><td>–</td><td>40</td></tr>
<tr><td>Natrolite ......</td><td>–</td><td>–</td><td>–</td><td>–</td><td><1</td></tr>
<tr><td>Eudialyte .....</td><td>–</td><td>–</td><td>5</td><td>–</td><td>–</td></tr>
<tr><td>Altered eudialyte ....</td><td rowspan="2">12</td><td>7</td><td>–</td><td rowspan="2">4</td><td>6</td></tr>
<tr><td>Steenstrupine ..</td><td>11</td><td>5</td><td>5</td></tr>
<tr><td>Britholite .....</td><td><1</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>Sphalerite .....</td><td><1</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
</table>

Only 382 points were counted in no. 37.

DANSK RESUMÉ

En undersøgelse af Steenstrupins forekomstmåde i Ilímaussaq massivet; Sydvestgrønland.

Det sjældne mineral steenstrupin er hidtil kun blevet beskrevet fra Ilímaussaq i Sydvestgrønland og fra Lovozero på Kolahalvøen. Det forekommer i begge disse massiver i peralkaline nefelinsyeniter af agpaitisk type.

I 1949 påpegede nu afdøde chefgeolog Richard Bøgvad, at den sydgrønlandske steenstrupin kunne få økonomisk betydning på grund af et vist indhold af thorium. De senere års undersøgelser i Ilímaussaq har vist, at steenstrupin har en betydelig større udbredelse end tidligere antaget og at mineralet, foruden thorium, også indeholder lidt uran. De steenstrupinholdige bjergarter har derfor været genstand for en del opmærksomhed fra geologisk side (Grønlands geologiske Undersøgelse og Universitetets mineralogiske Museum) og fra kemisk side (Atomenergikommissionen).

I nærværende afhandling beskrives nogle "typiske" steenstrupinforekomster, og steenstrupinens dannelsesforhold forsøges tolket. Afhandlingen er et led i en serie publikationer om Ilímaussaqs mineralogi.

I. Indledning.

I Sydgrønland findes en del alkaline intrusioner af hvilke Ilímaussaq er den mest kendte på grund af N. V. Ussings mesterlige beskrivelse fra 1911. Kun en del af Ilímaussaq-intrusionen vil blive behandlet i nærværende afhandling, nemlig den østlige del, som opbygges af agpaitiske nefelinsyeniter. Kun to af de agpaitiske bjergarter forekommer i de beskrevne områder; den ene af disse bjergarter, naujait, findes øverst i intrusionen, mens den anden, lujavrit, underlejrer naujaiten. Naujaiten blev dannet i den første agpaitiske intrusionsfase; lujavriten tilhører den anden og afsluttende fase.

Steenstrupin findes i begge de nævnte bjergarter, samt i sene tynde årer som skærer naujaiten. I afhandlingen beskrives steenstrupinforekomsterne i nogle få udvalgte områder: øen Qeqertaussaq i Kangerdluarssukfjorden; bunden af Kangerdluarssukfjord nord for Lilleelv og en del af nordkysten af Tunugdliarfikfjord (fig. 1).

II. Qeqertaussaq.

Denne ø opbygges af båndet naujait med fladtliggende lag (fig. 2, 3 og 4). Naujaiten indeholder konforme pegmatitgange med en øvre zone rig på mikroklin, arfvedsonit, nefelin, m. m., en nedre zone rig på eudialyt, og en intermediær ægirinzone med rinkit, molybdænglans, zinkblende, lepidolit, m. m. I en af pegmatiterne findes et replacementlegeme med natrolit, steenstrupin, albit, m. m. (fig. 5 og 6). Naujait og pegmatiter skæres af næsten lodrette årer, som er op til nogle få cm tykke.

Disse årer kan inddeles i tre grupper: grønne bestående af filtagtig ægirin, sorte af lujavritisk type, og multiple bestående af grønne, sorte og lyse komponenter. Alle gangtyper indeholder små steenstrupinkrystaller.

III. Bunden af Kangerdluarssuk.

I naujaiten nord for Lilleelv findes en pegmatit af ovennævnte type. Den har steenstrupinrige replacementlegemer, som overvejende består af albit og analcim. Naujaiten (og pegmatiten) skæres af grønne og sorte årer, som kan blive op til en meter tykke. Hvor grønne og sorte bjergarter findes i samme åre, synes de sorte at være yngst. Årerne indeholder en del steenstrupin. En af årerne har grovkornede partier med ussingit, steenstrupin, m. m.

IV. Nordkysten af Tunugdliarfik.

Denne del af Ilímaussaq-massivet opbygges af sort lujavrit med indeslutninger af naujait (fig. 7, 8, 9, 10 og tavle 1). Tre små områder beskrives nøjere:

Igdlúnguaq: Den vestlige del af denne pynt er rig på naujaitindeslutninger, mens den østlige del næsten udelukkende består af sort lujavrit (fig. 9). Lujavriten i den vestlige del er rig på grovkornede partier og på indeslutninger af stærkt omdannet naujait. De naujaitiske indeslutninger skæres af tre typer tynde, sene årer: grønne årer opbygget af filtagtig ægirin, brune årer rige på akmit og/eller arfvedsonit, og lyse årer rige på analcim og natrolit. Alle årer indeholder steenstrupin og mangler eudialyt. Træk af Igdlúnguaqs geologi er vist i fig. 11–25.

Tugtup agtakôrfia: Denne klint opbygges af båndet sort lujavrit, som har fladtliggende lagdeling. I den vestlige del af klinten findes to årer af albitit i lodrette sprækker i en naujaitindeslutning. Den ene af årerne findes i forlængelse af en apofyse fra den lujavrit, som underlejrer naujaiten. Denne lujavrit er kraftigt omdannet i kontakt med albititen. Foroven kiler albititåren ud i den næsten vandrette grænse mellem naujaitindeslutningen og den overliggende lujavrit. Denne øvre del af åren er rig på analcim og indeholder desuden de to sjældne berylliummineraler chkalovit og berylliumsodalit. Albititåren har mørke grænsezoner rige på akmit og steenstrupin. Spredt i albititen findes steenstrupin, lepidolit, schizolit, zinkblende, epistolit, mikroklin, akmit, gul sodalit, m. m. Fig. 26–29 viser træk af Tugtup agtakôrfias geologi.

Steenstrupinholdige lujavriter: I tre horizonter er fundet poikilitiske korn af steenstrupin i grøn, brun og sort lujavrit (fig. 30). De grønne bjergarter er indesluttet i de sorte.

V. Petrografi.

I dette kapitel beskrives de i afhandlingen omtalte bjergartstyper. Beskrivelserne illustreres af fig. 31 og tavle 3–16.

VI. Diskussion.

Naujaitpegmatiterne: De zonare pegmatiter tænkes dannet under naujaitmagmaets størkning i magmalommer med et vist indhold af volatiler. Naujaitens krystallisation foregik ovenfra nedad. Pegmatiternes replacementlegemer er yngre end de grønne ægirinfiltårer, som, i hvert fald stedvis, er dannet i bevægelseszoner i en fuldstændig størknet naujait. Replacementlegemerne må derfor være væsentlig senere end naujaiten (og dens pegmatiter) og må være dannet af udefra kommende "fluider". I denne forbindelse må nævnes, at replacementlegemerne i granitpegmatiter af mange pegmatitspecialister anses for at være dannet ved processer i et lukket pegmatitsystem. Naujaitpegmatiterne har mange lighedspunkter med de agpaitiske pegmatiter i Lovozero (VLASOV et al., 1959).

Lujavriten: En strukturel undersøgelse af sydvestpynten af Igdlúnguaq har vist, at lujavritens intrusion har fulgt fremtrædende jointretninger i naujaiten, samt at de i lujavriten indesluttede naujaitblokke er kippet og roteret under lujavritens fremtrængen (fig. 32).

Lujavritårer og årer med akmit, albit og analcim-natrolit forekommer i umiddelbar forlængelse af hinanden på sprækker i naujaiten (se f. ex. fig. 21). Lujavriten skæres aldrig af de tynde grønne, brune og lyse årer, men den kan stedvis indeslutte brudstykker af grønne årer (fig. 19). Lujavriten er således yngre end de grønne årer og nogenlunde samtidig med de brune og lyse årer.

Det har tidligere været diskuteret om lujavriterne er af magmatisk eller metasomatisk oprindelse (SØRENSEN, 1958). På grundlag af de nu foreliggende oplysninger konkluderes, at den sorte lujavrit er magmatisk, men at den er dannet ved så lave temperaturer, at den magmatiske krystallisation er gået jævnt over i processer af metasomatisk art.

Spheroidale strukturer i den sorte lujavrit (fig. 12) kan være fuldstændigt rekrystalliserede indeslutninger af grøn lujavrit eller af naujait. Det er dog også muligt, at spheroiderne er opstået ved ublandbarhedsprocesser i lujavritmagmaet.

Tætte analcimbjergarter rige på små eudialytkrystaller og undertiden båndede findes i naujaiten i nær tilknytning til tynde lujavritårer. De tætte bjergarter anses for at være dannet ved rekrystallisering af bevægelseszoner i naujaiten.

De grovkornede partier i den sorte lujavrit og de dermed associerede analcimrige bjergarter: De grovkornede bjergarter synes at være dannet ved assimilation af naujait i lujavriten. De analcimrige bjergarter er rekrystalliserede naujaitindeslutninger, som kan være delvis mobiliserede, idet steenstrupinholdige analcimårer grener fra indeslutningerne ud i den omgivende lujavrit (fig. 14, 15, 16).

Tynde årer af ægirinfilt, akmit, albit og analcim-natrolit: *De grønne årer* består overvejende af ægirinfilt, desuden af mikroklin, sen analcim og natrolit, samt albit og steenstrupin. Årerne findes i bevægelseszoner i naujaiten (fig. 18) og anses for at være dannet i første fase af den intrusionsperiode, som kulminerede med dannelsen af den sorte lujavrit.

De brune akmit-arfvedsonitårer er ligesom de grønne årer knyttet til bevægelseszoner i naujaiten, og de kan undertiden findes i forlængelse af lujavritårer (fig. 20 og 21). Akmitårerne anses for at være nogenlunde samtidige med lujavritdannelsen og for at være knyttet til shearzoner i naujaiten dannet i forbindelse med lujavritens intrusion. Grovkornede partier i de brune årer indeholder analcim, natrolit, gul sodalit, steenstrupin, pyrochlor, m. m. og er sandsynligvis dannet af rest-fluider fra lujavriten. De brune årers akmit er, i hvert fald delvis, opstået ved omdannelse og knusning af naujaitisk ægirin og arfvedsonit i bevægelseszoner i naujaiten.

De natrolit-analcim-rige årer og til dels de *albitholdige årer* anses for at være specielle tilfælde af ovennævnte brune årer.

På grundlag af en sammenligning af ovennævnte årer og lignende årer i andre områder konkluderes, at årerne overvejende er af hydrothermal oprindelse. Særlig stor lighed er fundet med visse replacementdannelser og sprækkefyldninger i Khibina og Lovozero på Kolahalvøen og med pegmatiter og årer i Bearpaw Mountains, Montana.

Albititårerne ved Tugtup agtakôrfia er senere end lujavriten og tænkes dannet af fluider afgivet fra lujavriten under eller i slutningen af dennes størkning.

Grovkornede bjergarter i visse af de sene årer anses for at være rester af indesluttet naujait eller af gangbjergarter i naujaiten.

De ovennævnte tynde årer har et vist indhold af mineraler med sjældne jordarter, Th, Nb, Mn, Li, Zn, P, S m. m. De vigtigste af disse mineraler er steenstrupin, monazit, britholit, epistolit, pyrochlor, igdloit, lepidolit, schizolit, zinkblende. Steenstrupin findes især hvor årerne skærer eudialytrige lag i naujaiten. Da eudialyten indeholder en ringe mængde Th, sjældne jordarter, Nb, Mn, m. m., og da de sene årer ikke indeholder eudialyt, men nok pseudomorfoser efter dette mineral, ser det ud til at steenstrupin krystalliserer, hvor der i forvejen er en lidt større koncentration af de sjældne grundstoffer som indgår i steenstrupinen. De omdannede eudialytfragmenter i årerne kan have tjent som krystallisationskim for steenstrupinen. De sjældne grundstoffer stammer da dels fra omdannet eudialyt, dels fra lujavritens restfluider og dels fra materiale udludet langs de sprækker gennem hvilke fluiderne er strømmet. Replacementlegemerne i naujaitpegmatiterne er sandsynligvis dannet af tilsvarende fluider, og disse legemers sjældne mineraler er da udfældet på lignende måde på steder, hvor der i forvejen var en lidt højere koncentration af sjældne grundstoffer. Det spørges til slut, om replacementlegemerne i granitpegmatiter ikke kunne være af tilsvarende oprindelse.

Alkali-aluminium-silicaterne: På grundlag af de i litteraturen tilgængelige resultater af experimentelle undersøgelser af disse mineralers stabilitetsforhold og ud fra kemiske og optiske undersøgelser af de i denne afhandling beskrevne mineraler drages en række konklusioner med hensyn til de forskellige bjergarters dannelsesforhold.

Lujavritens feldspater er en næsten ren maksimum-mikroklin og en meget ren lav-albit. Disse mineraler synes at være dannet i indbyrdes ligevægt. Dette skulle ifølge eksisterende data betyde, at lujavriten er størknet ved lav temperatur, måske omkring 400° C. En lav dannelsestemperatur antydes også af at lujavritens feldspater har stor lighed med authigene feldspater, samt af at analcim i mange tilfælde replacerer albit (og undertiden også mikroklin og nefelin). En del af denne analcim synes at være af direkte magmatisk udfældning, selv om størstedelen vel er af senmagmatisk (deuterisk) oprindelse.

De lyse mineraler i de sene årer er dannet ved samme temperatur eller lavere temperaturer end lujavriten. Om albit eller de vandholdige mineraler analcim og natrolit opstår synes at afhænge af temperaturen, den totale kemiske sammensætning af det givne system og det partielle vandtryk.

Mikroklin findes kun i de grønne filtagtige ægirinårer. En del af denne mikroklin kan være dannet ved knusning af naujaitisk mikroklin, men der er utvivlsomt også tale om nydannet mikroklin. I de fleste grønne årer er mikroklinen delvis eller fuldstændigt replaceret af albit, analcim eller natrolit.

De fra lujavritmagmaet afgivne fluider har været rige på natriumhalogenider og natriumsilicater. Fluiderne har sandsynligvis været af alkalin karakter (cf. FRANCK, 1956 og BARNES og ERNST, 1960), selv om alkaliniteten har varieret, som diskuteret af KORZHINSKY. Fluiderne er afgivet ved temperaturer på ca. 400° C og tryk på nogle få tusinde atmosfærer (vulkanske overfladebjergarter, som af USSING anses for at være knyttet til de alkaline bjergarter i Ilímaussaq, overlejrer sidstnævnte, og det må derfor antages, at de agpaitiske bjergarter er størknet i få kilometers dybde). Fluiderne har derfor til at begynde med mest sandsynligt været kondenserede vandige opløsninger, men med aftagende tryk er en dampfase fraspaltet.

Ægirin/akmit og arfvedsonit – oxidation-reduction: Da ægirin/akmit indeholder Fe^{3+} og arfvedsonit overvejende Fe^{2+} (men også noget Fe^{3+}), kan disse mineralers tilstedeværelse eller fravær i de forskellige bjergarter give oplysninger om det partielle oxygentryk der rådede da bjergarterne blev til. Det må dog bemærkes, at de nævnte mineralers stabilitetsforhold, foruden af det partielle oxygentryk, også er bestemt af temperaturen, den totale kemiske sammensætning og af det partielle vandtryk. Da ægirin/akmit i mange tilfælde synes at være dannet tidligere end den sorte lujavrits arfvedsonit, er det rimeligt at antage, at det partielle oxygentryk var højest i lujavritens første krystallisationsfase.

Det er velkendt at Fe^{2+} oxideres lettere end Mn^{2+}. I overensstemmelse hermed indeholder de akmit-ægirin-holdige bjergarter Mn^{2+}-mineraler som schizolit og neptunit.

Som tidligere beskrevet af Buchwald og Sørensen (1961) er steenstrupinkrystallerne ofte zonare med lyse metamicte kerner, som er stærkt radioaktive, og mørke anisotrope randzoner, som er svagt radioaktive. Det blev dengang antaget, at de ydre dele af steenstrupinkrystallerne var oxiderede således at U^{4+} var omdannet til U^{6+}, som dernæst var udludet. Denne forklaring støttes af den i nærværende afhandling omtalte iagttagelse, at den anisotrope steenstrupin ofte findes i kontakt med akmit.

Steenstrupin og andre sjældne mineraler: I de steenstrupinholdige sene årer mangler eudialyt næsten fuldstændigt, dog er eukolit set i enkelte tilfælde. Steenstrupin findes i det hele taget kun undtagelsesvis associeret med uomdannet eudialyt. Dog kan eudialytkrystaller af og til have steenstrupinrande, og steenstrupin er ofte associeret med pseudomorfoser efter eudialyt. Steenstrupin og eudialyt er krystallografisk beslægtede, men steenstrupinen kan dog ikke opfattes som en pseudomorfose efter eudialyt, idet der som regel er foregået en fuldstændig nedbrydning af eudialyten inden steenstrupindannelsen.

Tre typer steenstrupin er iagttaget i lujavritiske bjergarter:

a. I sort lujavrit fra Tuperssuatsiaq og enkelte andre steder findes små steenstrupinkrystaller sammen med disse bjergarters interstitielle og sidst dannede arfvedsonit. Uomdannet eudialyt er sjælden, hvorimod pseudomorfoser efter eudialyt er almindelige. Steenstrupindannelsen i disse bjergarter anses for at være fremkaldt af et stort indhold af P, Th, Nb og sjældne jordarter i den lujavritiske restsmelte, samt af en lav temperatur.

b. I indeslutninger af grøn og brun lujavrit i sort lujavrit findes poikilitiske steenstrupinkorn. De indesluttede korn af ægirin, mikroklin, etc. er orienteret som i den omgivende bjergart, men er mindre end i denne. Steenstrupinen er altid ledsaget af analcim og anses for at være dannet på steder hvor fluider fra den sorte lujavrit er trængt ind i indeslutningerne af grøn og brun lujavrit.

c. Sort lujavrit i kontakt med naujait har ofte poikilitiske korn af steenstrupin, som synes dannet i forbindelse med krystallisationen af disse bjergarters analcimgrundmasse. Indeslutningerne i steenstrupinen har her bevaret deres oprindelige orientering og størrelse.

De sene årers steenstrupin forekommer som regel i veludviklede krystaller med få indeslutninger. I naujaiten i kontakt med sort lujavrit findes ofte tilsvarende steenstrupinkrystaller, som i de første dannelsestrin er udviklet som krystalskeletter. Steenstrupinkrystallerne i disse bjergarter har ofte udøvet et tryk på omgivelserne under deres vækst og er konformt omsluttet af ægirin, arfvedsonit og feldspat.

De petrografiske studier har vist, at steenstrupin substituerer eudialyt i de analcimrige bjergarter. Dette kan bedst forklares ud fra den antagelse, at steenstrupin er stabil ved lav temperatur, mens eudialyt er stabil ved højere temperatur. Ifølge CHRISTOPHE-MICHEL LÉVY (1961) dannes eudialyt i alkalint milieu ved temperaturer over 440° C. Denne eksperimentelt fastlagte temperatur er i god overensstemmelse med de ovennævnte betragtninger over lujavritens dannelsestemperatur. Det er derfor rimeligt at antage, at steenstrupinen er dannet ved temperaturer under 400° C.

Steenstrupinen er afsat af lujavritiske restfluider med et vist indhold af Th, sjældne jordarter, Nb, P, Mn, Cl, F, m. m. Udskillelsen har ofte fundet sted på omdannede eudialytkorn, hvilket kan forklares ud fra de beslægtede krystalstrukturer. En del af steenstrupinens bestanddele kan derfor stamme fra omdannet eudialyt, men tilført materiale må også have spillet en rolle, idet naujaiten er meget fattig på phosphor, som jo er en vigtig bestanddel af steenstrupinen. De steenstrupindannende fluider må, som anført ovenfor, have været kondenserede vandige opløsninger rige på Na, Cl og F. Det er derfor naturligt at antage, at transporten af de sjældne grundstoffer, som indgår i steenstrupinen, er foregået i form af komplexioner. Med aftagende tryk og temperatur blev komplexerne ustabile, og udfældning fandt sted under dannelse af phosphater, silico-phosphater (steenstrupin), silicater og niobater. Hydrolyse har spillet en vigtig rolle ved udfældningen og resulterede i en frigørelse af HCl og HF, som fjernedes fra systemet. HF har dog stedvis givet anledning til udfældning af NaF (villiaumit) i et sent trin ved lav temperatur. Ved nedbrydningen af eudialyt er frigivet Zr, som delvis er fjernet fra systemet. Det er af betydelig interesse at få fastslået, om en del af det frigivne zirconium er afsat på højere niveauer (cf. caldasit i Poços de Caldas, Brasilien).

VII. Resumé og konklusioner.

Det konkluderes om steenstrupindannelsen, at den er nært knyttet til størkningen af den sorte lujavrit. En del steenstrupin er dannet i en sen fase af lujavritens krystallisation, men vigtigere er den steenstrupindannelse, som er et resultat af den deuteriske krystallisation af analcim i lujavriterne. Endelig er steenstrupin også udfældet fra lujavritiske restopløsninger, som er sivet igennem sprækker i naujaiten, og som har dannet de sene årer.

Appendix I: En alfabetisk ordnet oversigt over de i afhandlingen nævnte mineraler.

Appendix II: Punkttællinger på en del finkornede og forholdsvis homogene bjergarter. Det understreges, at en del af disse tællinger kun må opfattes som eksempler på de pågældende bjergarters sammensætning.

LIST OF REFERENCES

AFANASYEV, M. S., 1937: The Yukspor lovchorrite deposit. XVII Int. Geol. Congr. Moscow, Northern Excursion. 115–118.

AMES, L. L. jr., 1958: Chemical analyses of the fluid inclusions in a group of New Mexico minerals. Ec. Geol. 53, 473–480.

ANDERSON, A. L., 1961: Thorium mineralization in the Lemhi Pass Area, Lemhi County, Idaho. Ec. Geol. 56, 177–197.

BARNES, H. L. & W. G. ERNST, 1960: Reactions with supercritical alkaline aqueous solutions. Ann. Rep. of the director of the Geophysical Laboratory 1959–1960, 63–67.

BARTH, T. F. W., 1952: The differentiation of a composite aplite from the Pribilof Islands, Alaska. Am. Journ. Sc. Bowen volume, 27–36.

— 1956: Studies in gneiss and granite. Norske Vid.-Ak. Oslo I. Mat.-Nat. Kl. 1956, 1. 35 p.

— 1959: The interrelations of the structural variants of the potash feldspars. Zeitschr. Krist. 112, 263–274.

BARTH, T. F. W. & H. BERMAN, 1930: Neue optische Daten wenig bekannter Minerale. Chemie der Erde, 5, 22–42.

BASKIN, Y., 1956: A study of authigenic feldspars. Journ. of Geol. 64, 132–155.

BEARTH, P., 1959: On the alkali massif of the Werner Bjerge in East Greenland. Medd. om Grønl. 153, 4, 63 p.

BEUS, A. A., 1958: The rôle of complexes in transfers and accumulations of rare elements in endogenic solutions. Geochemistry 1958, 4, 388–397.

BONDAM, J. & J. FERGUSON, 1962: An occurrence of villiaumite in the Ilímaussaq intrusion. Medd. om Grønl. 172, 2 (in press).

BONDAM, J. & H. SØRENSEN, 1958: Uraniferous nepheline syenites and related rocks in the Ilímaussaq area, Julianehaab district, Southwest Greenland. Second United Nations Int. Conf. on the peaceful uses of atomic energy, vol. 2, 555–559.

BOYD, F. R., 1959: Hydrothermal investigations of amphiboles. In: P. H. Abelson (ed.). Researches in geochemistry, 377–396. New York, J. Wiley & sons Inc.

BØGGILD, O. B., 1953: The mineralogy of Greenland. Medd. om Grønl. 149, 3, 422 p.

BØGGILD, O. B. & C. WINTHER, 1899: On some minerals from the nephelite-syenite at Julianehaab, Greenland. Medd. om Grønl. 24, 181–213.

BRØGGER, W. C., 1890: Die Mineralien der Syenitpegmatitgänge der Südnorwegischen Augit- und Nephelinsyenite. Zeitschr. Krist. Min. 16, 1–235 and 1–663.

BROTZEN O., 1959: On zoned granitic pegmatites. Acta Univ. Stockholmiensis. Contr. in Geology, III, 3, 71–81.

BROUWER, H. A., 1912: On the formation of primary parallel structure in the lujavrites. Proc. Kon. Ak. Amsterdam, 1912, 734–739.

BUCHWALD, V. & H. SØRENSEN, 1961: An autoradiographic examination of rocks and minerals from the Ilímaussaq batholith, South West Greenland. Medd. om Grønl. 162, 11, 35 p.

BURRI, C., 1928: Zur Petrographie der Natronsyenite von Alter Pedroso (Prov. Alemtejo, Portugal) und ihrer basischen Differentiate. Schw. Min. Petr. Mitt. 8, 374–437.

CAMERON, E. N., R. H. JAHNS, A. H. MCNAIR & L. R. PAGE, 1949: Internal structure of granitic pegmatites. Ec. Geol. Monograph 2, 1–115.

CHAYES, F., 1950: On a distinction between late magmatic and post magmatic replacement reactions. Am. Journ. Sc. 248, 52–66.

CHIRVINSKY, P. N., 1939: Paleohydrogeology of Khibina Tundras (in Russian). Bull. Ac. Sc. S.S.S.R., Sér. Géol. 1939, 4, 23–43.

COOMBS, D. S., 1955: X-ray observations on wairakite and non-cubic analcime. Min. Mag. 30, 699–708.

— 1960: Lower grade mineral facies in New Zealand. XXI Int. Geol. Congr. 1960, XIII, 339–351.

COOMBS, D. S., A. J. ELLIS, W. S. FYFE & A. M. TAYLOR, 1959: The zeolite facies; with comments on the interpretation of hydrothermal synthesis. Geoch. Cosmoch. Acta, 17, 53–107.

CHRISTOPHE-MICHEL LÉVY, M., 1954: Reproduction synthétique de minéraux voisins de l'aegyrine par voie hydrothermale, II. Temperature de formation de l'aegyrine. Bull. Soc. Fr. Min. Crist. 77, 1328–1329.

— 1961: Reproduction artificielle de quelques minéraux riches en zirconium (zircon, eudialyte, catapléite, elpidite); comparison avec leurs conditions naturelles de formation. Bull. Soc. Fr. Min. Crist. 84, 265–269.

DANØ, M. & H. SØRENSEN, 1959: An examination of some rare minerals from the nepheline syenites of South West Greenland. Medd. om Grønl. 162, 5, 35 p.

DREVER, H. I., 1960: Immiscibility in the picritic intrusion at Igdlorssuit, West-Greenland. XXI Int. Geol. Congr. 1960, XIII, 47–58.

EMMONS, R. C., 1953: Petrogeny of the nepheline syenites of Central Wisconsin. Mem. Geol. Soc. Am. 52, 71–87.

ERNST, W. G., 1959: Alkali amphiboles. Ann. Rep. of the director of the Geophysical Laboratory 1958–1959, 121–126.

EUGSTER, H. P., 1959: Reduction and oxidation in metamorphism. In: Researches in geochemistry. Ed. by Ph. H. Abelson, 397–426. New York, John Wiley & sons, Inc.

FERGUSON, J., 1962a: A possible mode of emplacement of the Ilímaussaq intrusion (summary). Medd. Dansk geol. Foren. 15, 144–145.

— 1962b: Geology of the Ilímaussaq intrusion. Medd. om Grønl. 172, 4 (in press).

FERGUSON, R. B., 1960: The low temperature phases of the alkali feldspars and their origin. Can. Min. 6, 415–436.

FERSMAN, A., 1929: Geochemische Migration der Elemente. Teil I. Abh. prakt. Geol. und Bergwirtschaftslehre, 18, 1–73.

— 1937: Mineralogy of the Khibina and Lovozero Tundras. Ac. Sc. Press, Moscow, Eng. Ed. 152 p.

FISCHER, G. & J. NOTHHAFT, 1954: Natronamphibol (Osannit)—Aegirinschiefer in den Tarntaler Bergen. Tsch. Min. Petr. Mitt. 3. folge, 4, 396–420.

FLINK, G., 1898: Berättelse om en mineralogisk Resa i Syd-Grønland sommaren 1897. Medd. om Grønl. 14, 221–62.

FRANCK, E. U., 1956: Hochverdichteter Wasserdampf. Ionendissociation von HCl, KOH, und H_2O in überkritischem Wasser. Z. f. physik. Chemie N. F. 8, 92–106, 107–126, & 192–206.

FRANCO, R. R. & W. LOEWENSTEIN, 1948: Zirconium from the region of Poços de Caldas. Am. Min. 33, 142–151.

Friedman, I., 1950: Immiscibility in the system H_2O—Na_2O—SiO_2. Am. Chem. Soc. Journ. 72, 4570–4574.

Frondel, C. & U. B. Marwin, 1959: Cerianite, CeO_2, from Poços de Caldas, Brazil. Am. Min. 44, 882–884.

Fyfe, W. S., F. J. Turner & J. Verhoogen, 1958: Metamorphic reactions and metamorphic facies. Mem. Geol. Soc. Am. 73, 259 p.

Garrels, R. M., 1960: Mineral equilibria. New York. 254 p.

Gerassimovsky, V. I., 1956: Geochemistry and mineralogy of nepheline syenite intrusions. Geochemistry, 1956, 5, 494–510.

Ginzbourg, A. I., 1960: Specific geochemical features of the pegmatitic process. XXI Int. Geol. Congr. 1960, XVII, 111–121.

Goldsmith, J. R. & F. Laves, 1954: The microcline—sanidine stability relations. Geoch. Cosmoch. Acta, 5, 1–19.

Goldschmidt, V. M., 1930: Elemente und Minerale pegmatitischer Gesteine. Nachr. Gesell. Wiss. Göttingen, math. phys. Kl. 370–378.

Gorai, M., 1951: Petrological studies on plagioclase twins. Am. Min. 36, 884–901.

Goranson, R. W., 1927: Aegirite from Libby, Montana. Am. Min. 12, 37–39.

Gordon, S. G., 1924: Minerals obtained in Greenland on the Second Academy-Vaux Expedition, 1923. Proc. Ac. Nat. Sc. Philadelphia, 76, 249–268.

Guimaraes, D., 1948: The zirconium ore deposits of the Poçoc de Caldas plateau, Brazil. Bol. Inst. Tech. Indust. Minas Gerais, 1948, 6, 41–79.

Heinrich, E. Wm., 1958: Mineralogy and geology of radioactive raw materials. Mc. Graw-Hill, New York, 654 p.

Hemley, J., 1959: Some mineralogical equilibria in the system K_2O—Al_2O_3—SiO_2—H_2O. Am. Journ. Sc. 257, 241–270.

Huang, W. T., 1959: Occurrences of eucolite in northern Hudspeth County, Texas. Can. Min. 6, 399–402.

Hytönen, K., 1959: On the petrology and mineralogy of some alkaline volcanic rocks of Toròr Hills, Mt. Moroto, and Morulinga in Karamoja, Northeastern Uganda. Bull. Comm. Géol. Finl. 184, 75–132.

Jahns, R. H., 1954: Pegmatites of southern California. Calif. Div. Mines, Bull. 170, chapter VII, 37–50.

Jahns, R. H., 1955: The study of pegmatites. Ec. Geol. 50th. Ann. Vol. II, 1078–1112.

Kaplan, G. E. & T. A. Uspenskaya, 1958: Investigations on alkaline methods for monazite and zircon processing. U. N. Peaceful Uses of Atomic Energy. Proc. second Int. Conf. vol. 3, 378–382.

Kennedy, G. C., 1955: Some aspects of the role of water in rock melts. Geol. Soc. Am. Special paper 62, 489–503.

Koizumi, M. & R. Kiriyama, 1957: Hydrothermal study of dehydrated natrolite. Bull. Geol. Soc. Am. 68, 1755 (abstract).

Korzhinsky, D. S., 1956: Dependence of activity of components upon the solution acidity and reaction sequence in postmagmatic processes. Geochemistry, 1956, 643–652.

— 1959: The advancing wave of acidic components in ascending solutions and hydrothermal acid base differentiation. Geoch. Cosmoch. Acta, 17, 17–20.

— 1960: Acidity—Alkalinity in magmatic processes. XXI. Int. Geol. Congr. 1960, XXI, 160–170.

Kosterin, A. V., 1959: The possible modes of transport of the rare earths by hydrothermal solutions. Geochemistry, 1959, 4, 381–387.

KOSTYLEVA, E. E., 1929: Isomorphe Reihe Eudialyt-Eucolit aus den Chibina- und Lujawrurt Tundren. Trav. Mus. Min. Ac. Sc. S.S.S.R., 3, 169–222 (abstract N. Jahrb. 1931, I, 363–366).
KRAUSKOPF, K. B., 1948: Mechanism of eruption at Parícutin Volcano, Mexico. Bull. Geol. Soc. Am. 59, 711–732.
KULLERUD, G., 1953: The FeS—ZnS system. A geological thermometer. Norsk geol. Tidsskr. 32, 61–147.
KUZMENKO, M. V., 1950: Chalcedony-like natrolite in pegmatites of alkalic magmas (in Russian). Dokl. Ac. Sc. SSSR, 1950, 72, 767–770 (abstract Min. Abstr. 11, 549).
LANDES, K. K., 1933: Origin and classification of pegmatites. Am. Min. 18, 33–56 & 95–103.
LARSEN, E. S., 1941: Alkalic rocks of Iron Hill, Gunnison County, Colorado. U.S. geol. Surv. Prof. Paper. 197A, 64 p.
LARSEN, E. S., C. S. HURLBUT, et al., 1939 & 1941: Igneous rocks of the Highwood Mountains, Montana. Bull. Geol. Soc. Am. 50, 1939 & 52, 1941.
LARSEN, E. S. & J. T. PARDEE, 1929: The stock of alkaline rocks near Libby, Montana. Journ. Geol. 37, 97–112.
LORENZEN, J., 1881: Undersøgelse af Mineralierne i Sodalith-Syeniten fra Julianehaabs Distrikt. Medd. om Grønl. 2, 43–80.
LOVERING, J. K. & C. DURRELL, 1959: Zoned gabbro pegmatites of Eureka Peak, Plumas County, California. Journ. Geol. 67, 253–268.
LUCHITSKI, V. J., 1947: Alkali metasomatism in the region of the Ukrainian crystalline massif (in Russian). Dokl. Ac. Sc. SSSR, Nov. Ser. 55, 49–52 (abstract in Z.bl. Min. 1949 II, 306).
MACKEVETT, E. M. jr., 1958: Geology of the Ross-Adams uranium-thorium deposit, Alaska. U.N. Peaceful Uses of Atomic Energy, Proc. second Int. Conf. vol. 2, 502–508.
MACHATSCHKI, F., 1931: Über den Steenstrupine. N. Jahrb. Min. Beil. Bd. 64A, 235–250.
MACKIN, J. H. & E. INGERSON, 1960: An hypothesis for origin of ore-forming fluid. US Geol. Surv. Prof. paper, 400-B, 1–2.
MARTIN, H., M. MATHIAS & E. S. W. SIMPSON, 1960: The Damaraland subvolcanic ring complexes in South West Africa. XXI Int. Geol. Congr. 1960, XIII, 156–174.
MASON, B., 1957: Gonnardite (ranite) from Langesundfjord. Norsk geol. Tidsskr. 37, 435–437.
MAURICE, O. D., 1949: Transport and deposition of the non-sulphide vein minerals, V. Zirconium minerals. Ec. Geol. 44, 721–731.
MILTON, C., E. C. T. CHAO, J. J. FAHEY & M. E. MROSE, 1960: Silicate mineralogy of the Green River Formation of Wyoming, Utah, and Colorado. XXI. Int. Geol. Congr. 1960, XXI, 171–184.
MOORE, F. E., 1952: Authigenic albite in the Green River Shale. Journ. Sed. Petr. 20, 227.
MOREY, G. W., 1957: The solubility of solids in gases. Ec. Geol. 52, 225–251.
MOREY, G. W. & W. T. CHEN, 1955: The action of hot water on some feldspars. Am. Min. 40, 996–1000.
MOREY, G. W. & E. INGERSON, 1937: The pneumatolytic and hydrothermal alteration and synthesis of silicates. Ec. Geol. 32, 607–761.
MUELLER, R. F., 1961: Oxidation in high temperature petrogenesis. Am. Journ. Sc. 259, 460–480.

MURTHY, M. V. N., 1958: On the crystallization of accessory zircon in granitic rocks of magmatic origin. Can. Min. 6, 260–263.

NABOKO, S. I., 1957: A case of gaseous fluorine metasomatism of an active volcano. Geochemistry 1957, 5, 452–455.

NEUMANN, H., 1948: On hydrothermal differentiation. Ec. Geol. 43, 77–83.

NEUMANN, H., T. SVERDRUP & P. C. SÆBØ, 1957: X-ray powder patterns for mineral identification. III. Silicates. Norske Vid.-Ak. Oslo. I. Mat.-Nat. Kl. 1957, 6.

OEN ING SOEN & H. SØRENSEN, 1962: An occurrence of nickel arsenides and nickel antimonides at Igdlúnguaq, the Ilímaussaq alkaline complex. Medd. om Grønl. 172, 1 (in press).

OFTEDAHL, C., 1960: Permian rocks and structures of the Oslo Region. "Geology of Norway" (Ed. O. HOLTEDAHL). N.G.U. 208, 298–343.

OLSON, J. C., D. R. SHAWE, L. C. PRAY & W. N. SHARP, 1954: Rare-earth mineral deposits of the Mountain Pass District, San Bernardino County, California. U.S. Geol. Surv. Prof. Paper, 261, 1–75.

OLSON, J. C. & S. R. WALLACE, 1956: Thorium and rare-earth minerals in Powderhorn District, Gunnison County, Colorado. Geol. Surv. Bull. 1027–0, 693–723.

ORVILLE, P. M., 1959: Feldspars. Ann. Report of the director of the Geophysical Laboratory 1958–1959, 118–121.

— 1960: Alkali feldspar—alkali chloride hydrothermal ion exchange. ibid. 1959–1960, 104–108.

OSBORN, E. F., 1959: Role of oxygen pressure in the crystallization and differentiation of basaltic magma. Am. Journ. Sc. 257, 609–647.

PAGE, L. R. et al., 1953: Pegmatite investigations 1942–1945. Black Hills, South Dakota. U.S. Geol. Surv. Prof. Paper 247, 228 p.

PECORA, W. T., 1942: Nepheline syenite pegmatites, Rocky Boy Stock, Bearpaw Mountains, Montana. Am. Min. 27, 397–424.

— 1948: Telescoped, xenothermal association in alkalic pegmatites and related veins, Vermiculite prospect, Bearpaw Mountains, Montana (abstract). Am. Min. 33, 205–206.

PECORA, W. T. & J. H. KERR, 1953: Burbankite and calkinsite, two new carbonate minerals from Montana. Am. Min. 38, 1169–1183.

PERRENOUD, J.-P., 1952: Étude du feldspath potassique contenu dans le "Pontiskalk" (Trias, Valais). Schw. Min. Petr. Mitt. 32, 179–184.

POVARENNYKH, A. S., 1954: Problems of zeolitization of alkaline rocks (in Russian). Dokl. Ac. Sc. SSSR, 94, 761–764. (Abstracts: Min. Abstr. 12, p. 482 and Z.Bl. Min. Petr. 1955 II, 15).

RAMBERG, H., 1960: A study of veins in Caledonian rocks around Trondheim Fjord, Norway. Norsk geol. Tidsskr. 41, 1–44.

RAMSAY, W., 1890: Geologische Beobachtungen auf der Halbinsel Kola. Petrographische Beschreibung der Gesteine des Lujavrurt. Fennia, 3, 7, 52 p.

RAMSAY, W. & V. HACKMAN, 1894: Das Nephelinsyenitgebiet auf der Halbinsel Kola. I. Fennia, 11, 2, 225 p.

REINHARD, M., 1931: Universal Drehtischmethoden. Einführung in die kristalloptischen Grundbegriffe und die Plagioklasbestimmung. Basel. 119 p.

REITAN, P. H., 1960: The genetic significance of two kinds of basified zones near small pegmatite veins. XXI. Int. Geol. Congr. 1960, XVII, 102–107.

REKHARSKII, V. I., 1960: Zoning in hydrothermal alteration halos near veins of rare metals. Geochemistry, 1957, 3, 307–316.

REYNOLDS, D. L., 1954: Fluidization as a geological process, and its bearing on the problem of intrusive granites. Am. Journ. Sc. 252, 577–613.

Ringwood, A. E., 1955: The principles governing trace element behaviour during magmatic crystallization. Geoch. Cosmoch. Acta, 7, 189–202 & 242–254.
Rose, H. J. jr., L. V. Blade & M. Ross, 1958: Earthy monazite at Magnet Cove, Arkansas. Am. Min. 43, 995–997.
Rowe, R. B., 1958: Niobium (columbium) deposits of Canada. Geol. Surv. Canada, Ec. geol. Ser. 18, 108 p.
Sabine, P. A., 1950: The optical properties and composition of the acmitic pyroxenes. Min. Mag. 29, 113–125.
— 1960: The geology of Rockall, North Atlantic. Bull. Geol. Surv. Great Britain 16, 156–178.
Safiannikoff, A., 1955: Classification des pegmatites du Congo Belge et du Ruanda-Urundi. Soc. géol. Belgique, 78, fasc. spec. 57–70.
Sahama, Th. G., 1956: Optical anomalies in arfvedsonite from Greenland. Am. Min. 41, 509–512.
Sahama, Th. G. & K. Hytönen, 1957: Unit cell of mosandrite, johnstrupite and rinkite. Geol. Fören. Stockh. Förh. 79, 791–796.
Sand, L. B., R. Roy & E. F. Osborn, 1957: Stability relations of some minerals in the Na_2O—Al_2O_3—SiO_2—H_2O system. Ec. Geol. 52, 169–179.
Schaller, W. T., 1925: The genesis of lithium pegmatites. Am. Journ. Sc. 210, 269–279.
— 1955: The pectolite—schizolite—serandite series. Am. Min. 40, 1022–1031.
Schüller, K.-H., 1958: Das Problem Akmit—Ägirin. Beitr. Min. Petr. 6, 112–138.
Semenov, E. I. & A. V. Bykova, 1960: Beryllosodalite (in Russian). Dokl. Ac. Sc. SSSR, 133, 1191–1193.
Shand, S. J., 1949: Eruptive rocks. J. Wiley & Sons, Inc. 488 p.
Shcherbina, V. V., 1957: Behavior of uranium and thorium in the sulfate—carbonate and phosphate environments of the supergene zone. Geochemistry 1957, 6, 579–597.
— 1960: Die Verteilungseigenarten einiger seltener Elemente in Mineralien einer gemeinsamen Paragenese. N. Jb. Min. Abh. 94, Festband Ramdohr, 1093–1100.
Smith, F. G., 1948: Transport and deposition of the non-sulphide vein minerals. III. Phase relations at the pegmatite stage. Ec. Geol. 43, 535–546.
— 1954: Composition of vein-forming fluids from inclusion data. Ec. Geol. 49, 205–210.
Smith, J. V. & Th. G. Sahama, 1954: Determination of the composition of natural nephelines by an X-ray method. Min. Mag. 30, 439–449.
Solodov, N. A., 1959: Certain regularities of distribution of rare elements in sharply zoned granite pegmatites. Geochemistry 1959, 4, 388–405.
Sørensen, H., 1958: The Ilímaussaq batholith, a review and discussion. Medd. om Grønl. 162, 3, 48 p.
— 1960a: On the agpaitic rocks. XXI. Int. Geol. Congr. 1960, XIII, 319–327.
— 1960b: Beryllium minerals in a pegmatite in the nepheline syenites of Ilímaussaq, South West Greenland. XXI. Int. Geol. Congr. 1960, XVII, 31–35.
Stobbe, H. & E. G. Murray, 1956: A new occurrence of eucolite near Wausau, Marathon County, Wisconsin. Am. Min. 41, 932–934.
Strakhov, N. M., 1958: Méthodes d'Étude des roches sédimentaires. Ann. Serv. d'Inform. géol. du Bur. Rech. Géol. Géoph. et Minières. I & II.
Strauss, C. A. & F. C. Truter, 1950: The alkali complex at Spitzkop, Sekuniland, Eastern Transvaal. Geol. Soc. South Africa, trans. 53, 81–130.
Strunz, H., 1957: Mineralogische Tabellen. 3. Aufl. Leipzig.

SUZUKI, J., 1938: On the occurrence of aegirite-augite in natrolite veins in dolerite from Nemuro. Journ. Fac. Sc. Hokkaido. Imp. University. Ser. IV. 3, 183–191.

TILLEY, C. E., 1958: Problems of alkali rock genesis. Quart. Journ. Geol. Soc. 113, 323–360.

TRÖGER, W. E., 1956: Optische Bestimmung der gesteinsbildenden Minerale. Teil 1. Bestimmungstabellen. Stuttgart. 147 p.

TUTTLE, O. F. & I. I. FRIEDMAN, 1948: Liquid immiscibility in the system H_2O—Na_2O—SiO_2. Am. Chem. Soc. Journ. 70, 919–926.

TURNER, F. J. & J. VERHOOGEN, 1960: Igneous and metamorphic petrology. McGraw-Hill Book Company, 694 p.

UPTON, B. G. J., 1961: Textural features of some contrasted igneous cumulates from South Greenland. Medd. om Grønl. 123, 6, 29 p.

USSING, N. V., 1894: Mineralogisk-petrografiske Undersøgelser af Grønlandske Nefelinsyeniter og beslægtede bjergarter. Medd. om Grønl. 14, 1–220.

— 1911: Geology of the country around Julianehaab. Greenland. Medd. om Grønl. 38, 376 p.

VARLAMOFF, N., 1958: Zonéographie de quelques champs pegmatitiques de l'Afrique centrale et les classifications de K. A. Vlassov et de A. I. Guinsbourg. Bull. Soc. géol. Belgique, 82, 55–87.

VLASOF, K. A., M. V. KUZMENKO & E. M. ESKOVA, 1959: The Lovozero Alkaline Massif (in Russian). The Academy of Sciences, Moscow, 624 p.

WAGER, L. R., G. M. BROWN & W. J. WADSWORTH, 1960: Types of igneous cumulates. Journ. Petrology, 1, 73–85.

WALKER, F., 1953: The pegmatitic differentiates of basic sheets. Am. Journ. Sc. 251, 41–60.

WHITE, D. E., 1957: Thermal waters of volcanic origin. Bull. Geol. Soc. Am. 68, 1637–1658.

WILKINSON, J. F. G., 1958: The petrology of a differentiated teschenite sill near Gunnedah, New South Wales. Am. Journ. Sc. 256, 1–39.

WILSHIRE, H. G., 1961: Sedimentary xenoliths and dolerite patch pegmatites from an analcite basalt intrusion. Am. Journ. Sc. 259, 260–279.

WYART, J., 1954: Reproduction synthétique de mineraux voisins de l'aegyrine par voie hydrothermale. I. Synthèse de l'aegyrine $NaFeSi_2O_6$ et de l'aegyrine potassique $KFeSi_2O_6$. Bull. Soc. Fr. Min. Crist. 77, 1322–1327.

WYART J. & M. CHRISTOPHE-MICHEL LÉVY, 1955: Reproduction hydrothermale des feldspathoides du groupe de la nepheline et de la sodalite. Bull. Soc. Fr. Min. Crist. 78, 577–584.

WYART, J. & G. SABATIER, 1956a: Mobilité des ions alcalins et alcalino-terreux dans les feldspaths. Bull. Soc. Fr. Min. Crist. 79, 444–448.

WYART, J. & G. SABATIER, 1956b: Transformations mutuelles des feldspaths alcalins. Reproductions du microcline et de l'albite. Bull. Soc. Fr. Min. Crist. 79, 574–581.

YAGI, K., 1953: Petrochemical studies on the alkalic rocks of the Morotu District, Sakhalin. Bull. Geol. Soc. Am. 64, 769–810.

YODER, H. S., 1958: Effect of water on the melting of silicates. Ann. Rep. of the Director of the Geophysical Laboratory 1957–1958, 189–191.

Færdig fra trykkeriet den 8. juni 1962.

PLATES

Plate 1.

Geological map of the southwest point of Igdlúnguaq. The dark coarse-grained inclusions in lujavrite are indicated as coarse-grained lujavrite. The light coloured inclusions as analcime rocks, but the latter symbol also incorporates the "dense" analcime rocks and the coarse-grained patches in the acmite veins.

GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND

MEDD. OM GRØNL. BD. 167 NR. 1 (H. SØRENSEN)

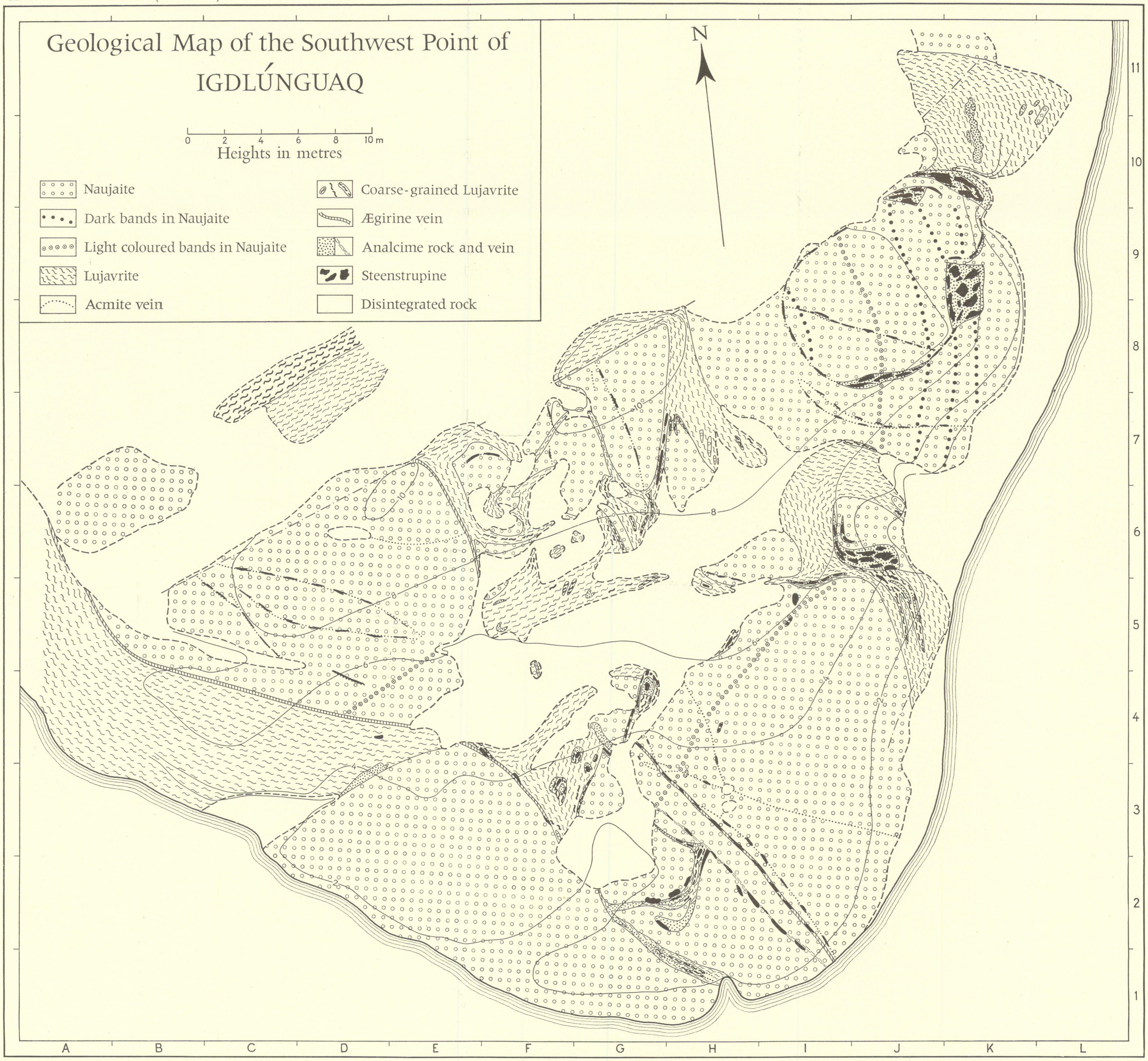

Plate 2.

Aerial photograph of the tip of the southwest point of Igdlúnguaq (copyright the Geological Survey of Greenland). In centre the white band at **H.3** of plate 1. The photograph covers the area south of the line **D.4** to **J.7** (plate 1). The white areas to the left are minute icebergs.

Plate 3.

Fig. 1.

No. H18467f. $\times 33$, + nic. Twinned analcime with patches displaying the "gritty" structure. Vein no. 3, the Head of Kangerdluarssuk.

Fig. 2.

No. 21159a. $\times 27$, + nic. Zoned crystal of eudialyte enclosed in matrix of analcime with arfvedsonite (bottom centre) and natrolitized nepheline (top right). Small patchy grains of steenstrupine occur along the margin of the eudialyte. Vein no. 3, the Head of Kangerdluarssuk.

Fig. 3.

No. 18506a. $\times 27$, + nic. Microcline with chess board twinning (bottom) and "gritty" structure (top). In the "gritty" part of the grain the chess board twinning is faintly seen. In the lower part of the photograph there are irregular fractures parallel to the border between the two parts of the microcline grains. Green vein, the southwest point of Igdlúnguaq.

(Chr. Halkier, phot.).

Fig. 1.

Fig. 2.

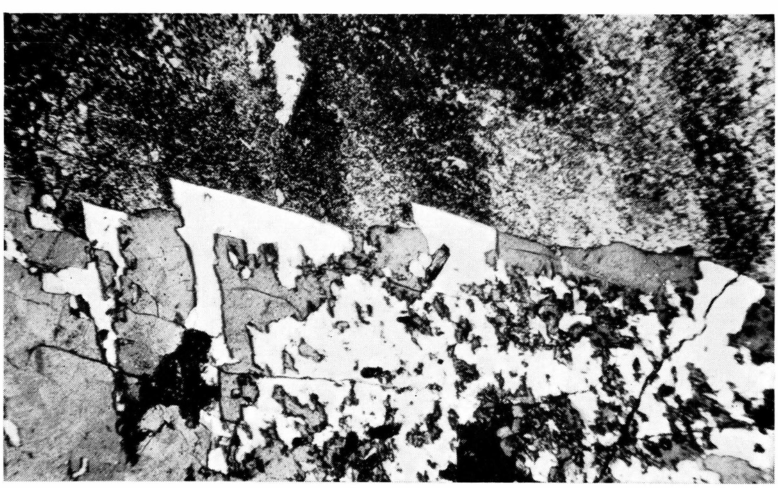

Fig. 3.

Plate 4.

Fig. 1.

No. 5. × 27, 1 nic. Border between lujavrite (left) and "dense" analcime rock (right). The "dense" rock is composed of small crystals of eudialyte (high relief) and closely packed nepheline grains in a sparse network of analcime. The lujavrite has, in addition to these minerals, arfvedsonite and a subordinate amount of microcline. The west coast of Igdlúnguaq.

Fig. 2.

No. 21049b. × 27, 1 nic. Border between "dense" rock and lujavrite. The "dense" rock is rich in small eudialyte crystals (high relief) and further contains scattered grains of nepheline, deformed microcline, arfvedsonite and ægirine in a groundmass of analcime. The lujavrite contains large grains of arfvedsonite (black), small eudialyte crystals and corroded nepheline grains in a groundmass of analcime. The arfvedsonite contains inclusions of eudialyte, ægirine and analcime. In centre: a hole in the thin section. Southwest point of Igdlúnguaq.

Fig. 3.

No. 18512a. × 33, 1 nic. "Dense" analcime-rich rock with small crystals of eudialyte and prisms of arfvedsonite (with inclusions of eudialyte and ægirine). Bottom left: a large pseudomorph after eudialyte associated with large grains of arfvedsonite. Southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

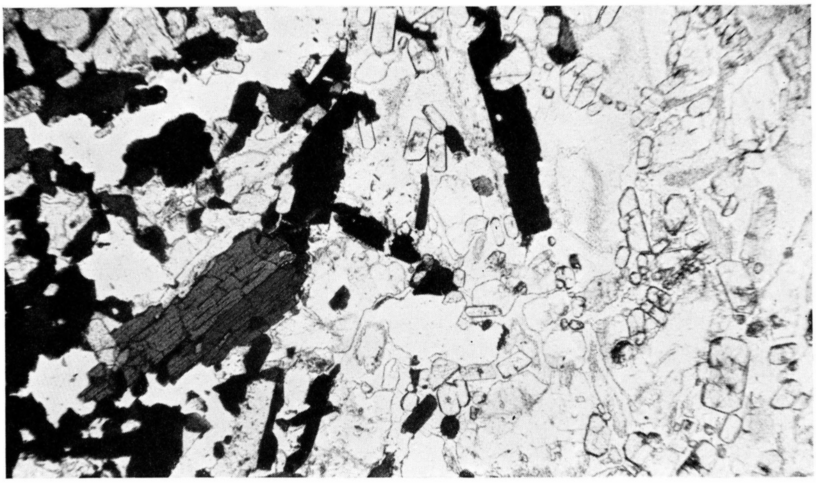

Fig. 1.

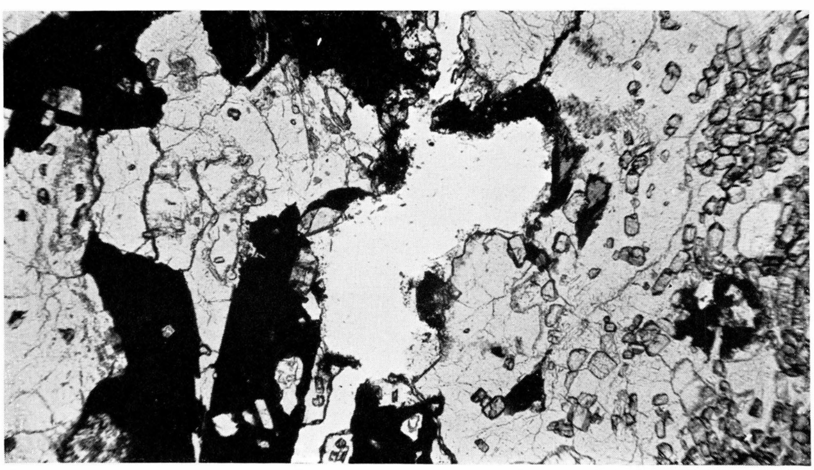

Fig. 2.

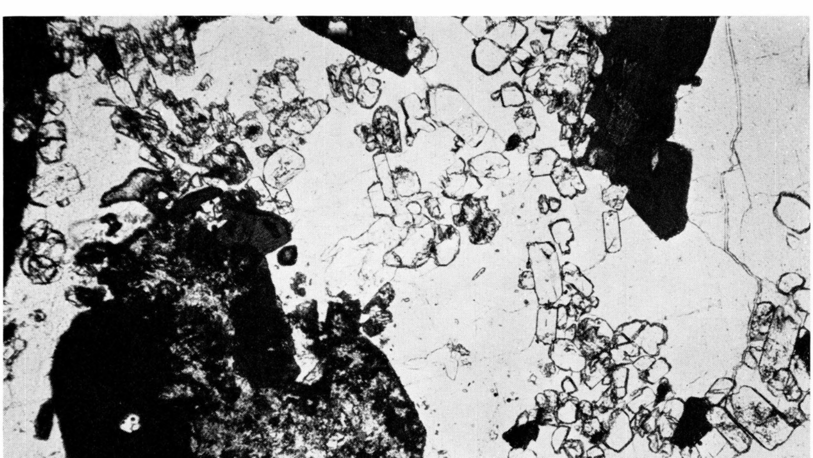

Fig. 3.

Plate 5.

Fig. 1.

No. 21136b. × 27, + nic. Albitite composed of albite laths, often with three twin lamellae (see p. 216). Centre right: a flake of astrophyllite. Albitite from thin vein, Qeqertaussaq.

Fig. 2.

No. 21157a. × 27, + nic. Albitite with scattered small laths of microcline (e. g. centre right). Pegmatite to the north of Lilleelv.

(Chr. HALKIER phot.).

Fig. 1.

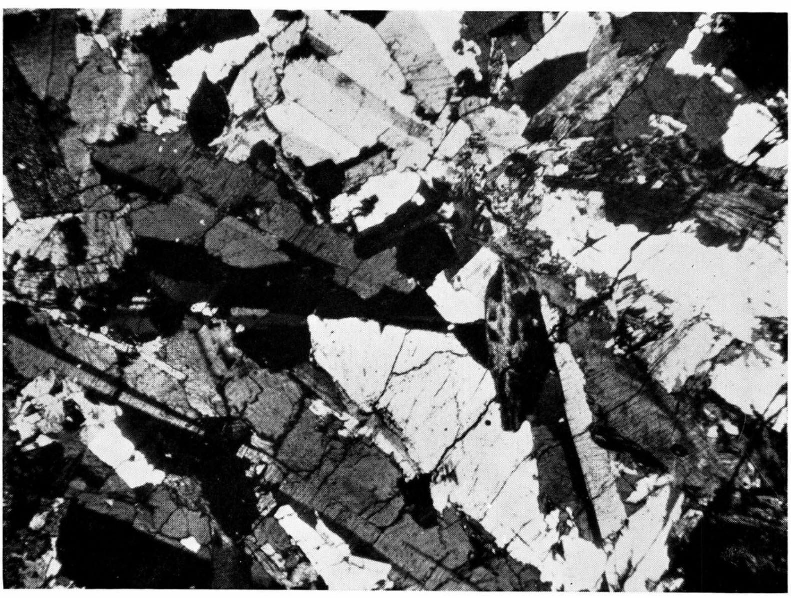

Fig. 2.

Plate 6.

Fig. 1.

No. 21120a. × 27, 1 nic. Black vein with equidimensional grains of analcime in a matrix of small microcline laths and arfvedsonite needles. Qeqertaussaq.

Fig. 2.

No. 21122a. × 27, 1 nic. Large arfvedsonite prisms along the border of a multiple vein have irregular extinction and are surrounded by a fine-grained aggregate of arfvedsonite, steenstrupine, altered eudialyte, microcline and analcime. The white area in the lower left corner is analcime. Qeqertaussaq.

(Chr. Halkier phot.).

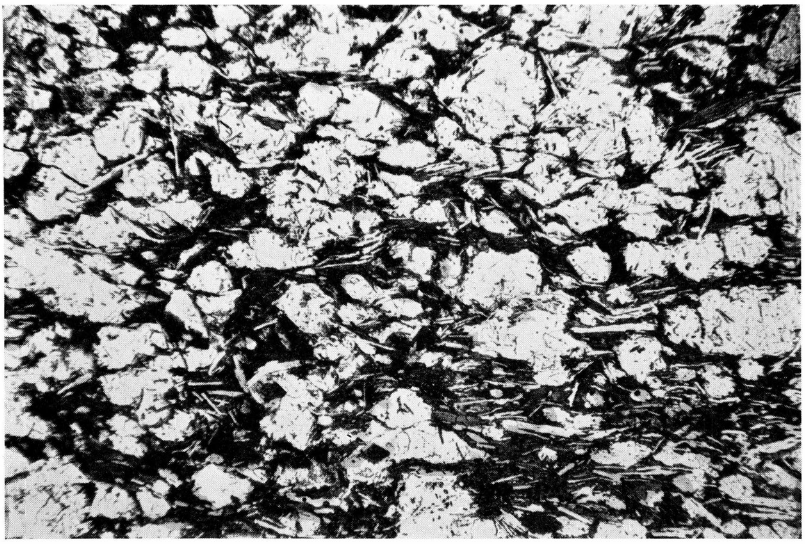

Fig. 1.

Fig. 2.

Plate 7.

Fig. 1.

No. 21118. ×27, 1 nic. Green vein composed of ægirine felt with a subordinate amount of microcline (white) and steenstrupine (black). Qeqertaussaq.

Fig. 2.

No. 21122b. ×27, 1 nic. Multiple vein with aggregates of ægirine felt intergrown with larger anhedrae of arfvedsonite (black) which contain inclusions of ægirine. The white matrix is composed of fine-grained albite with small laths of microcline. A few of the small dark grains are steenstrupine. Qeqertaussaq.

Fig. 3.

No. 21123b. ×27, 1 nic. Streaks of ægirine and arfvedsonite in a matrix of albite which apparently penetrates the dark streaks. Some of the small white laths in the dark streaks are of microcline. Multiple vein, Qeqertaussaq.

(Chr. Halkier phot.).

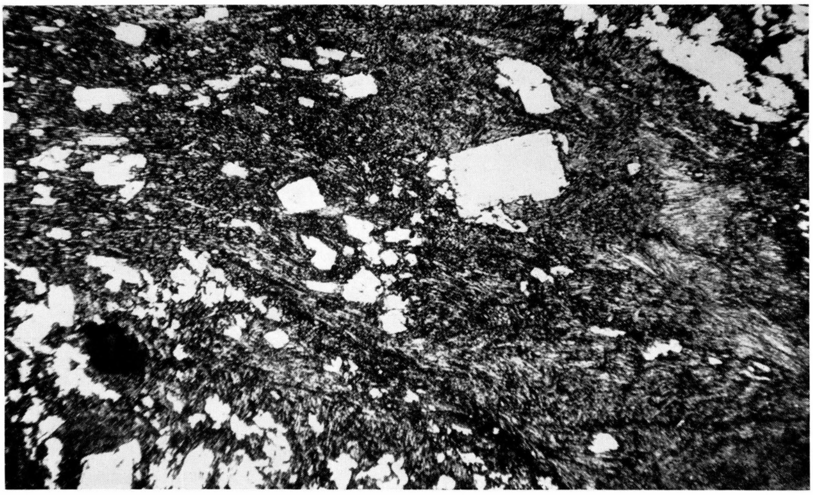

Fig. 1.

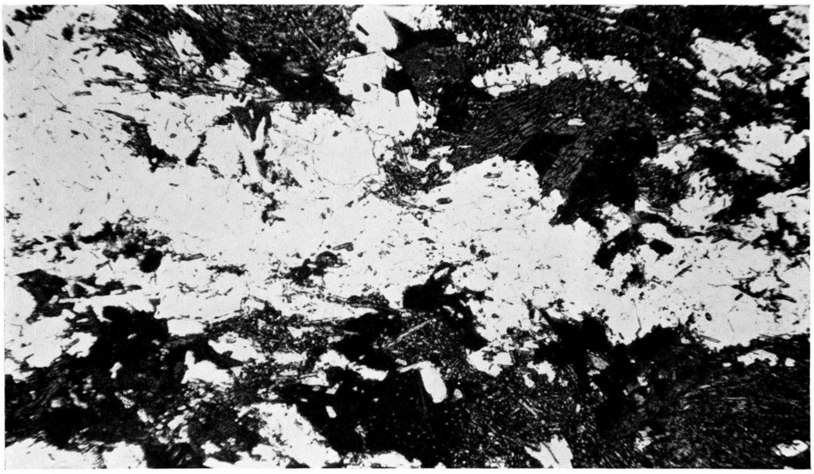

Fig. 2.

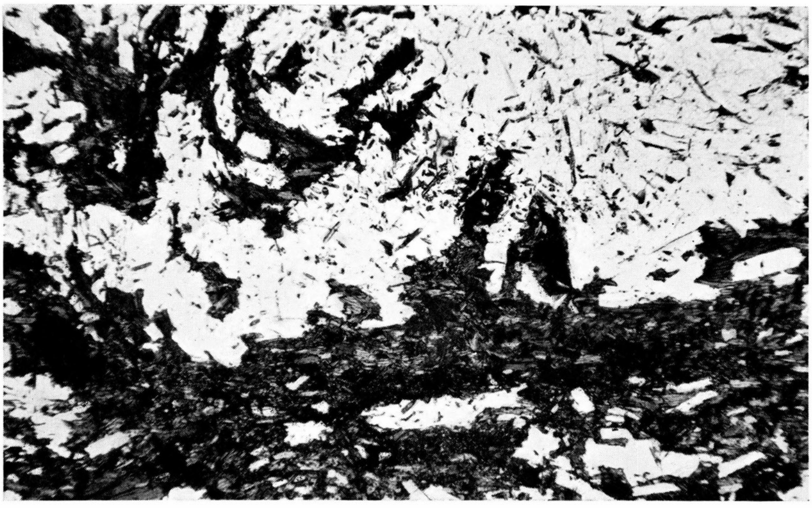

Fig. 3.

Plate 8.

Fig. 1.

No. 21022d. ×27, 1 nic. Aggregates of ægirine felt (grey) intergrown with large grains of arfvedsonite (black) in a matrix of microcline laths. The southeast point of Igdlúnguaq.

Fig. 2.

No. 21077. ×27, 1 nic. Inclusions of ægirine felt in lujavrite. Aggregates of ægirine (grey) enclosed in an analcime-arfvedsonite rock. The southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

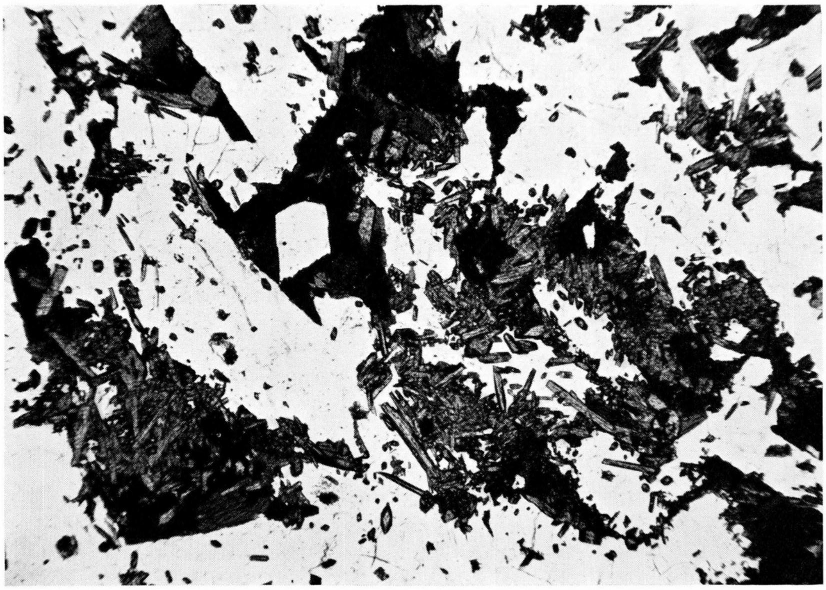

Fig. 1.

Fig. 2.

Plate 9.

Fig. 1.

No. 21154. × 27, 1 nic. Steenstrupine crystal in rock composed of microcline laths with interstitial arfvedsonite (black) and ægirine (grey). The steenstrupine contains inclusions of arfvedsonite and microcline which are smaller than their interstitial varieties. The central part of the steenstrupine crystal is rather cloudy. Vein no. 2, the Head of Kangerdluarssuk.

Fig. 2.

No. H18467a. × 27, 1 nic. The matrix is composed of a fine-grained aggregate of ægirine (grey) and arfvedsonite (dark grey). The large dark areas are steenstrupine crystals with scarce small inclusions of ægirine, arfvedsonite and analcime. The white parts of the matrix are composed of analcime. Vein no. 3, the Head of Kangerdluarssuk.

Fig. 3.

No. 18506b. × 33, 1 nic. Crystals of steenstrupine with scarce inclusions of ægirine and microcline in a matrix composed of these two minerals. Bottom left: a eudialyte pseudomorph. Green vein, the southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

Fig. 1.

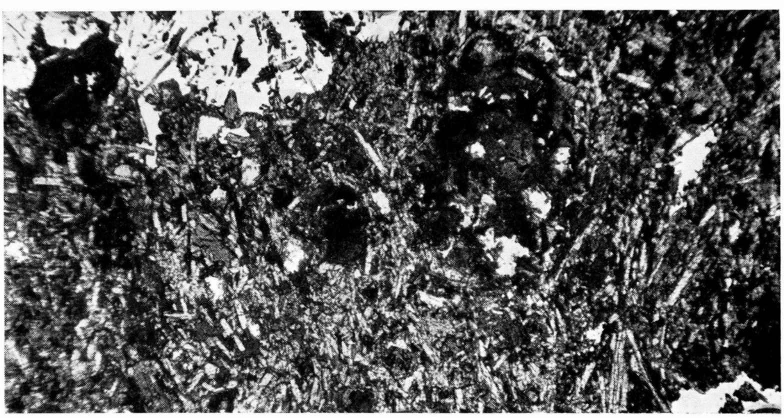

Fig. 2.

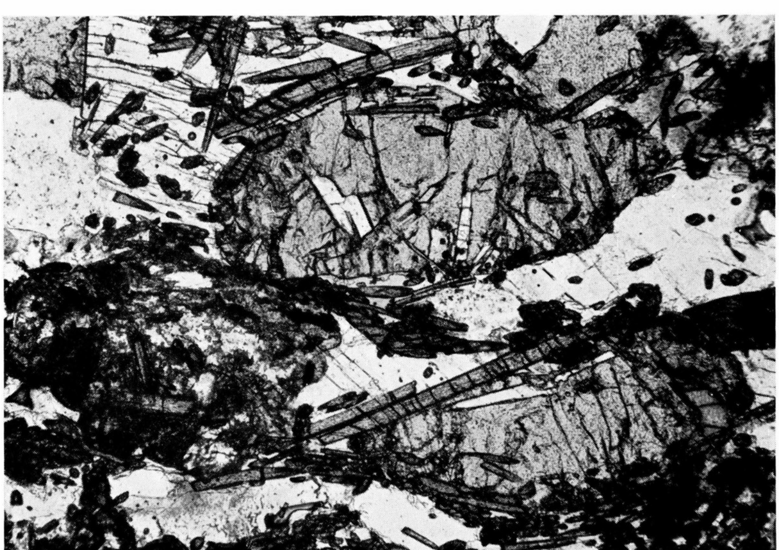

Fig. 3.

Plate 10.

Fig. 1.

No. 21005,1. $\times 27$, 1 nic. Large grains of arfvedsonite partially replaced by acmite (grey). Brown vein, the southwest point of Igdlúnguaq.

Fig. 2.

No. 21042. $\times 27$, 1 nic. Large grains of arfvedsonite being bent and replaced by aggregate of small arfvedsonite grains (towards the bottom of the photograph). The white areas are natrolite. Brown vein, the southwest point of Igdlúnguaq.

Fig. 3.

No. 21043. $\times 27$, 1 nic. Acmite aggregate with interstitial arfvedsonite enclosed in arfvedsonite aggregate with scattered grains of acmite. Brown vein, the southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

Fig. 1.

Fig. 2.

Fig. 3.

Plate 11.

Fig. 1.

No. 21067b, $\times 27$, 1 nic. Lujavrite composed of laths of microcline (white), square crystals of nepheline (white) and eudialyte crystals (grey) in a matrix of arfvedsonite (black). There is a thin interstitial network of analcime which is seen very indistinctly in the photograph, for instance in the lower left and right corners (dusty shadows). Tugtup agtakôrfia.

Fig. 2.

No. 21019. $\times 27$, 1 nic. Border between acmite (dark grey mineral in bottom part of the photograph) and analcime patch (white at the top). In the border zone there are prisms of acmite and steenstrupine crystals (light grey) with irregular borders towards the acmite. Brown vein, the southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

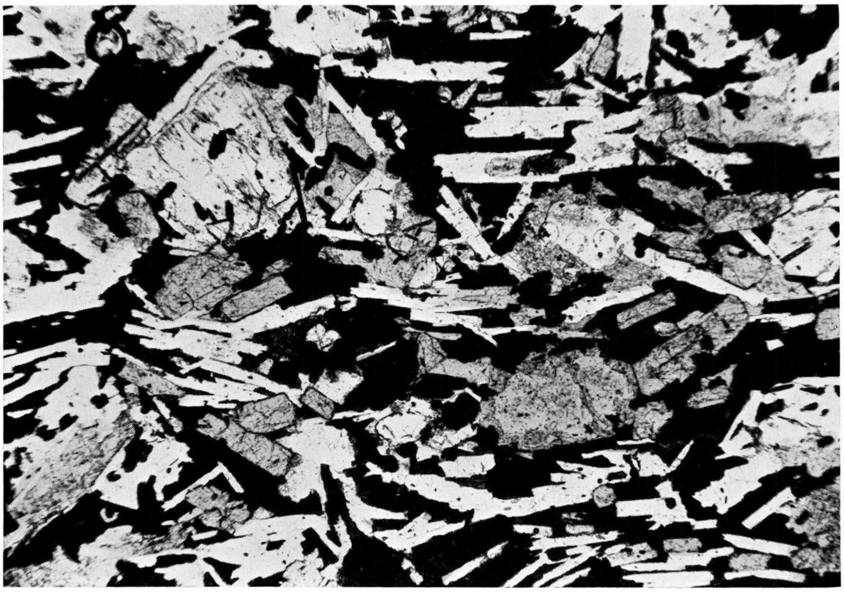

Fig. 1.

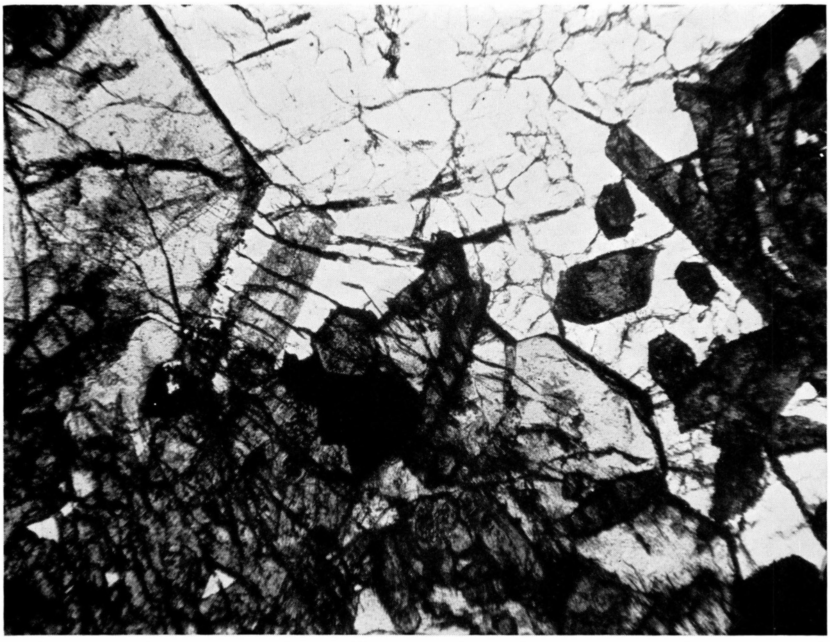

Fig. 2.

Plate 12.

Fig. 1.

No. 18491b. $\times 27$, + nic. Large grain of microcline cut by a zone of fine-grained albite (white in the lower right part of the photograph). Top left: anisotropic crystal of steenstrupine associated with epistolite and schizolite. Albitite, Tugtup agtakôrfia.

Fig. 2.

No. 18491a. $\times 27$, 1 nic. Larger laths of albite in a matrix of sugary-grained albite. Deformed small laths of microcline are seen at the centre and bottom left. Albitite, Tugtup agtakôrfia.

Fig. 3.

No. 18491c. $\times 27$, 1 nic. Arfvedsonite replaced by aggregate of acmite in matrix of sodalite and analcime. Albitite, Tugtup agtakôrfia.

(Chr. Halkier phot.).

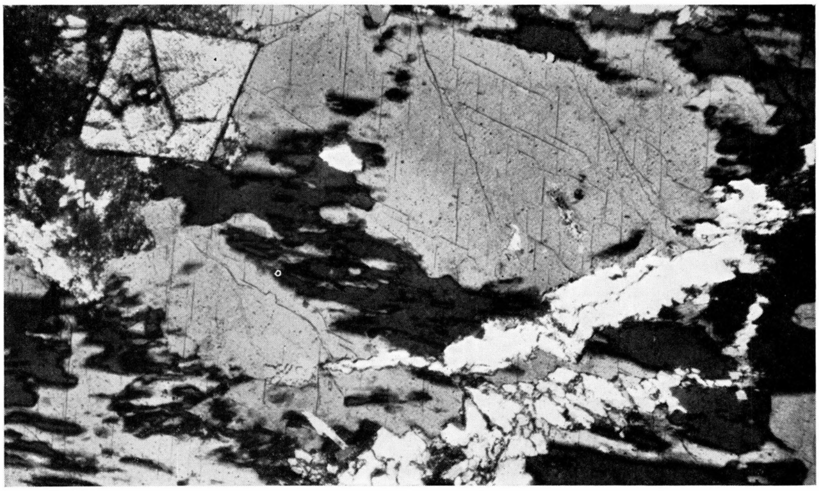

Fig. 1.

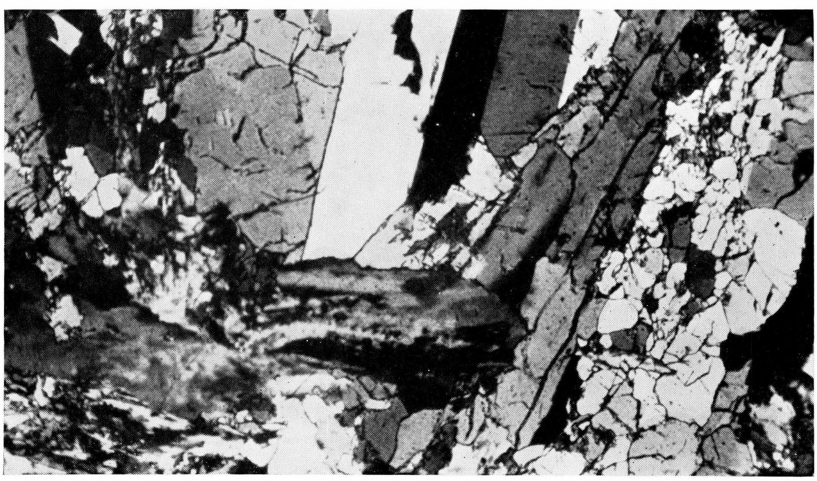

Fig. 2.

Fig. 3.

Plate 13.

Fig. 1.

No. 21148. ×27, 1 nic. Eucolite with distinct cleavage (bottom half of photograph) in matrix of albite and ussingite (white) with numerous small grains of altered lovozerite (black and grey) and small needles of ægirine (grey). Centre right: steenstrupine (dark grey) growing on the eucolite and being surrounded by a dense aggregate of lovozerite. Vein no. 4, the Head of Kangerdluarssuk.

Fig. 2.

No. 21144a. ×27, 1 nic. Small crystals of steenstrupine (grey with dark marginal zones) in a fine-grained matrix of ægirine, arfvedsonite, albite, and microcline. The steenstrupine contains minor inclusions of ægirine. Top right: white nodule composed of albite, analcime, microcline, minor ægirine and steenstrupine. Vein no. 4, the Head of Kangerdluarssuk.

Fig. 3.

No. 18468a. ×33, 1 nic. Steenstrupine crystals with inclusions of lovozerite which may be arranged parallel to the crystal faces of the steenstrupine. The matrix is composed of microcline with small crystals of lovozerite and needles and prisms of ægirine. Vein no. 4, the Head of Kangerdluarssuk.

(Chr. Halkier phot.).

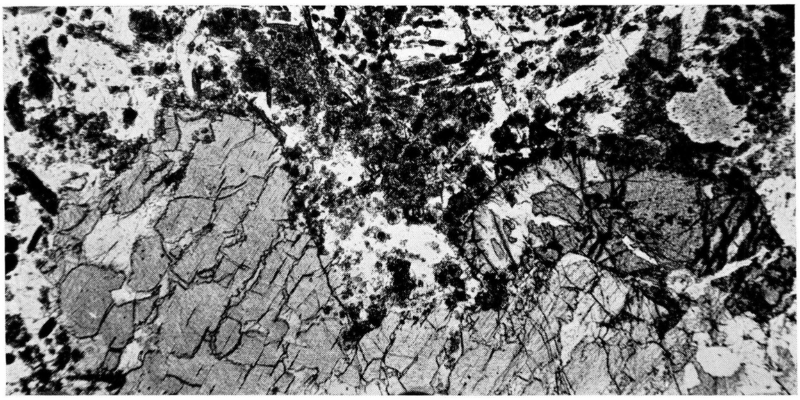

Fig. 1.

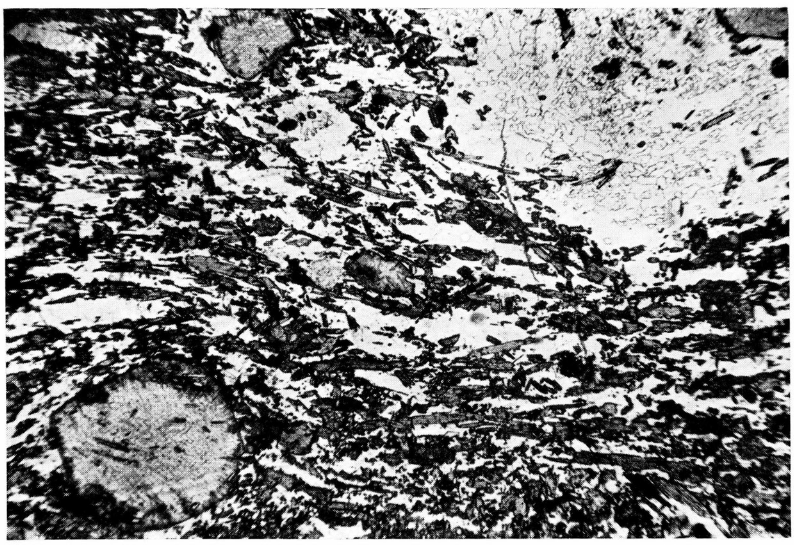

Fig. 2.

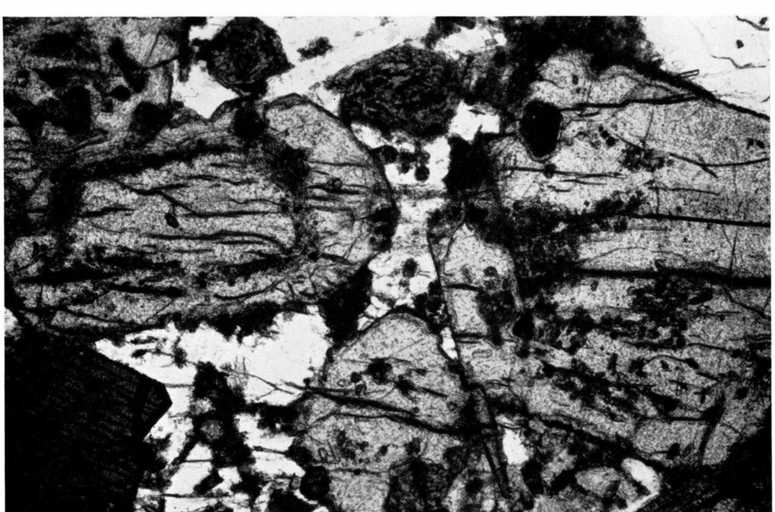

Fig. 3.

Plate 14.

Fig. 1.

No. 18512c,1. $\times 33$, 1 nic. Aggregate of eudialyte pseudomorphs rich in neptunite (black) in a matrix of analcime and natrolite. Small grains of steenstrupine occur along the margins of the pseudomorphs (top left and right, bottom left). Altered naujaite, the southwest point of Igdlúnguaq.

Fig. 2.

No. 18512c,1. $\times 33$, 1 nic. Steenstrupine crystal (centre) growing at the expense of altered eudialyte (dark). Below the steenstrupine a small unaltered eudialyte grain, to the left a large eudialyte pseudomorph. Altered naujaite, the southwest point of Igdlúnguaq.

Fig. 3.

No. 18495a. $\times 33$, 1 nic. Steenstrupine crystals in a matrix of analcime. All crystals contain remnants of altered eudialyte (dark). Recrystallized naujaite, the southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

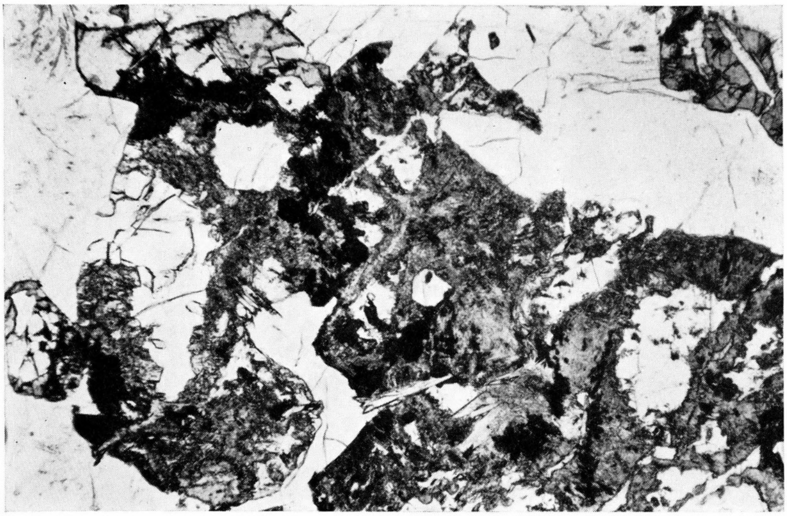

Fig. 1.

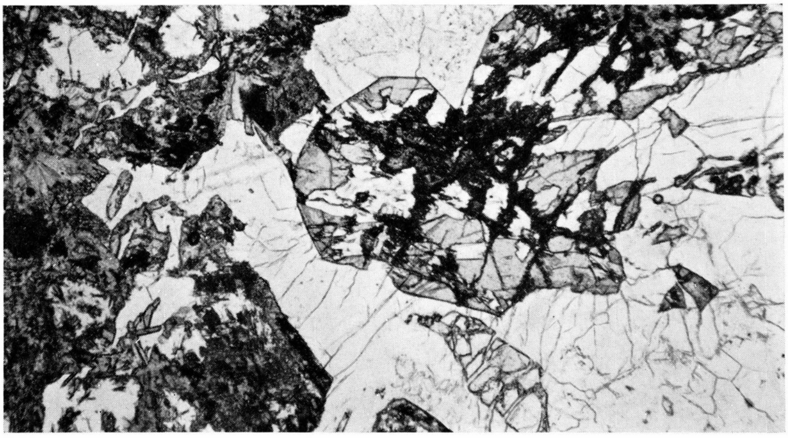

Fig. 2.

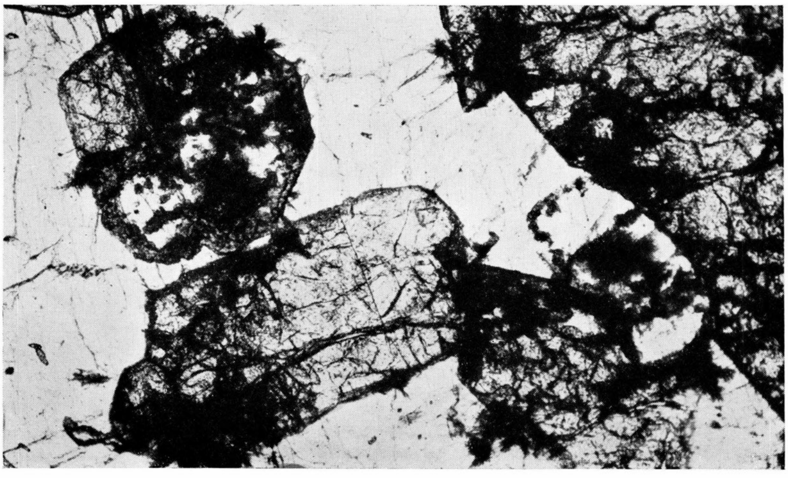

Fig. 3.

Plate 15.

Fig. 1.

No. 18465. $\times 33$, 1 nic. Steenstrupine crystals with irregular colouration in matrix of microcline, analcime and small needles of ægirine. The radioactive rock of the pegmatite on the south coast of Qeqertaussaq.

Fig. 2.

No. 18516,2. $\times 33$, 1 nic. Poikilitic steenstrupine grain in analcime with needles of arfvedsonite. Enclosed in the steenstrupine are arfvedsonite, lath-shaped analcime, small microcline laths and altered eudialyte. Lujavrite, the southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

Fig. 1.

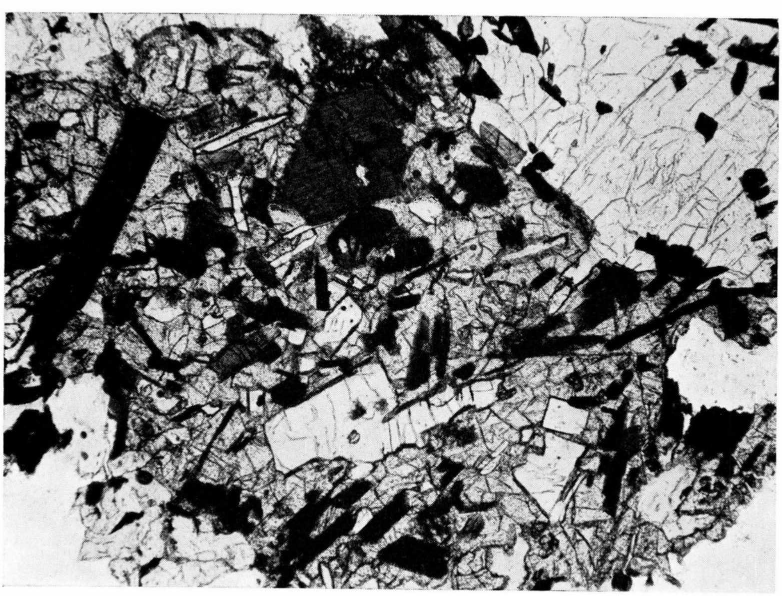

Fig. 2.

Plate 16.

Fig. 1.

No. 21110. ×27, 1 nic. Poikilitic steenstrupine with inclusions of arfvedsonite, eudialyte, microcline and ægirine/acmite. The matrix is composed of sodalite, analcime, microcline, eudialyte and arfvedsonite. The lujavrite under the albitite at Tugtup agtakôrfia.

Fig. 2.

No. 18500b. ×27, 1 nic. Steenstrupine with lath-shaped analcime inclusions and a few eudialyte pseudomorphs. Recrystallized naujaite, the southwest point of Igdlúnguaq.

Fig. 3.

No. 21049b. ×27, 1 nic. Poikilitic steenstrupine grain with inclusions of arfvedsonite (black), eudialyte crystals, and lath-shaped and polygonal analcime. The matrix is composed of analcime, arfvedsonite and small eudialyte crystals "Dense" analcime rock, the southwest point of Igdlúnguaq.

(Chr. Halkier phot.).

Fig. 1.

Fig. 2.

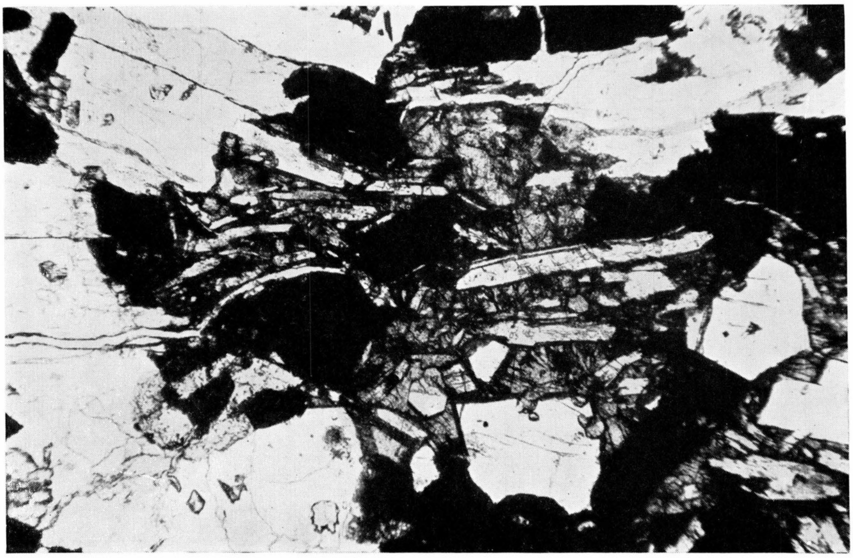

Fig. 3.