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IGNEOUS ROCKS OF THE IVIGTUT REGION, GREENLAND

PART I

THE NEPHELINE SYENITES OF THE GRØNNE DAL — IKA AREA

BY

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WITH 4 FIGURES IN THE TEXT AND 2 PLATES

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PREFACE

Through the courtesy of Kryolith Mine og Handels Selskabet I had in 1927 for the first time the opportunity of investigating the cryolite deposit at Ivigtut, South Greenland, and I sincerely thank the former technical director, Mr. Niels Jagd for having made this visit possible for me. During the investigations it soon became clear to me that the origin of the cryolite and its geological history must be considered in connection with some occurrences of igneous rocks in the country around Ivigtut. It was therefore of importance for me to obtain an opportunity for extending the investigations also to these occurrences. The Kryolith Mine og Handels Selskab were extremely courteous and generous in meeting my wishes and defrayed the expenses in connection with a second journey in 1931 for me and my two collaborators, Richard Bøgvad, M. Sc. and Helge Gry, Phil. Dr. and I feel desirous of extending my sincere thanks to Kryolith Mine og Handels Selskabet not only for the two valuable journeys but also for the great support the Company as well as its successor, the present Kryolitselskabet Øresund, in every respect have given my work. It is my pleasant duty to extend a special thank to the director, Mr. C. F. Jarl for the interest he always has shown my work.

I am further glad to thank the two chief engineers, Messrs. Poul Mørch and S. Corp as well as their staff for their kind reception and great readiness to help me at Ivigtut. I owe Mr. R. Bøgvad, M. Sc. and Mr. Helge Gry, Phil. Dr. cordial thanks for their indefatigable and energetic collaboration in the field and Mr. L. H. C. Halkier for his skilful work with the microphotographs.

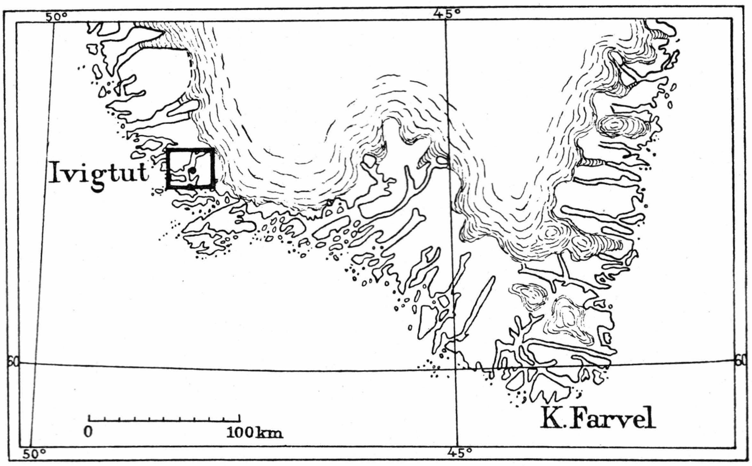

Fig. 1. Index map showing location of the region investigated.

INTRODUCTION

The well-known cryolite mine at Ivigtut is situated on the southern side of the Arsuk Fjord in the Frederikshaab district on the south-western coast of Greenland, at 61°12′7″ N. lat. and 48°10′25″ W. long. In this region the narrow strip of ice-free land between the sea and the inland ice is only 30—40 km wide, while in the greater part of West Greenland the ice-free land reaches a width of 100—200 kilometers.

The country is strongly intersected by deep fjords and divided up into numerous islands and peninsulas. The Arsuk Fjord has a very irregular shape. Its wide estuary is filled with a great number of small and large islands on which the mountains in several places reach heights of up to 1000 m. The Kũnait Mountain on the northern side of the fjord with its 1400 meters is the highest mountain in this part of Greenland; it is visible from a great distance and serves as a beacon for shipping. The interior 2—3 km wide part of the Arsuk Fjord — also called the Ivigtût Fjord—has a tortuous course and ends at the inland-ice where a small glacier—"Arsuk Fjords Isblink"—descends into the fjord. Round this part of the fjord the country on the whole consists of rather low mountains and only few tops rise above 300—400 meters' height; but the ground is very uneven and intersected by numerous bays and narrow fjords. In the valleys the vegetation is very rich, and in several places the willow-copses are almost man-high. Towards the south the Ivigtut Peninsula is bounded by the long narrow Ika Fjord that cuts 12—13 km into the country in north-eastern direction.

The cryolite deposit at Ivigtut is almost entirely enclosed in a small massif of pink granite which in several places along its border has brecciated the gneiss bed rock by its intrusion. Several xenoliths of this granite, as well as of the gneiss, are found in the cryolite.

Between the granite and the cryolite mass pegmatitic material often occurs. Originally a great deal of the cryolite was covered by a large pegmatite mass which at the west end of the quarry reached a thickness of about 30 m. The pegmatite is chiefly composed of quartz and feldspar individuals some of which may reach up to 1—2 m in length. The feldspar is microcline without the ordinary cross-hatching, but shows an irregular twin structure (moiré-microcline). It contains a very small amount of albite only; according to an analysis made by J. LORENZEN the K_2O-content is almost 17 per cent.[1]) Besides cryolite occurs, mostly dark coloured, and chiefly forming apophyses of 0.1—1 m or more in width in the pegmatite. Further siderite, galena and a number of other minerals are found in smaller amounts.

The granite is commonly porphyritic with phenocrysts of feldspar and quartz. The feldspar is microcline microperthite with a considerable amount of albite. Not infrequently it is graduating into cryptoperthite. It closely corresponds to the microcline microperthites of the Julianehaab District described by N. V. USSING[2]). Between crossed nicols the potash feldspar of the perthite shows no cross-hatching but a very irregular, fine twin structure of the same type as the microcline of the pegmatite. Dark coloured silicate minerals are never abundant. Biotite is most common, but also ægirine-augite and soda-amphibole are found in some specimens. The granite is more or less altered owing to emanations from the cryolite-pegmatite, and in large parts of the rock an intense greisening has taken place.

For years it has been a well known fact that some outcrops of alkaline rocks occur in the region around Ivigtut. They are found within three separate areas, viz. 1) the Grønne Dal [Green Valley]—Ika area about 10 km E and SE of Ivigtut (se map fig. 2, p. 19) where nepheline syenite appears, 2) the Kũnait Mountain about 15 km W of Ivigtut where the dominating rock is augite-syenite, and 3) a southern area at Nunarssuit about 50 km S of Ivigtut, where syenite and granite occur.—Besides numerous dyke rocks consisting as well of diabase as of alkaline rocks occur all over the region.

These eruptives have not hitherto been made the object of any close examination. On the other hand the view has previously been

[1]) Cf. F. JOHNSTRUP: Kryolitens Forekomst i Grönland. 12. Skandinaviska Naturforskaremötets Förhandlingar, Stockholm 1880.

[2]) N. V. USSING: Alkalifeldspaterne i de sydgrønlandske Nefelinsyeniter og beslægtede Bjærgarter, 1894. Medd. om Grønland, Vol. *14*.

advanced that the cryolite deposit at Ivigtut is genetically connected with these eruptive rocks, a hypothesis with which I fully agree. This view was first set forth by N. V. USSING in an article in Geografisk Tidsskrift 1908[1]) in which he says [in translation]: "The cryolite formation must be supposed to belong to a distant period when the whole region was the seat of an intense volcanic activity among the results of which also the surrounding granite porphyry and several syenite rocks in the vicinity of the Arsuk Fjord are to be found."

In the course of my work I was soon convinced that the cryolite deposit, as well as the just mentioned occurrences of alkaline rocks, all belong to the same petrographic province as the alkaline rocks in the Julianehaab district described by N. V. USSING[2]). The Julianehaab rocks are situated about 120 km E of Ivigtut. No doubt USSING in his above quoted statement (1908) was also thinking of the Julianehaab rocks. In his Memoir 1938[3]) he says (p. 306): "In other parts of South Greenland a great many Plutonic masses occur which are also younger than the Algonkian Julianehaab granite, and are probably contemporaneous with the batholites of Ilimausak and Igaliko." In the following he mentions among these plutonites the nepheline syenite east of Ivigtut (viz. the Grønne Dal — Ika) and the batholite of Cape Desolation, viz. the Nunarssuit massif. USSING does not mention the cryolite occurrence at Ivigtut in this connection, but the above quotations distinctly show his view.

Before his all too early death USSING succeeded in carrying out field investigations of the Nunarssuit area as well as some rather preliminary investigations of the other western occurrences. Since then supplementary collections, a greater number of slices, and some chemical analyses of rocks from Ivigtut, Grønne Dal, Ika, and the Kũnait Mountain have been made for the purpose of the present work. From the investigations several characteristics appear, chemical as well as mineralogical, in favour of a real genetic relationship to the Julianehaab rocks.

In the present paper the nepheline syenites and related rocks of the Grønne Dal — Ika area are treated. Later publications will deal with the other occurrences.

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[1]) N. V. USSING: Kryoliten ved Ivigtut. Geografisk Tidsskrift, 19. Bind, 5. Hefte, 1907—1908, p. 197: "Kryolitdannelsen maa antages at tilhøre en fjærn Tid, da hele Egnen var Sædet for en intensiv vulkansk Virksomhed, til hvis Resultater ogsaa den omgivende Granitporfyr og adskillige Syenitbjærgmasser i Arsukfjordens Nærhed henhører."

[2]) N. V. USSING: Geology of the Country around Julianehaab, Greenland. Medd. om Grønland *38.* København 1912.

[3]) Ibid. p. 306 ff.

Earlier investigations. The Mineralogical Museum of the University of Copenhagen possesses very considerable collections of minerals from the cryolite deposit and these collections have in the course of time continually been increased. Systematic collections of rock specimens have only been undertaken in recent times.

The first to undertake more comprehensive collections was K. L. Giesecke[1]) who during his mineralogical journey in Greenland 1806—1813 several times visited this region. In 1806 he undertook an excursion to the top of the Kũnait Mountain and in his diary he has briefly described the structure and rocks of the mountain. Giesecke was the first mineralogist who came to Ivigtut, where in 1809 he discovered the outcrop of cryolite in a small bay in the Arsuk Fjord where the cryolite at high tide was partly covered by water; the mineral cryolite had at the time been known for some years.

Later various mineralogists and geologists have visited Ivigtut; only few of them (T. Thomsen, 1869, F. Johnstrup 1874, and N. V. Ussing 1908) have also visited the Kũnait Mountain and earlier collections from this locality are sparse. In 1931 we succeeded in collecting a rather considerable amount of rock specimens, also from the top of the mountain which R. Bøgvad ascended. The inaccessibility of the mountain has, however, provided too many obstacles to closer investigations.

From the Grønne Dal — Ika region the older collections are also very scanty. It seems as if the nepheline syenite was first discovered by Tayler, one specimen coming from his collections in 1855. A few other specimens were brought home by T. Thomsen. K. J. V. Steenstrup, F. Johnstrup, and Gustav Lunn. In 1880 the Swedish geologist N. O. Holst travelled in south-western Greenland and in his report[2]) he gives a short survey of the country rocks. Some of the specimens collected by him are described by A. E. Törnebohm[3]) who calls them augite syenite, mica syenite, and syenite. Unfortunately no part of the said collections have been transferred to the Mineralogical Museum in Copenhagen.

In 1900 N. V. Ussing accompanied by O. B. Bøggild undertook geological investigations in the Grønne Dal — Ika area, i. e. the area between the little inlet Ekaluit (also spelt Eqaluit) and the head of the Ika Fjord. Ussing, who further supplemented his investigations

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[1]) K. L. Giesecke: Mineralogisches Reisejournal. 2. vollständige Ausgabe, Medd. om Grønland *35*, 1910.

[2]) N. O. Holst: Berättelse om en år 1880 i geologisk syfte företagen resa till Grönland, Sveriges Geologiska Undersökning, Ser. C, No. 81. 1886.

[3]) A. E. Törnebohm: Mikroskopisk undersökning af några bergartsprof från Grönland indsamlade af Dr. N. O. Holst, Geol. Fören. i Stockholm Förhandl. Bd. VI. 1883.

in 1908, brought a considerable number of specimens home from the said area. In 1931 the material was supplemented by further collections and investigations in the field.

The Nunarssuit area comprises the Isle of Nunarssuit, part of the Isle of Alángorssuaq as well as some small islands, the North Kitsigsut Islands. Among the earlier collections from this area only a few specimens of younger granite and syenite are present; they are all collected by GIESECKE and K. J. V. STEENSTRUP. N. V. USSING first visited some of these places in 1900. Later, on his journey in Greenland in 1908 he spent about two months in investigations within this field. He brought home some very considerable collections, and his diaries contain elaborate notes on his observations in the field. Unfortunately he did not live to carry out the laboratory work.—In 1931 my collaborators and I myself had no occasion to visit this field.

Finally C. E. WEGMANN in the summers of 1936 and 1937 travelled along the south western coast of Greenland from 60° to 61°15′ N lat. and made geological investigations with a special view to tectonic conditions. His results are published in a preliminary report: "Geological Investigations in Southern Greenland. Part I. On the Structural Divisions of Southern Greenland." Medd. om Grønland, Bd. *113*. No. 2, 1938. With regard to the relations between the younger granite and syenite massifs here dealt with and the Tunugdliarfik massifs (Julianehaab) WEGMANN, starting from another point of view, comes to almost the same result. He says among other things (p. 121): "A direct contact between the alkaline massifs of Tunugdliarfik and the younger granite massifs has not hitherto been found. Thus no direct proof of their relationship is available. Yet we have certain clues to a hypothetic parallelisation:

Both groups of rocks are younger than most of the diabases. Both are accompanied and succeeded by fluoritic exhalations. The latter fact, however, need not mean that they are strictly synchronous . . ."

"It is quite probable that in South Greenland the two groups belong to the same cycle, only their position within it is doubtful."

Already the following year WEGMANN, however, arrived at a somewhat different view. He then writes: "Bei der ersten vorläufigen Übersicht wurden die postorogenen Granite noch in eine Gruppe zusammengefasst, deren Stellung zur Gardarformation unsicher war. Durch die Aufteilung der Gruppe wurde mehr Klarheit geschafft. Ein grosser Teil jener Granite ist älter als Gardar; es ist sehr wahrscheinlich, dass diese Granite, welche leicht in Grus zerfallen, als Nährgebiete für den Igalikosandstein wichtig waren."[1])

[1]) Tagung der Naturforschenden Gesellschaft Schaffhausen 11/12-III-1939, p. 208.—Mitt. d. Naturforsch. Ges. Schaffhausen (Schweiz) Bd. XVI, Jahrg. 1940. Herausgegeben Oktober 1939.

THE PRE-CAMBRIAN BASEMENT

In this region, as well as in wide areas in South Greenland, the bed-rock consists of crystalline rocks, chiefly gneisses and metamorphic schists. Besides a very widely distributed old granite, the Julianehaab granite, occurs in the neighbouring districts. There can scarcely be any doubt that the said rocks are of Pre-Cambrian age, as has also been assumed in earlier literature.

N. V. USSING in his classical memoir on the "Geology of the Country around Julianehaab"[1]) has drawn up a chronological scheme about which he says on p. 8: "From the stratigraphical relations and the petrographical characters of the different rocks, and from a comparison of the sediments with those of East Greenland and of the north-east of Canada, we may infer not only the order of succession of the different rocks but also their probable geological age." In this way he arrived at the following classification:

Quaternary	Moraines and alluvium.
Devonian (?)	Plutonic rocks (granite, nepheline-syenite, etc.) and volcanic sheets. Red Sandstone.
Algonkian (?)	Plutonic rocks (granite, diorite, etc.) Arsuk group.
Archæan	Gneisses and crystalline schists.

In the above scheme, which cannot now be retained without modifications, the term "Arsuk group" is applied in the sense hitherto used in Greenland geology, i. e. as a name for the succession of intensely folded slates, phyllites, dolomites, quartzites, graphite-schists and metamorphosed diabases and tuffs occurring in Arsuk Island and some surrounding localities. When USSING (1911) placed "the Arsuk group" in a younger geological period than the gneiss bed-rock he acted in conformity with the views prevailing at the time concerning the Pre-Cambrian formations.

[1]) Medd. om Grønland, Bd. *38*, 1912, p. 9.

In his above mentioned paper on South Greenland C. E. WEGMANN[1]) draws up a new chronological classification in which he like other recent authors, for instance L. R. WAGER in the case of East Greenland (Medd. om Grønland, Bd. *105*, Nr. 2, 1934), abstains from referring the rock formations to definite geological periods. WEGMANN divides the rocks into

a) an old basement, "the Ketilides," and
b) younger formations, "the Gardar Formation."

The Gardar Formation which corresponds to USSING's "Devonian(?)" will not be discussed in this place.

The *Ketilides* correspond to USSING's Pre-Cambrian rocks. They are subdivided into

a) the Sermilik group, and
b) the Arsuk group.

The Sermilik group is to a great extent made up of pelitic and psammitic sediments which are strongly metamorphosed. The rocks consist mainly of gneisses tending partly towards micaschists, partly towards quartzites. Various types of amphibolites often occur. In several places a darker, more slaty division with pyrites and graphitic shales is found. The whole series terminates in thick beds of dark amphibolites traversing the upper part of the series in which the supercrustal rocks have been metamorphosed to a less extent.

It is this series of slightly metamorphosed sediments together with the traversing volcanic rocks which according to USSING were called "the Arsuk group."—Now C. E. WEGMANN (p. 23) proposes "to name the upper, almost purely volcanic series the Arsuk group."

The whole series, the Sermilik as well as the Arsuk group, has been folded, migmatitised, and granitised which according to WEGMANN is largely connected with the *mise-en-place* of the Julianehaab granite. Certain parts of the Julianehaab granite may be regarded as palingenetic originating from the first activated granitic basement of the Ketilidian series. During the Ketilidian orogenic cycle migmatites arose in some regions, while the actual Julianehaab granite was formed

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[1]) Medd. om Grønland, Bd. *113*. Nr. 2, 1938.

Unfortunately the said paper is marred by a series of rather bad and incorrect attacks on Professor O. B. BØGGILD and a number of other geologists, among them the present author. The remarks are not as a rule accompanied by sufficient references to existing literature; only in one place is a direct page-reference to be found. But happily I need not comment further on C. E. WEGMANN's reflections as the latter already have been repudiated by RICHARD BØGVAD in Medd. fra Dansk Geologisk Forening, København, Bd. *9*, 1938.

in other places. Within certain areas, e. g. around the Arsuk Fjord, the migmatitisation has often reached complete granitisation.

With regard to the Pre-Cambrian in the Ivigtut region I completely share C. E. WEGMANN's view. During my visits to Ivigtut I did not undertake any special investigation of the gneiss bed-rock, and in the following I shall add a few further remarks only. In 1931 Dr. HELGE GRY, however, undertook some investigations at Tayler's Harbour, Weber's Harbour as well as on either side of the narrow sound of Ikerasak between Arsuk Island and the mainland. Through these investigations he came to the same view, namely that the difference between the gneiss bed-rock and the crystalline schists on Arsuk Island and the other localities just mentioned depended on the degree of metamorphism only and that the "gneisses" accordingly were to be considered as migmatites formed of the rocks of the Arsuk group.

It appears from GRY's observations at Ikerasak and at Weber's Harbour—which he has kindly placed at my disposal—that "the Arsuk group" (to use USSING's terminology) rests without discordance on the gneiss bed-rock and that the latter formations gradually merge into each other. USSING has in his diary-notes placed the boundary between the Arsuk group and the gneiss under the thick quartzitic sandstone at the northern side of Ikerasak. The gneiss under the quartzite is, however, thin schistose and concordant with the quartzite and the migmatitising only starts about 300 m from the quartzite. The further one gets from the quartzite the more metamorphosed becomes the gneiss.

At Weber's Harbour a similar fine schistose gneiss occurs in connection with the typical less metamorphosed rocks of the Arsuk group; the said gneiss towards the north gradually merges into migmatites of the "Ivigtut gneiss" type.

Unfortunately comprehensive investigations within Denmark's geology have left HELGE GRY no time for the elaboration of his collections and the publication of his results from this journey.

THE COUNTRY ROCKS

In the country round Ivigtut the gneiss is light grey, on weathered surfaces almost white. It is intensely folded in small and large folds. Strike and dip of the gneiss varies from one place to another. On the Ivigtut peninsula the strike is chiefly about N—S; on the distance Ivigtut—Grønne Dal the gneiss has a rather uniform NNW-strike and the bedding dips at large angles towards WSW; but on both sides of Ikerasak the bedding according to measurements recorded by USSING and GRY strikes N 80° E and dips abt. 60° towards S 10° E.

The main rock is a fine-grained plagioclase biotite gneiss made up of alternating white layers with only a small content of dark coloured minerals and grey layers with a considerable amount of biotite. Within some small areas the gneiss has a pronounced granitic habit; also granitic layers are met with. In other places layers of mica schists appear. Further numerous layers of rather fine-grained amphibolite occur varying in thickness from 1 cm to several meters. Pegmatitic and aplitic veins and some amphibolite dykes traverse the gneiss discordant to the bedding.—Besides there are several non-metamorphosed dykes.

The banded biotite gneiss. In the gneiss at Ivigtut the chief constituent of the white layers is an oligoclase with about 22—23 $^0/_0$ An. It is twinned according to the albite law; besides pericline lamellae are very common and in some crystals dominant. The oligoclase is somewhat sericitised. The quartz has a slight undulatory extinction. Orthoclase with a fine perthitic structure occurs in essentially smaller amount than the quartz; it almost looks like a kind of mesostasis but is sometimes also included in the plagioclase. Redbrown biotite occurs but sparingly. Ore and apatite is almost absent. A few grains of orthite, zircon, and probably rutile are seen. Myrmekite is present, but only in small quantities.

The grey layers mainly consist of the same mineral components, but in other proportions. Orthoclase is almost absent. Biotite is abundant, it often shows pleochroic haloes around zircon inclusions. A few small grains of hornblende are seen. Apatite is rather abundant and occurs in relatively large grains without crystalline forms. The other accessories are the same as in the white layers.

In the gneiss at Ivigtut mortar structure is common, but in other localities this feature is absent, e. g. at Christianshavn. Here, too, the gneiss contains a small amount of muscovite and some layers of mica schists are seen in the gneiss.

Granitic varieties are found in many places, e. g. at Ivigtut and in several localities in the area between Ekaluit and the Ika Fjord. These rocks differ from the banded gneiss not only by a very slightly pronounced or totally lacking schistosity but also because orthoclase- or microcline-perthite as a rule are more abundant than plagioclase. The rock is rather fine-grained. At Ivigtut the biggest grains reach a length of about 3 mm; they consist of a very fine perthitic orthoclase. At the eastern occurrences microcline perthite is often the dominating feldspar. In one case microcline and plagioclase roughly estimated are present in about equal quantities. The plagioclase in these rocks is mostly an oligoclase containing up to 31—32 $^0/_0$ An., but in one specimen it is pure albite. On the whole the mineral components are the same as in the above mentioned gneisses. Some of the rocks contain a little muscovite, in others hornblende appears. In one slice zoisite has been observed. In one occurrence only the feldspar consists almost entirely of plagioclase (oligoclase-andesine with abt. 30 $^0/_0$ An.), and in this rock hornblende is present in greater quantities than biotite. —Myrmekite frequently occurs, but rather sparingly only.

In all the granitic gneisses mortar structure is very conspicuous.

Plagioclase amphibolites. Only a few amphibolites have been examined some of which will be mentioned here. The rocks are rather fine-grained, more seldom medium-grained, and distinctly foliated. In this preliminary examination it has not been possible to ascertain any essential difference in the mineralogic constitution between amphibolites occurring as concordant layers in the gneiss and such amphibolites which as dykes traverse the gneiss discordant to the bedding. In all cases the chief constituent is hornblende which, broadly considered, makes up about 70—80 per cent. of the rock. It is a common green variety with pleochroism:

α light yellow
β brownish green
γ bluish green.

The extinction angle $c:\gamma$ is abt. 17—18°. Twinning parallel to the orthopinacoid is rather common.

The other essential component is plagioclase. Within some parts of the rock brown biotite is rather abundant whereas biotite in other parts of the same rock specimen may be practically absent. The minor constituents vary somewhat in quantity in the different rocks. White veins of quartz and plagioclase are observed here and there in the amphibolites.

At Ivigtut some amphibolite dykes occur traversing the gneiss. In one of them gneiss fragments are included. The best exposed dyke was found in a cut for a new building. It has a width of abt. 4 m, strikes abt. N—S and dips steeply towards W. It is definitely foliated parallel to the contact with the gneiss. The dyke must accordingly have been injected and metamorphosed at a late stage in the development of the Pre-Cambrian basement. Unfortunately the dyke could only be traced over a quite short distance. It was then hidden by vegetation and was no more to be re-traced. The plagioclase in this amphibolite is oligoclase-andesine with 32—33 $^0/_0$ An. The crystals always show twin-lamellation and the pericline lamellae are predominant to lamellae according to the albite law. As a rule the grains are quite clear, or only dusty. Quartz is present in rather considerable quantities. As accessories there are iron ore and sparingly apatite.

In another amphibolite occurring in the valley south of Ivigtut the plagioclase is a little more acid, abt. 25 % An. and somewhat sericitised. Besides epidote occurs abundantly as filling substance in small cracks. Quartz and apatite are found in sparing quantities, titanite is relatively abundant. Iron ore is almost entirely absent.

In an amphibolite dyke occurring N of Grønne Dal the plagioclase is mostly untwinned. Biotite is rather abundant. Quartz is not observed. Titanite is present in considerable quantities. The ore grains consist entirely of pyrite. Apatite occurs not infrequently as relatively large crystals. Some few epidote grains are seen. Calcite fills out some narrow cracks.

A totally unfoliated amphibolite occurs in the northern part of the Grønne Dal area at the junction of the nepheline syenite with the gneiss. Some gneiss fragments are included in the amphibolite. The rock is fine-grained and dark grey. The chief constituent is the same green hornblende as in the other amphibolites. The plagioclase is an andesine with abt. 35 % An. in the central part of the crystals and abt. 32 % An. in the border zone. It appears mostly as small elongated or even lath-shaped crystals twinned according to the albite- and the pericline-laws. Besides a number of bigger phenocryst-like plagioclase grains occur that are almost totally sericitised, but in some cases they are partially transparent and they then show zonar structure. Along the edge they are intergrown with hornblende and sometimes hornblende grains are scattered through the feldspar. These plagioclase crystals are undoubtedly relics of igneous minerals; they are more resistant to weathering than the other constituents of the rock and are therefore rather conspicuous on the rock surface. Iron ore and red brown deeply coloured biotite are present, but only in small quantities. A few small quartz grains occur. Idiomorphic apatite is common.

On considering the mode of occurrence of this amphibolite dyke immediately at the border of the nepheline syenite, the lack of foliation and the relic structure of the rock, which at least is not common among the amphibolites, it does not seem improbable that the amphibolite may be derived from a diabase dyke by contact-metamorphism caused by the nepheline syenite.

THE GRØNNE DAL – IKA REGION

At a distance of about 7 km NE of Ivigtut the nepheline syenite is found in the south shore of the inlet of Ekaluit (see map fig. 2). The whole area occupied by igneous rocks extends from Ekaluit about 9 km in south-easterly direction across the Grønne Dal to the head of the Ika Fjord. The northern part: Ekaluit—Grønne Dal will in the following be mentioned as the Grønne Dal area, the southern part as the Ika area. The eastern limit of the massif is not determined in details. The width is greatly differing in the various places but does not exceed some few kilometers.—In the sketch maps figs. 2 and 3 some of the investigated localities are marked with the figures 1—15.

The massif has a very irregular form, most likely it ought to be called a stock. In the southern part of the region it seems divided into nearly two parts of a several kilometers long wedge of the gneiss country rock. At the north end of the stock, a little south of Ekaluit, lies another more than 1.5 km long lense shaped gneiss wedge enclosed in the nepheline syenite; in all probability these gneiss wedges are 'roof-pendants'. Further the nepheline syenite in a few places of the shore near Ekaluit has penetrated through the gneiss along joints (see map, fig. 3, p. 23, locs. 7 and 8).

It is possible that there is no continual connection in the surface between the igneous rocks in the northern and the southern area, but no doubt they are parts of the same plutonic mass and are thus connected at a deeper level.

The main part of the rocks within this region is of a rather uniform character. The principal rock is a very coarse-grained foyaite which varies somewhat in composition from one place to another owing to the different relative amounts of the mineral constituents. In the vicinity of the gneiss country rock the grain size decreases somewhat, yet often not enough to make the rock fine-grained; in several places it is still coarse-grained immediately at the gneiss. In several other places fine-grained or porphyritic border facies are found, and in one of the small occurrences where the foyaite fills out fissures in the gneiss

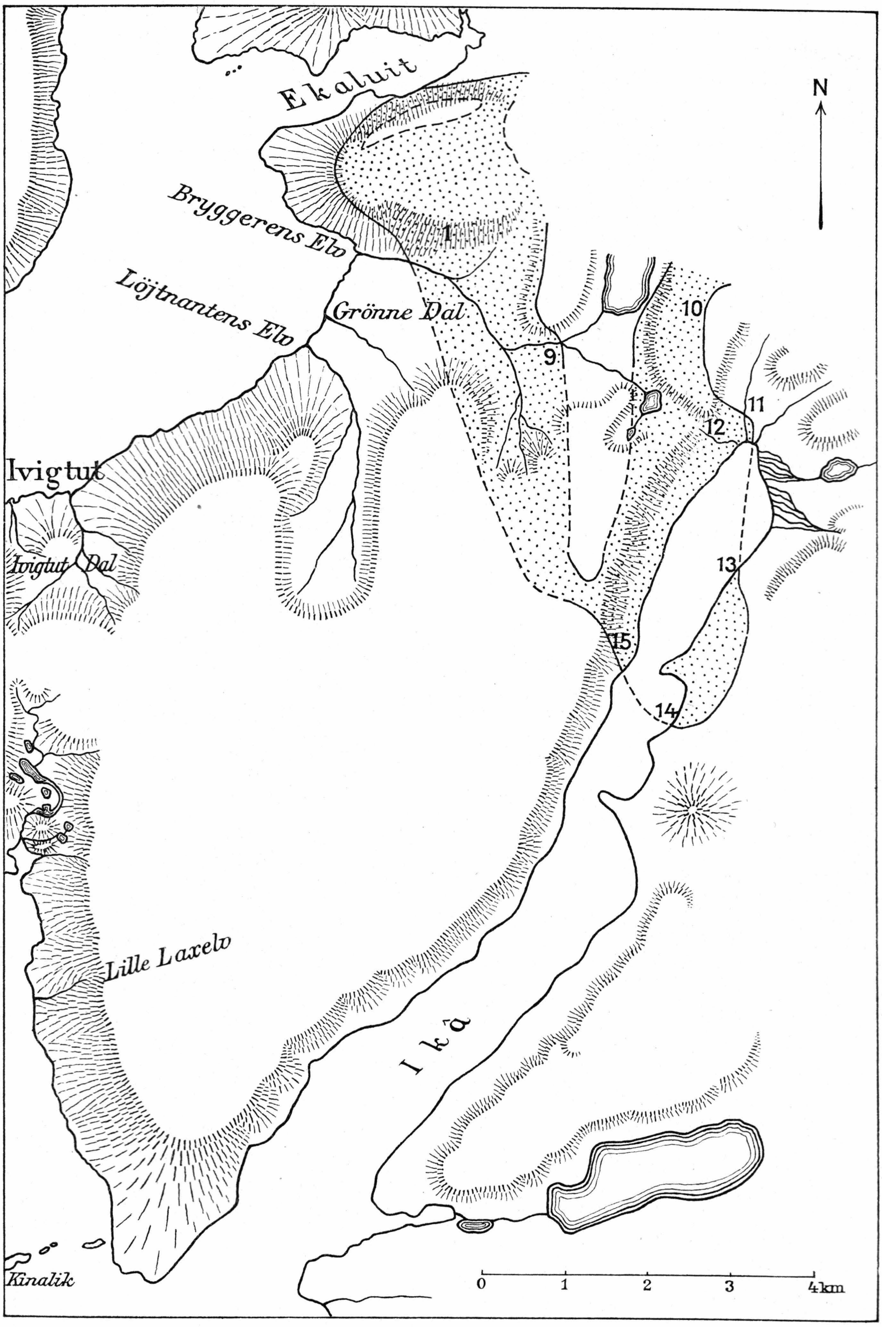


Fig. 2. Sketch map of the Grønne Dal—Ika region.
The dotted areas indicate the nepheline syenites.

(fig. 3, loc. 7) the rock is porphyritic in the central parts and becomes very fine-grained and 'schlieric' along the wall.

The rocks are very rapidly crumbling and have broken up into smaller or greater blocks which cover the more level stretches with a layer of debris. On the slopes the blocks have rolled down and built up very extensive talus. Therefore the surface rock is usually found to be unsound, which makes it difficult to get fresh material for examination.

The foyaite of this region is rather closely related to the Korok-[1]) foyaite from Igaliko, Julianehaab, from which it, however, differs somewhat in chemical composition.

The most important rock constituent is a tabular *feldspar*. It is a microperthite, in most cases consisting of microcline and albite. Apart from this albite plagioclase is totally absent in these rocks. The feldspar tables most frequently are divergent but sometimes they show a tendency to a rough parallelism, especially in the upper parts of the stock.

Nepheline is present in varying amounts. In the foyaite of the Grønne Dal area it is usually abundant and may exceed the feldspar in quantity. In the Ika area the nepheline seems to be somewhat less abundant; but it is difficult to judge of the fact as nepheline-poor varieties of the foyaite vary with parts rich in nepheline.

It is characteristic of the rocks within this region that the nepheline when altered, is chiefly converted into gieseckite, more rarely into cancrinite, and still more rarely into sodalite or analcime whereas the nepheline in the alkaline rocks of the Julianehaab district most frequently is altered into analcime or sodalite, cancrinite or "spreustein".

The dark coloured minerals are chiefly *ægirine-augite* and *biotite* (lepidomelane) as well as small quantities of *ægirine* and *katophoritic amphibole*. But in the vicinity of the border of the stock the amount of ægirine and amphibole often increases. The *accessories* are those usual for foyaite, still *titanite* seems completely lacking except in a few basic segregations.

Pegmatite and *aplite* appear in small quantities only and mostly as irregular "schlieric" segregations in the foyaite. Only a few and small pegmatite veins are found some of which penetrate into the gneiss.

On the whole the content of nepheline and dark minerals is decreasing upwards in the massif. In several places in the uppermost parts of the Grønne Dal area the foyaite therefore gradually passes into pulaskite. In the Ika area a similar change is found but, as far as can be stated, the nepheline-poor varieties are associated with parts consisting almost entirely of nepheline. The rock as a whole must

[1]) The place name Korok is now spelt Qôroq.

therefore be considered as a foyaite in which the mineral components are very irregularly distributed.—But in detail such a regularity in the distribution of the rock varieties does not hold good. In the same way coarse-grained and more fine-grained rocks may be found side by side all over the massif.

On the whole the mineral constituents of the marginal facies are the same as those of the main rock, but their relative amounts may vary considerably. Nepheline frequently occurs very abundantly, but in some cases it is only scarcely present. Ægirine, katophoritic amphiboles and iron ore sometimes appear in relatively large amounts. In a single place only (fig. 2, loc. 9) a more extraordinary rock, namely ijolite is found as border facies of the foyaite.

In the Ika area segregations or impregnations of siderite, calcite, fluorite etc. occur rather abundantly in several places in the border zone of the massif; and in the adjacent gneiss some narrow fissures filled with carbonates are found, the most important of which is a siderite-vein about 20 cm wide.

The effects of contact metamorphisms on the gneiss are only slight and they chiefly consist in the formation of crocidolite. In the south-western part of the Ika area slickensides and finely crushed gneiss breccias amalgamated with crocidolite and dahllite occur.

Finally it must be mentioned that N. O. Holst on his journey mentioned above (p. 10) in 1880 found a deposit of magnetite lying in limestone in the area between Grønne Dal and the Ika Fjord. In his report (l. cit. p. 27) he writes about it [here quoted in translation]: "The ore is so rich that in another place it would have been worth working. It is penetrated by off-shoots of diabase dykes." Holst gives no further information about the occurrence. Later this deposit was re-discovered by Richard Bøgvad, M. Sc., who was kind enough to give the following particulars:

"The iron ore deposit discovered by N. O. Holst in 1880 occurs in the south side of Grønne Dal at heights varying from 300 to 400 m above sea level, nearly midway between the head of the Ika Fjord and the outlet of 'Bryggerens Elv'. The streambeds in this place are rustcoloured over long stretches, and frequently blocks of magnetite are found lying about. The occurrence seems to be extended in shape and is chiefly situated within the nepheline syenite area. The size of a strongly ferriferous part of the occurrence, abt. 320 m above sea level, is estimated at $200 \times 100 \times 50$ m; but the borders have not been determined. The place was visited in 1938 and 1939.

Holst mentions "Svartmalm" (magnetite ore) in limestone with off-shoots from diabase dykes and these rocks seem to occur most frequently. The area is greatly disturbed; there are various kinds of breccias, and slickensides are observed. Magnetite occurs in aggregates as large as a hand and as coarse-grained parallel layers of varying thickness in limestone. The specific gravity of the most compact pieces is 4.7, the magnetite must therefore contain some impurity. There are fissures with crystals of magnetite (rhombic dodecahedrons truncated by small octahedral faces). Great parts of the surface of the occurrence are converted into limonite; in the latter slight traces of galena have been found.—Some of the calcitebearing rocks contain some quartz, while others show a slight content of barite.—

In the vicinity of the occurrence greenish, syenite-like rocks are found with great magnetite content, with inclusions of calcite and traces of pyrite.

It is possible that the occurrence of iron ore deposits in Grønne Dal is connected with another smaller occurrence that is to be found at abt. 300 meters height in a ravine near the head of the Ika Fjord."

In this connection it may be added that diabase dykes with segregations of magnetite, partly crystallised in rhombic dodecahedrons, also occur in loc. 9 cutting across the ijolitic border rock.

THE GRØNNE DAL AREA

As appears from the map, fig. 3 the surface in this area chiefly consists of alkaline rocks which in the western part of the peninsular-like stretch of land is bordered by a lower lying edge of gneiss of the light grey type common in that district. In a single place only, at the coast of Ekaluit, (locality 8) the nepheline syenite stretches as far as to the fjord.

The contact with the gneiss is in several places along the coast well exposed, and in some localities characteristic border facies of the nepheline syenite are found. In the few places where the nepheline syenite has penetrated the gneiss along the joints a fine-grained or porphyritic border rock is found.

Within the northern edge of the stock, some way up lies, as mentioned above, a more than 1.5 km long lenticular gneiss fragment included in the nepheline syenite. To northwest the gneiss fragment cuts off a narrow strip of nepheline syenite which thus attains a dyke-like form. The rock in this "dyke" is somewhat less coarse-grained than the main rock. It is by partings divided into large blocks, and since the disintegration proceeds most rapidly along the joints the blocks have got somewhat roundish bag-like shapes. In the middle of the "dyke" the nepheline syenite forms a projecting ridge, while the rubbish has rolled down and formed a thick layer of debris along the

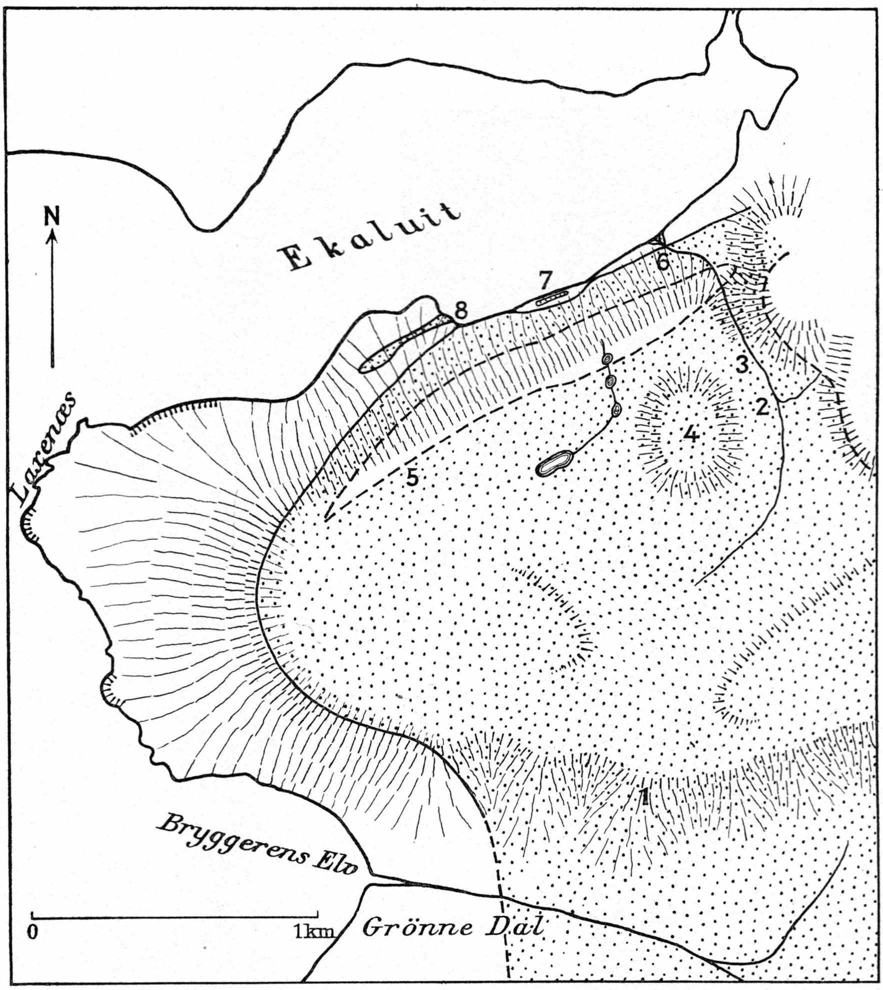
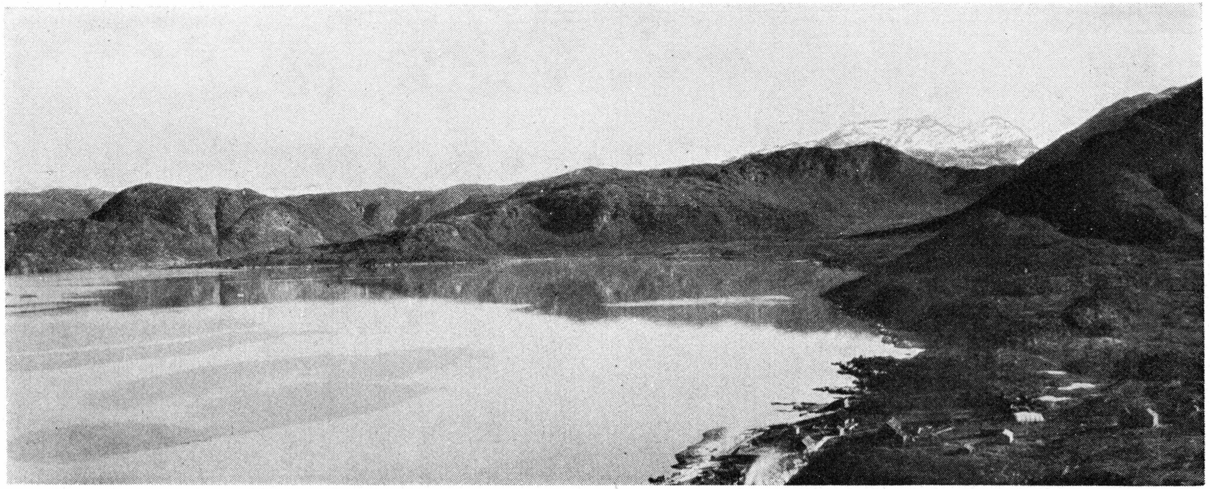


Fig. 3. Sketch map of the Grønne Dal area.
Dotted = nepheline syenites etc.

sides of the "dyke" which lie at a slightly lower level than the gneiss wall rock.

The main rock within the Grønne Dal Area consists of a grey or reddish-grey foyaite which appears in several varieties gradually passing into each other. But in the uppermost part of the area, i. e. from about 250—300 m up to 400 m above sea level the predominant rock is a coarse syenite rock, a pulaskite, with a slight content of nepheline and a smaller amount of dark coloured minerals than the foyaite. The pulaskite rests upon the foyaite. However, also varieties of the foyaite reach up to heights of about 300 m and in some places the different rock varieties change rapidly so that it is impossible to a.



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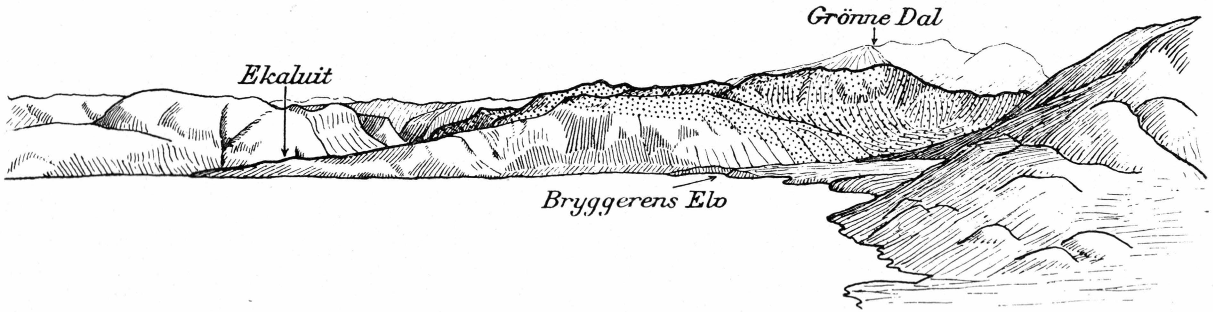

Fig. 4. a. Grønne Dal seen from Ivigtut. Samuel G. Gordon phot. 1923.
b. Sketch of the preceding. Dotted = nepheline syenites etc.

give any exact information concerning the distribution and thickness of the pulaskite. In the map fig. 3, p. 23 are some localities from which specimens of pulaskite have been collected, marked 2, 3, 4. But the pulaskite has a considerably wider extension west and south of these places; at any rate the surface rock in the upper part of this area is chiefly of the same outer habit.

PULASKITE

The rock is coarse-grained and mostly of a light grey colour; on the weathered surface it is frequently brownish. The chief constituent is a tabular feldspar which reaches a length of about 1.5 cm, a width of about 1 cm, and a thickness of 1 or 2 mm. The feldspar crystals show a marked tendency to parallel arrangement which gives the rock a trachytoid appearance. In some specimens biotite is seen as relatively thick crystals that may reach more than 5 mm in diameter. Pyroxene is scarce but is seen in one hand specimen.

Usually the feldspar is quite fresh, or only a little dusty. Nepheline and dark coloured silicates on the other hand appear greatly altered in all the specimens examined. Biotite is, however, most frequently distinguished by its perfect cleavage and seems originally to have been the predominant and in several cases the only dark mineral. It has appeared impossible to prove any pyroxene in the slices.

The *feldspar* crystals are tabular parallel to (010) and show no other crystal faces; usually they are twinned on the Carlsbad law. They consist of microcline microperthite in some inner parts of which the microcline sometimes shows a slightly developed cross-hatching or irregular twinning. In sections perpendicular to MP the microcline shows an extinction angle of 18°—19° to trace M. The perthite-plagioclase is albite with refractive indices lower than that of Canada balsam. It occurs most abundantly in the outer layers of the feldspars; not infrequently it shows a fine twin lamellation on the albite law. Small grains of green biotite or chlorite, and sometimes a number of apatite crystals, are found included in the feldspar. In some cases limonitic alteration products from the biotite have proceeded into cracks in the feldspars.

Fresh *nepheline* is not found but pseudomorphs consisting of gieseckite indicate the original presence of nepheline. That the pseudomorphs are derived from nepheline can in some cases be ascertained with certainty by their idiomorphic form, but they chiefly occur only in the angular spaces between the feldspars. A little *cancrinite* sometimes occurs. At one eastern place, at about 250 m height, neither nepheline nor cancrinite are present, further no pseudomorphs are found which with certainty have arisen from nepheline. On the whole the amount of nepheline is variable but never abundant.

Of *biotite* a few remnants only are left almost unaltered. With regard to alteration the biotite behaves in various ways. In some specimens it is chloritised and it often contains small grains of iron ore with metallic lustre (magnetite). In other cases there occur pseudomorphs after biotite consisting of chlorite, calcite, redbrown opaque limonitic products together with a colourless or faint brown mica which shows a small axial angle and rather strong double refraction, probably zinnwaldite. And finally the biotite may be totally converted into opaque ferriferous products which here and there are mixed with small grains of micaceous hematite; even in the latter pseudomorphs the cleavage of the biotite is recognisable, the original inclusions of magnetite being unaltered. As a rule the chlorite and biotite pseudomorphs fill out spaces between the feldspars, but not infrequently a few small gieseckite- and feldspar-crystals are included in the pseudomorphs.

In some of the specimens examined a number of small crystals, which cannot be exactly determined, are found in the biotite pseudomorphs. They mostly occur along the edge and the cleavage cracks and may form rather considerable parts of the pseudomorphs. The crystals are so full of brown dust that an examination in convergent light yields no result. Their outer form is most frequently rectangular, refractive index a little lower than that of Canada balsam, birefringence weak or moderate, elongation negative. Most probably they consist of secondary feldspar.

Iron ore, magnetite or titanomagnetite are scarce but sometimes occur in relatively large grains. *Titanite* is not found. *Zircon* is usually present, sometimes even in relatively large quantities and in rather large grains.

TRANSITION ROCKS BETWEEN PULASKITE AND FOYAITE

As previously mentioned rocks rich in nepheline appear side by side with the pulaskite. They usually show the same trachytoid structure as the pulaskite, and like the latter rock they include slight amounts of dark coloured silicate minerals which almost entirely consist of biotite.

In locality 3, at a height of 200—250 m, where the stream has cut down into the strongly crumbling pulaskite there occurs a light grey, slightly less coarse-grained rock variety, fairly rich in nepheline. This rock is conspicuous because it—though much jointed—is somewhat more resistant against the disintegration and therefore forms projecting parts in the pulaskite. This variety is, perhaps, best termed a mica-foyaite poor in dark coloured minerals. The greatly predominant mineral constituent is a thin tabular microline microperthite. Nepheline is present in not inconsiderable quantities. It is quite fresh and clear and intergrown with cancrinite in a micrographic manner that gives the impression that both minerals are crystallised simultaneously. Biotite is the only dark coloured mineral. It appears as irregularly shaped flakes, 2—3 mm in diameter and is very conspicuous in hand specimens, but the grains are so dispersed that the biotite may almost be wholly lacking in slices.

In the same locality boulders are found of a characteristic, very light almost white coarse-grained rock variety, and the same kind of boulders is found at the outlet of the stream into Ekaluit. The rock is in several respects closely related to the one just mentioned; the feldspar is the same and biotite appears in the same way which makes it probable that this rock occurs *in situ* in the neighbourhood. In structure it conforms with the pulaskite. Nepheline is not observed; instead cancrinite occurs. Zircon appears in relatively large crystals. The rock is traversed by irregularly running fissures some of which are filled with blue sodalite accompanied by siderite which partly appears as larger grains of up to 4 cm on the longest side, partly have penetrated into fine cracks in the other minerals. In another fissure-system the filling chiefly consists of ægirine in slender needles accompanied by small quantities of green biotite.

Further west in locality 5, at a height of abt. 300 m, the rock still retains a pulaskite-like appearance and a pronounced trachytoid structure owing to the sub-parallel arrangement of the thin tabular feldspar. But the nepheline content is here considerable. The rock is unfresh and strongly crumbling. It is coarse-grained and yellow or yellow brownish in colour. As usual the feldspar consists of microcline microperthite, sometimes in the central parts of the crystals graduating into cryptoperthite. No cross-hatching is seen. The perthite-plagioclase is albite which seems to form the greater part of the crystals. The feldspar is fresh, or a little dusty only, but here and there ferriferous alteration products from the biotite fill out cracks in the feldspar crystals and bring about the yellow brownish colour.

Nepheline is totally converted into gieseckite pseudomorphs which are present in considerable quantities. Usually the crystal form of nepheline is perfect; not infrequently the pseudomorphs are included in the feldspar, and in some few cases only they fill out spaces between the feldspars. Cancrinite is not found.

Biotite is to a great extent altered to an opaque hematitic product which under the microscope in reflected light partly shows a red brown colour, partly is seen to consist of magnetite grains with metallic lustre.

Besides the biotite is converted into a colourless mica with rather strong double refraction. It has not been possible to prove other dark coloured silicates than biotite.

Zircon occurs relatively abundantly.

These rock varieties must be considered as transition rocks between the pulaskite and the main foyaite. From locality 5 towards west and towards north the surface rock graduates into the pyroxene-rich foyaite which is characteristically developed in locality 8 (see below p. 42). It is impossible to tell where one begins and the other leaves off.—A similar gradational contact is found in the eastern part of the area and in the south slope of Grønne Dal.

On the other hand a case of sharp contact is also known to exist between the pulaskite and the foyaite as USSING in the interior area at about 280 m height found a wide dyke of foyaite cutting across the pulaskite. The dyke rock is relatively fine-grained and shows a pronounced trachytoid structure, but in all other respects it is quite similar to the main foyaite in locality 1 (see below p. 29).

It must further be mentioned that USSING at a height of about 300 m directly at the large gneiss fragment found a fine-grained porphyritic border facies of the foyaite closely agreeing with the border facies occurring at the shore of Ekaluit.

From these contact relations it is evident that the pulaskite has consolidated a little earlier than the foyaite. Since the pulaskite chiefly consists of feldspar while the underlying foyaite has a considerable content of heavier minerals it is probable that some gravitational differentiation took place during the crystallisation.—Presuming that the large gneiss fragment is a ‘roof-pendant’ it is probable that the roof of the stock has been lying at a comparatively low height over the present surface, and that the pulaskite represents the uppermost, or almost the uppermost, layer of the stock. Further that the present couped surface represents a section through the stock which partly cuts through the transition zone between the pulaskite and the foyaite. This assumption would explain that in one place pulaskite, in another foyaite or transition rocks are found as surface rocks.

That pulaskite and nepheline syenite appear as geologic and petrographic very closely related masses which pass gradually into another is well known from other occurrences. KRAATZ-KOSCHLAU and V. HACKMANN[1]) are for instance in the description of the occurrence in the Foya Hills, Serra de Monchique, Portugal, inclined to consider the pulaskite from Foya as a facies of the foyaite from Picota consolidated at

[1]) K. v. KRAATZ-KOSCHLAU und V. HACKMANN, Der Elaeolithsyenit der Serra de Monchique. T. M. P. M. *16*, 1896, 220.

a higher lever. Similar conditions are mentioned by Brögger[1]) from the Oslo district, by J. Fr. Williams[2]) from Fourche Mountain, Arkansas, and from still more places.

FOYAITE

The foyaite makes up the greater part of the eruptive mass in this area. As regards grain size, structure, and mineral composition the rock varies somewhat from place to place. The tabular feldspars are most frequently irregularly arranged, but sometimes they show a slight tendency towards a rough parallelism. Nepheline is abundant and may even exceed the feldspar in quantity, but the amount of nepheline is, however, somewhat varying. Dark coloured silicates as a rule play an important part; most often they consist of ægirine-augite and lepidomelane, but both the total quantity of these minerals and their relative amounts may vary rather considerably; the lepidomelane is for instance prevalent in the varieties comparatively poor in nepheline which approach the above mentioned transition rocks in composition. The pyroxene-richest varieties are met with only towards the boundary of the foyaite.

The Main Foyaite

The variety of foyaite which is considered to be the main type occurs on the north slope of the Grønne Dal at a height of about 200 m around the place which in the map fig. 3, p. 23 is marked locality 1. This rock is the most characteristic and as far as may be stated the one most widely distributed within this area.

This foyaite is coarse-grained and grey, or reddish grey, in colour. The fresh greyish tabular feldspar is about 3—4 mm in thickness and with an average length of about 15 mm. Repeated twinning on the Carlsbad law is common. There is no law of arrangement of the feldspar crystals. The nepheline is reddish grey, or brownish red, and of an elæolithic habit. Dark coloured silicates are present in considerable quantities; they mostly consist of a greenish black ægirine-augite; in somewhat smaller quantities a black or greenish black lepidomelane occurs which on account of its perfect cleavage is the most conspicuous dark mineral in the hand specimens.

Under the microscope are further seen cancrinite, apatite, magnetite, and accessory zircon, fluorite, and a little calcite.

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[1]) W. C. Brögger, Die Eruptivgesteine des Kristianiagebietes III, 1898, 183 ff.

[2]) J. Fr. Williams, The igneous rocks of Arkansas. Ann. Rep. Geol. Surv. of Arkansas for 1890. Little Rock, 1891, 120.

The *feldspar* crystals are, as mentioned above, of tabular habit parallel to (010) and usually elongated parallel to the a-axis; they are not, as a rule, bounded by other crystal faces.

The feldspar is a *microcline microperthite.* The plagioclase-component consists of *albite* with refractive indices lower than that of Canada balsam, it is thus an albite with less than 10 $^0/_0$ An. The albite is chiefly predominant in the peripheral parts of the feldspar, and particularly the smaller crystals have not infrequently a marginal zone of pure albite whereas the microcline forms the chief part of the central portion. Roughly estimated the two feldspars are present in about equal quantities. In sections parallel, or approximately parallel, to the basal plane the albite appears as irregularly fringed and reticularly branching veinlets which in some parts of the crystals show a tendency for short stretches to arrange themselves parallel to the edges (001):(110) and (001:(1$\bar{1}$0), more infrequently perpendicular to (010). The boundary line between albite and microcline is irregularly dented and for numerous quite minute distances it is parallel to trace (010). The albite shows a fine twin-lamellation on the albite law; the lamellæ are most often quite short; in the border zone where the albite is dominant the twin lamellæ are coarser.

The *microcline* in the rock sample analysed shows a fairly well developed cross-hatching (see pl. 1, fig. 1) by which it differs from the usual microcline microperthite in foyaitic rocks and particularly is in contrast to the microcline microperthites in the nepheline syenites described by N. V. USSING[1]) from the Julianehaab district. Nor in the other rocks in the Grønne Dal area is cross-hatched microcline common. Only in some slices is cross-hatching observed, and then generally in small parts of the microperthite only. On the other hand USSING[2]) mentions a microperthitic microcline-albite in nordmarkite from Nûngmiut, NW of Narssaq, "and this microcline shows a very marked cross-hatching. It is otherwise extremely rare to find cross-hatched microcline in the post-Devonian igneous rocks from this area."

In basal sections or sections nearly parallel to (001) where the cross-hatching appears most clearly the twin lamellæ according to the albite law as well as to the pericline law are distinctly visible, though on the whole they are less sharply outlined than in ordinary microcline. The examination of a number of sections gave for the twin lamellæ on the albite law a maximum extinction angle amounting to 16.5°—17.4°. The cross-hatching is best developed along the edge of the perthitic

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[1]) N. V. USSING: Meddelelser om Grønland, Vol. *14*, 1894, p. 21 ff.

[2]) N. V. USSING: Meddelelser om Grønland, Vol. *38*, 1912, pp. 194 and 241. Conf. further W. C. BRÖGGER: Zeitschr. f. Kryst. Bd. *16*, 1890, pp. 558—59.

albite intergrowths; in the intervals between the albite bands the cross-hatching gradually becomes submicroscopic; in these places the microcline shows extinction parallel to trace (010).

In sections nearly parallel to (010), showing a very distinct basal cleavage, the perthitic albite bands are arranged in the ordinary manner at an angle of about 70° to the basal cleavage, but the shape of the albite bands is too irregular to permit an exact measuring of the angle. On cleavage flakes parallel to b ($\perp \gamma$) immersed in clove oil the following extinction angles were found:

microcline α: trace (001) = 4°—6.5°
albite α: trace (001) = 18—19.5°

In most samples of foyaite from the Grønne Dal area the feldspar is fresh and clear or only slightly cloudy. Here and there small scales of secondary muscovite may appear. But in some specimens the feldspar is turbid, filled with muscovite aggregates and dust. The feldspar is comparatively free from inclusions but irregularly formed grains of pyroxene and biotite appear in small quantities. The minute needles of ægirine which frequently occur in the feldspars in the above mentioned Julianehaab-rocks are however not found.

Nepheline occurs rather abundantly. As seen in the table p. 36 it makes up abt. 40 per cent. of the whole rock. It is of elæolithic habit. In basal sections some of the grains show a small axial angle. On the whole the nepheline is idiomorphic towards the feldspar but occasionally small grains of feldspar are included within it. In most cases it is idiomorphic against pyroxene and biotite, but in a few instances it contains inclusions of pyroxene and brown mica.

In the specimen of foyaite analysed the nepheline is as a rule quite fresh or contains small quantities of secondary muscovite (gieseckite) only. Under the microscope many of the crystals are quite clear; in some of them fluid inclusions in zonary arrangement are seen. In other rock samples the nepheline is more or less changed to cancrinite or to muscovite aggregates, and in many instances it is totally altered to gieseckite-pseudomorphs.

Cancrinite occurs in varying quantities. In some slices it is relatively abundant while in others it is entirely absent. In the examined material it never attains macroscopic dimensions. It is always quite clear. Prismatic forms have not been observed. In the analysed specimen the cancrinite appears partly in irregular, mostly rounded, grains, partly it forms large lapped anhedra filling the spaces between the crystals of feldspar and nepheline. This cancrinite is frequently in a micrographic manner intergrown with the outer zones of the nepheline, more rarely also with the feldspar. The nepheline in these intergrowths may have been more or less converted into muscovite aggregates. The cancrinite is compact and unaltered, and it seems probable that it is, in part at least, a primary mineral which has crystallised contemporaneously with the nepheline.

In other specimens from nearly the same locality the nepheline is partly converted into radiating fibers of cancrinite which usually follow the edge of the nepheline and proceed along cracks through the nepheline crystals.

In a single case these two forms of cancrinite have been observed in direct association with each other. A thin section of a rock from the eastern part of the Grønne Dal area containing several of the above mentioned nepheline-cancrinite intergrowths shows that the nepheline besides to a certain extent is converted partly into muscovite and partly into a fibrous or scaly aggregate of cancrinite. In some places the cancrinite fibers are directly connected with and seem to radiate from the compact cancrinite, they have then sometimes—but not by far always—the same optic orientation as the compact cancrinite. But the cancrinite fibers more frequently appear at the junction between feldspar and nepheline. This feature seems to indicate that the compact cancrinite is of primary origin while the fibrous and scaly cancrinite has arisen at a later stage by autometamorphosis.

Finally it must be mentioned that some essentially larger cancrinite crystals have been found in a boulder from Grønne Dal collected in 1880 by the Swedish geologist N. O. HOLST. They are described by A. E. TÖRNEBOHM[1]) who calls the rock a fine grained augite syenite.

This cancrinite occurs as a fibrous aggregate in which the individuals may reach 2 cm in length and 2—3 mm in diameter. The contours of the crystals are always uneven, almost indented, but some crystals show in cross section a rather distinct hexagonal form. The cancrinite crystals are always closely crowded with small crystals and grains, chiefly of feldspar and ægirine but also, though more rarely, of biotite and apatite.—Unfortunately the Mineralogical Museum in Copenhagen possesses no specimens of these cancrinite crystals.

The prevalent dark coloured mineral is *ægirine-augite*, corresponding rather closely to the green augite described by USSING[2]). It makes up about 8—10 per cent. of the rock. Generally it occurs in allotriomorphic anhedra about 1 mm in diameter only, or smaller, but some of the grains show traces of the most common planes, (110), (010) and less

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[1]) A. E. TÖRNEBOHM, Geol. Fören. i Stockholm Förhandl. Bd. VI, 1883, pp. 693 and 695.

[2]) N. V. USSING: Medd. om Grønland, *14*, 1894, p. 188 ff.

frequently (100); most of the crystals are flattened parallel to (010). Other grains are elongated parallel to the c-axis and a few of these crystals are terminated by pyramid faces poorly developed. In few cases only the ægirine-augite shows small parts of an ægiritic border. Twins are not common but a few crystals twinned parallel to (100) have been observed. The pyroxene grains are often grouped together in heaps and in a very irregular manner intergrown with each other to aggregates mixed with some biotite and iron-ore. As inclusions in the pyroxene there are biotite, iron-ore, apatite and zircon.

The ægirine-augite is intensely green; in some of the crystals, especially in the elongated grains, the central parts are of a lighter pale green colour; in few cases only they show small parts of an ægiritic border. Usually the pyroxene is quite fresh but in a single slice some of the grains are discoloured along cracks and along the edge. The discoloured parts may be more or less brown coloured by segregated opaque particles; they have slightly higher interference colours than the green parts and very small extinction angles.

Double refraction is moderate. The axial plane is parallel to (010). The axial angle is very large, nearly 90°; optic character not determinable. In cross sections that show the emergence of the optic axis B the axial bar shows a distinct dispersion. The optic axis A in sections parallel to (100) is not dispersed. In the green crystals without zonar structure the extinction angle varies but slightly (3°—4°) from the central parts to the outer layers, usually $c:\alpha$ is about 40°. But in crystals with light coloured core the difference is greater. In a section normal to β was measured:

	$c:\gamma$	$c:\alpha$
The core	54°	36°
The marginal zone	75°	15°
Discoloured parts of the marginal zone	86°	4°

However, this section probably cuts across the pyroxene rather peripherally, in other sections was found $c:\alpha = 45°$, 48°, even up to 51° in the core and about 10° in the outer zone. Moreover, these crystals often show a considerable dispersion of the bisectrices and then the extinction angle is larger for green than for red light.

The pleochroism is strong:

α deep green or bluish green,
β clear green,
γ light brown or greenish brown.

The absorption is $\alpha > \beta > \gamma$.

Biotite (lepidomelane) is present in a quantity of about 6 per cent. of the whole rock. In the analysed rock it occurs in two different types, a brown and a very dark green biotite, both strongly pleochroic.

The brown biotite shows absorption tints ranging from a very dark brown, or almost black, to a light brownish-yellow with a reddish tint or to a quite pale yellow. A few grains are somewhat discoloured and have become greenish in colour about the edges; more rarely the whole grain is of an olive-brown colour. Between the cleavage flakes small segregations of iron ore are often seen, some of them are slightly translucent along the edges with a red to yellowish-red colour. In other specimens this alteration process has proceeded so far that only small remnants of the biotite are left, while the rest consists of iron ore. Segregations of quartz and calcite are not observed.

The green biotite is very dark coloured and only very thin sections show an intensely deep green colour. The absorption tints vary from dark green to quite black. As a rule this biotite contains numerous small segregations of iron ore intercalated between the cleavage flakes which make many of the grains almost opaque, so that the green colour is only to be seen by high magnifying power and by insertion of the condenser. In very thin cleavage flakes the biotite is seen to be uniaxial. The green biotite is always allotriomorphic. It fills out the spaces between the other minerals; sometimes it is intergrown with the pyroxene. Not infrequently it shows a fringed intergrowth with the feldspar and the nepheline. The green biotite is macroscopically the most conspicuous among the dark coloured minerals. It appears in the rock in grains of up to abt. one cm in diameter. But in other rock varieties from this area the dark green biotite is entirely lacking.

Accessories. The accessory minerals are *apatite*, *iron ore*, and very small quantities of *zircon*, *fluorite*, and *calcite.* The apatite is often associated with the dark coloured minerals but it also appears enclosed in feldspar and nepheline. The iron ore occurs sparingly or almost only as inclusions in pyroxene and biotite; some of the grains have a core of *pyrite.*

Sequence of crystallisation. From the above description it appears that the order of crystallisation is as follows: apatite and iron ore come first, then nepheline, then feldspar, and at last pyroxene and biotite. Still, single grains of pyroxene, mostly intergrown with brown biotite, may be found enclosed in the nepheline and in the border zone of the feldspar which proves that these minerals have begun to crystallise at an early stage of the consolidation. But the main portion of pyroxene and biotite fill out spaces between the feldspar and the nepheline crystals and must consequently have crystallised later than the main part of the other minerals of the rock. Consequently the pyroxene and the biotite show a wide range of crystallisation; yet the green biotite only occurs as the latest mineral in the succession.

Chemical composition. A chemical analysis of this rock was made for N. V. Ussing by Dr. Chr. Winther in 1901. This analysis with the results given in no. **1** of the following table has not earlier been published.

	1 %	Mol. Prop. of **1**	Norm of **1**		Niggli's System of **1**		**A**	
SiO_2	50.52	8420	Or	33.92	si	143.7	SiO_2	50.63
TiO_2	—	—	Ab	10.48	p	0.26	TiO_2	0.90(?)
ZrO_2	—	—	An	2.78	co_2	2.1	ZrO_2	—
Al_2O_3	24.51	2403	Ne	42.32	al	41.0	Al_2O_3	24.00
Fe_2O_3	2.15	134	Nc	1.27	fm	12.0	Fe_2O_3	2.33
FeO	2.72	378	Σ sal	90.77	c	5.5	FeO	2.21
MnO	0.10	14			alk	41.5	MnO	n. d.
MgO	0.15	37	Di	3.91	k	0.25	MgO	1.54
CaO	1.83	327	Ol	1.36	mg	0.05	CaO	2.13
Na_2O	11.24	1813	Mt	3.02	c/fm	0.47	Na_2O	11.36
K_2O	5.65	601	Ap	0.62	o	0.38	K_2O	4.39
H_2O — 110°	0.21	—	Σ fem	8.91			H_2O (Ign.)	0.63
H_2O + 110°	0.85	472	H_2O	0.85	section IV			
P_2O_5	0.21	15		100.53			P_2O_5	0.28(?)
CO_2	0.54	123			al—alk = —0.5			
Cl	0.03	8			al—fm = 29.0			
SO_3	tr				qz = —122.3			
	100.71							100.40
Deduct Cl_2 = O	0.01	Quantitative System: I″. 7. 1. 4. Laugenose.						
	100.70	Niggli's Type: Urtitic.						
		Sp. Gravity 2.670.						

1. Nepheline Syenite, Grønne Dal, Ivigtut, S. Greenland. Chr. Winther, analyst.
A. Nepheline Porphyry, Lougendal, Norway. G. Forsberg, analyst. (W. C. Brögger: Die Eruptivgesteine des Kristianiagebietes III, 1898, 158).

The analysis shows a composition rather uncommon for the nepheline syenites and, as will appear from the discussion below, it can hardly be quite correct. Among other earlier analyses I have found a single one only, quoted in the table under **A**, which in its chemical proportions approximates to the former, namely the analysis of a "nepheline porphyry"[1]) from Lougendal, Norway. Though differing somewhat with regard to the mineral components the two rocks show on the whole rather similar relative amounts of the feldspars, the feldspatoids, and the dark coloured minerals.

[1]) Later by Brögger called "Lardalitporphyr". Op. cit. VII, 1933, p. 76.

A calculation of analysis No. **1** according to the results of the microscopical examination gave the following approximate mineral composition:

Or	19.6	per cent.
$Ab_{93}An_7$	17.4	—
Nepheline	40.0	—
Cancrinite	6.7	—
Sodalite	0.4	—
Pyroxene	8.6	—
Lepidomelane	5.6	—
Apatite	0.46	—
Calcite	0.46	—
Magnetite	1.0	—
	100	per cent.

In the calculation the analysis showed a surplus of Na_2O of 0.42 per cent. The average composition of feldspar calculated should be about $Or_{53}Ab{+}An_{47}$ and that of the albite about $Ab_{93}An_7$ which agree with the microscopic determinations.

In the calculation P_2O_5 is calculated as apatite and the small Cl-content as sodalite. According to the high Na_2O- and Al_2O_3-contents and the low SiO_2-content the feldspatoids must be very abundant. It has been assumed that the nepheline and the cancrinite are of the same composition as those from Litchfield analysed by CLARKE[1]).

For the *ægirine-augite* a composition is assumed corresponding to that calculated for the pyroxene from analysis No. **2** (see below p. 52) and analysis No. **3** (p. 63), the pyroxene of which rocks shows the same optic properties as the pyroxene in question. The composition of the present ægirine-augite should then be about:

SiO_2	52.67	per cent.
Al_2O_3	5.47	—
Fe_2O_3	15.82	—
FeO	7.21	—
MnO	0.23	—
MgO	1.16	—
CaO	7.44	—
Na_2O	9.30	—
K_2O	0.35	—
H_2O	0.35	—
	100.00	per cent.

The composition of the *lepidomelane* is calculated from the rest left over after calculation of the other minerals. It should be about:

[1]) F. W. CLARKE: Amer. Journ. of Sc. *31*, 1886, 262 (nepheline) and ib. *31*, 1886, 263 (cancrinite).

SiO_2	31.36	per cent.
Al_2O_3	17.21	—
Fe_2O_3	5.92	—
FeO	27.78	—
MnO	1.43	—
MgO	0.90	—
CaO	1.25	—
Na_2O	1.61	—
K_2O	8.60	—
H_2O	3.94	—
	100.00	per cent.

In the calculation of the composition of the pyroxene and biotite it is assumed that both minerals have a high content of FeO. Yet a small excess of 0.23 per cent. FeO remained which was calculated as Fe_2O_3. The corresponding figures of the analysis should therefore in all probability be: Fe_2O_3 = 2.40 per cent., FeO = 2.49 per cent. Further it must be noted that TiO_2 was not determined. In all probability the compositions of the pyroxenes and the biotite would be somewhat more correct if a small amount of TiO_2 had been calculated for these minerals and a corresponding amount subtracted from the Al_2O_3.

Finally I would believe that the MgO-content: 0.15 per cent. perhaps is a little too low, and the CaO-content correspondingly too high; that would give a more probable composition of the lepidomelane. It must, however, be pointed out that a low MgO-content, and a rather low CaO-content too, are just characteristic of these rocks.

Biotite Foyaite

In several places the main foyaite by decreasing pyroxene content grades into biotite foyaite. Such varieties are found for instance in the southern slope of Grønne Dal and in the dyke-like occurrence along the NW-border of the massif near Ekaluit. In some cases the biotite foyaite is closely related to the transition rocks between the pulaskite and the main foyaite, but differs from these varieties by containing a considerable amount of nepheline and biotite.

The biotite foyaite is rather coarse-grained and the tabular feldspars mostly show a slight tendency to parallelism. Besides feldspar, nepheline, and biotite a few grains of ægirine-augite sometimes occur. In one slice amphibole is observed. Apatite usually appears in stout prisms, not seldom inclosed in the feldspar. Magnetite occurs rather richly.

The microscopic examination shows that the *feldspar* crystals possess a very fine perthitic structure that is a little coarser in some patches, mostly in certain parts of the outer layers where albite is then predominant; more seldom the border zone grades into pure albite. In the main part of the interior the structure is extremely fine, almost cryptoperthitic. Totally homogeneous patches also occur and in sections $\perp \gamma$ they show an extinction angle α : P of 8°—9°. In the year 1905 H. E. JOHANSSON in a diagram plotted the extinction angles of analysed feldspars of the potash-soda-series to show how the extinction angles on the M-face varies with the chemical composition[1]). According to this diagram an extinction angle of 8°—9° corresponds to a composition of about 45—50 $^0/_0$ Ab. In cleavage flakes parallel to P the homogeneous parts of the feldspar in question show straight extinction. Sections $\perp$ MP show a large optic angle 2 V and negative character. No sign of microcline structure is observed.

In the nepheline syenites from the Grønne Dal — Ika area it is a common feature that neighbouring feldspars are intergrown with each other along the edges so that irregularly formed parts of one feldspar are seen within the border of the other. Such intergrowths are particularly strongly developed in the biotite foyaite, especially in the foyaite from the northern part of the massif (see pl. 1, fig. 2).

Pseudomorphs after *nepheline* occur abundantly; most frequently they are idiomorphic. But in some slices considerable remnants of fresh nepheline are present.

The biotite foyaite is on the whole rather strongly altered and the easily decomposable minerals, nepheline and biotite, are often totally metamorphosed. As a rule the feldspar is somewhat dusty. The nepheline is most frequently totally converted into gieseckite which often contains some relatively large flakes of muscovite. In the most altered rocks the muscovite has proceeded from the nepheline into the neighbouring feldspars so that the original contour of the nepheline has totally disappeared. Cancrinite occurs very sparingly. The alteration of the biotite is so similar to that already described for biotite in the pulaskite (p. 26) that it need not be repeated. Pyroxene, when present, is unaltered or in some cases a little discoloured only.

In several places along the border of the massif hydrothermal and pneumatolytic activity took place to a somewhat greater extent than elsewhere. Some fissures in the rock are lined with fine-grained albite. At the same time analcime occurs together with gieseckite as alteration product of nepheline. This analcime shows the 'eudnophitic' double refraction, it occurs along the edges of the nepheline and branches from there into the muscovite between the cleavage flakes. The analcime also occurs as alteration product of the feldspar, and often as filling in the spaces between the feldspars.

[1]) This diagram is published by NILS H. MAGNUSSON: The Alkaline Rocks in Särna. Geol. Fören. i Stockholm Förhandl., Bd. *45*, 1923, p. 308.

In one slice a rather complicated alteration product occurs in considerable quantity. It consists of a very fine-grained aggregate the components of which cannot all be determined with certainty, but muscovite flakes generally play an essential part which indicates that the aggregate chiefly has arisen from nepheline. In some cases the outer form of the aggregate also reminds of the crystal form of the nepheline; but often it branches into the adjacent feldspar and besides it seems in its mineral composition to be influenced by decomposition products from the biotite. Finally it is seen in certain parts of the thin section attached to fine fissures in the rock. The outer form of the aggregate is therefore often very irregular.

Among the components of the aggregate the muscovite flakes occur in somewhat varying sizes. In such cases where the crystal form of the nepheline is fairly well preserved the outer zone of the pseudomorph mainly consists of muscovite scales, while greater or smaller parts of the interior consist of tiny needles or skeleton crystals of a mineral with high index of refraction, higher than that of muscovite, and a very weak double refraction. Elongation positive. Not rarely the needles are collected in bundles abt. 0.2 mm long and with six-sided cross-sections showing a fibrous structure and spherulitic extinction. Possibly these needles consist of *topaz* (pycnite).—Frequently there is also a large number of quite small isotropic crystals with high index of refraction; they are deep green in colour and often intergrown with diminutive black ore grains. They have an irregular or polygonal, sometimes six-sided, form; and in a few cases it is possible by means of strong magnifying to see that the crystal form is the rhombic dodecahedron. They may perhaps consist of *garnet.* Some of the crystals are imbedded in a secondary redbrown, highly pleochroic *mica* (red brown—light yellow), which is clearly different from the common green or green-brown biotite in the rock. These crystals occur in greatest quantities in the neighbourhood of decomposed biotite.—As a kind of mesostasis or groundmass *analcime* appears in some cases, fine-grained *albite* in others.

Pyroxene-rich Foyaite

A variety of the foyaite extraordinarily rich in pyroxene occurs somewhat west of loc. 1. This rock is of a brown or a reddish brown colour. It is very rapidly crumbling producing a considerable accumulation of brown coloured debris at the base of the western part of the north slope of the Grønne Dal, while the above mentioned grey foyaites gives a grey talus along the eastern part of the wall. This difference in colour is conspicuous at a long distance.

The rock is rather coarse-grained. The main constituent is a grey thin tabular feldspar with a slight tendency to parallel arrangement which gives a trachytic appearance to the rock. The crystals often reach 15—25 mm in length, but as a rule they are not more than one or two millimeters in thickness. The most conspicuous crystals are light coloured, yellow or reddish pseudomorphs after nepheline consisting of gieseckite. They occur in almost all cases as idiomorphic crystals which reach a length of 5 mm or more and a thickness of up to 4 mm. On account of the light colour and the pronounced idiomorphy the gieseckite has a phenocryst-like appearance, especially on weathered surfaces of the rock, though the pseudomorphs are much smaller in size than the feldspar crystals. On a rough estimate the feldspar constitutes a considerably larger percentage of the rock than the nepheline-pseudomorphs. Pyroxene makes up a large part of the rock. A measurement by means of the integration-stage yielded about 28—29 per cent. But it mostly occurs in rather small grains. Thus biotite, occurring in rather large grains, becomes macroscopically the most conspicuous of the dark coloured minerals, though the geometric measurement showed only 8 vol. per cent. biotite & ore. Further were found: feldspar 40 vol. per cent., gieseckite 21 and apatite 1.5 vol. per cent.

Under the microscope the minerals seen are: alkali-feldspar, gieseckite-pseudomorphs, ægirine-augite, and biotite. Among the accessories apatite is relatively abundant, iron ore (magnetite or titanomagnetite) occurs but sparingly. As alteration products ferric hydrates occur abundantly, calcite in small quantities.—Zircon and titanite are not observed.

The *feldspar* is tabular parallel to (010) and shows no other crystal faces. As a rule the crystals are Carlsbad twins, some of them are Baveno twins. The feldspar is a microperthite with a fine perthitic structure which in the peripheric portions is comparatively coarse and rich in plagioclase. The perthitic bands consist of pure albite with refracting indices $\alpha' < 1.54$ (Canadabalsam) $\leqq \gamma'$. In sections parallel to (010) the albite bands are seen to be rather straight; they form an angle of about 72° to the basal cleavage cracks. In basal sections the albite bands appear as a network which in the inner portions of the crystals has very fine meshes and often graduate into cryptoperthite (see plate 2, fig. 1). In sections $\perp$ MP the cryptoperthite shows a large optic angle 2 V and a negative character. In sections $\perp \gamma$ it shows an extinction angle of 13°.

The potash feldspar is only to be seen within the very small meshes between the albite bands. It is difficult to examine it closely and to determine whether it consists of orthoclase or microcline. As a rule all the potash feldspar patches show the same extinction within certain parts of a microperthite crystal. In basal sections the extinction angle is frequently about 15°—16° and accordingly microcline is present; in a few cases some indistinct small parts of the potash feldspar are seen which show a different extinction and seem to consist of the other individual of the microcline twin. In other parts of the basal sections the potash feldspar patches are extinguished at a much smaller angle, and in certain parts the extinction is parallel to (010). In the latter cases the albite net is extraordinarily fine and it cannot be determined with certainty whether the feldspar consists of orthoclase or cryptoperthite. This feldspar very much resembles the feldspar of the foyaite from Korok, Julianehaab district, described by Ussing[1]).—Inclusions of other minerals in the feldspar are rare.

The *gieseckite-pseudomorphs* occur abundantly. Mostly they show the ordinary form of nepheline, but sometimes they are grouped together in small aggregates. They consist entirely of small muscovite scales and no remnants of the original nepheline have been observed. Though as a rule idiomorphic towards all the other minerals of the rock the gieseckite may sometimes include a few pyroxene crystals.

The *pyroxene* consists of ægirine-augite and is optically identical with that in the main foyaite already described. It occurs in comparatively small crystals some of which are idiomorphic showing the forms (010) and (110). Probably the pyroxene in this rock shows a somewhat greater tendency towards idiomorphy than that mentioned above. Twins are not common, but some crystals are found which are twinned parallel to (100), and in some cases a narrow twin plate appears lying parallel to (100). The pyroxene crystals partly fill out spaces between feldspar and nepheline, they are partly included in biotite, and in a few cases in the border zone of the feldspar.

Biotite is present in considerable quantities. It occurs in rather large allotriomorphic grains consisting of brown lepidomelane. The absorption tints vary from a light yellow-brown to quite black. But only some remnants of the biotite are left. The greater part is converted into an opaque product of ferric hydrates, here and there mixed with small scales of micaceous hematite.

The *sequence of crystallisation* is quite the same as in the above described main foyaite. The characteristic feature that the crystallisation of the pyroxenes stretches over almost the whole consolidation period and that the main portion of the dark coloured minerals is crystallised as the last group is still more conspicuous in this rock on account of the high content of pyroxene. The biotite here occurs as the latest mineral in the succession only.

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[1]) N. V. Ussing. Medd. om Grønland *38*, 1912, 233.

No chemical analysis has been made of this rock. The samples examined have only been obtained from boulders, and not from the rock *in situ*, they were not sufficiently fresh to be used for any analysis.

BORDER ROCKS

The contact between the nepheline syenite and the gneiss is exposed in several places and is particularly well developed in the low cliffs at the south shore of Ekaluit. Further N. V. USSING in 1900 at a height of about 300 m in the immediate vicinity of the large gneiss wedge found a porphyritic border facies of the foyaite closely agreeing with border facies occurring at the shore of Ekaluit. Moreover O. B. BÖGGILD has found the contact on the southern slope of Grønne Dal.

The marginal facies of the nepheline syenite varies somewhat as well mineralogically as structurally as will be described in detail below. On the whole the grain size in the vicinity of the contact decreases, but often in an irregular way; thus close to the gneiss a more coarse-grained rock may occur than at a couple of meters' distance. The border rock is often porphyritic, sometimes 'schlieric', and in one locality it is found mixed with pegmatitic and aplitic segregations.

Mineralogically some of the rock specimens examined are characterised by a particularly high content of nepheline, while other specimens from the same locality have an essentially lower content of nepheline than the main foyaite. Dark minerals may also vary considerably in quantity, but most often they occur in great quantities; not infrequently amphibole occurs in the vicinity of the edge of the massif.

As the contact is best exposed along the northern side of the massif at Ekaluit these occurrences will be dealt with first.

At **locality** 8 (see map fig. 3, p. 23) the nepheline syenite reaches as far out as the fjord and forms the cliffs over a distance of somewhat over 100 m. In the greater part of the field between the shore and the great gneiss wedge the rock consists of normal coarse-grained pyroxene-biotite-foyaite the feldspar grains of which averagely have a length of abt. 1.5 cm and a thickness of abt. 0.5 cm; there is no parallelism of crystal orientation. All transitions are found between this rock and the biotite foyaite occurring SW of it. The rock is reddish grey in colour, it is strongly crumbling and has rounded surface forms.

In the vicinity of the contact coarse-grained and medium-grained parts of the foyaite alternate. In some places at the shore (locs. 8 and 7) the foyaite has intruded into fissures in the gneiss. In the narrow foyaite wedge which is marked on the map at locality 8 the rock is medium-grained and pyroxene is the predominant dark mineral. Quite the same variety occurs at the contact abt. 1 km SW of loc. 8, but in this part of the contact line porphyritic or fine-grained varieties are not found. The medium-grained pyroxene foyaite may therefore at any rate be considered as the predominant border rock type in this part of the area.

The main constituents are as usual feldspar and nepheline. But the amount of dark coloured minerals is on the whole considerable and increases towards the contact with the gneiss. They consist chiefly of pyroxene in which the ægirine plays a greater part than in the rock varieties described above. Biotite is always present, but as a rule in small quantities. Only in a few specimens of rather strongly altered foyaite the biotite—which at any rate mostly is secondary—is the only dark coloured silicate mineral which it has been possible to ascertain, (see below p. 46). Subordinately, occurring in varying amounts and sometimes lacking, there are sodalite and brown amphibole; in a single case astrophyllite is observed. Zircon is scarce; apatite in small crystals and a little iron ore are always present. As secondary products analcime, iron ore, and small quantities of cancrinite and calcite appear.

The *feldspar* is thin tabular parallel to (010) and commonly twinned on the Carlsbad law. It consists of microcline perthite. The plagioclase component is pure albite with about 5 $^0/_0$ An., it makes up a considerable part of the whole feldspar and is generally most abundant in the outer layers. The microcline shows no cross-hatching, it is a "moiré-microcline", built up of two twin-individuals penetrating each other and extinguishing in different positions. The albite network is often so finely ramified that the microcline structure cannot be seen.

Some of the feldspar grains are completely clear and fresh, but most of them are filled with a brownish dust. In sections parallel, or nearly parallel to (010) remarkably many inclusions of tiny green biotite scales are seen, especially in the central parts of the crystals. These biotite scales are little conspicuous in cross sections of the feldspar tables, they must consequently be intercalated parallel to (010). Inclusions in the feldspars of small well developed pyroxene crystals are in some sections extremely numerous, in others almost absent.

Nepheline occurs in considerable quantity; some of the grains show rectangular or six-sided sections, but in most cases the nepheline fills out spaces between the feldspars. In some slices the nepheline is fresh and clear and only along the edges converted into radiating needles of cancrinite. Other grains are besides more or less altered to gieseckite.

The *Biotite* is a green or brown lepidomelane. Not infrequently it is brown in the central part and green in the peripheral; sometimes it is a little chloritised along the border. Some very dark brownish crystals have six-sided forms and seem to be basal sections, but they are totally intransparent and give no axial figure in convergent light.—Brown biotite further occurs as reaction rim around ore grains.

Pyroxene occurs in somewhat different forms. A great number of small well developed crystals are frequently included in feldspar and a still greater number in nepheline. As a rule they are bounded by the prism (110) and by the first pinacoid (100); of terminal faces a prism of the third order, probably ($\bar{1}11$) and a pinacoid of the second order, probably ($\bar{1}01$) are sometimes seen. Besides there occur somewhat larger slender crystals, which usually show no terminal faces, and further larger pyroxene crystals mostly of irregular forms which only appear in the spaces between the feldspar and the nepheline. Finally secondary ægirine occurs as aggregates of small radiating needles.

Under the microscope the pyroxene crystals reveal a characteristic zonar structure. The core consists of light coloured diopside; it is surrounded by deep green ægirine-augite and the outer layer consists of a more or less thick coating of ægirine which is often of a lighter green colour than the ægirine-augite; not infrequently the border zone of the ægirine is quite colourless or brown. Some small well developed crystals are quite light greenish yellow. Cross sections of the crystals sometimes show a marked crystallographic border between the core and the ægirine-augite zone. Then the core is not infrequently seen to be flattened parallel to (010) while (100) is the predominant face in the outer crystal form.—Twins are not common but here and there some crystals built up of two individuals twinned parallel to (100) are seen.—Apatite crystals and small ore grains are frequently included in the inner parts of the pyroxene, very seldom in the ægirine zone.

In the core bisetrix γ is lying nearest c. The optic angle 2 V is about 40° estimated from the curvature of the axial bar in a section normal to the optic axis B[1]); optic character positive. The diopsidic core is often of slight extension so that most of the sections cut through the outer layers of the crystals only. In the ægirine-augite zone is observed an essentially larger optic angle 2 V which is estimated at about 80°; optic character negative; dispersion of the optic axis A is $\varrho > v$. The optic orientation of the whole pyroxene crystal is $b = \beta$, i. e. the axial plane is parallel to (010).

The extinction angles measured in a section normal to β gave the following values:

	$c:\gamma$	$c:\alpha$
The core, certain small central patches	36°	54°
The core, main part	30°	60°
Inner greenish zone	38°	52°
Grass-green outer zone	60°	30°
Ægirine border	94°	4°

[1]) F. E. Wright: The Methods of Petrographic-Microscopic Research, Carnegie Inst. of Washington Publication No. 158, 1911, 168.

In another section normal to β was measured $c:\alpha = 5.5°$ in the colourless outer ægirine zone; besides the colourless ægirine shows a somewhat higher interference colour than the green zone.

It is noteworthy that the extinction angle $c:\gamma$ in the core reaches such low value as about 30°, however, this value must be correct, in several β-sections is measured $c:\gamma = 30°—32°$. As further the optic angle 2 V is essentially smaller than usual for diopside these features probably indicate that the core consists of a diopsidic pyroxene of the diopside-clinoenstatite series[1]).

The light coloured core shows no pleochroism; in the green coloured parts pleochroism is quite marked:

α grass-green, light green or bluish green
β yellowish green
γ yellowish green or yellow.

Most of the pyroxene grains are more or less altered, and the alterations show somewhat different features. In some slices it is common that the alteration begins in the core with segregation of dark brownish products, here and there containing ore particles, whereby the interior of the crystal may become completely opaque. In other cases the core is bleached, partly dissolved and the cavities filled with fine-grained calcite; besides biotite scales sometimes occur. Moreover some pyroxene grains occur in which the diopsidic core has been replaced by secondary colourless or greyish brown ægirine. This ægirine has a fibrous appearance and branches in a ragged and irregular way into the surrounding ægirine-augite. It is always accompanied by small quantities of fluorite and of extremely small grains of a mineral with very weak double refraction, perhaps a zeolite.

The marginal ægirine-zone is often secondarily discoloured, a feature which as a rule is distinguished from the above mentioned primary discolouring (p. 44) by the fact that simultaneously with the discolouring a segregation of brownish particles has taken place. This feature has been thoroughly dealt with by Ussing[2]), who argues in favour of the fact that the brown substance in both instances has arisen by oxydation of the FeO of the ægirine to Fe_2O_3.

Among the above mentioned alteration products biotite plays no great role but appears now and then, particularly in the ægirine-augite zone where it is sometimes accompanied by some extremely fine-grained colourless minerals, perhaps zeolites. However, there occur a number of other biotite aggregates which have proved to be pseudomorphs after

[1]) Cf. A. N. Winchell: Elements of Optical Mineralogy, Part II, 1927, 182, Diagram Fig. 96 according to which a pyroxene of this series with 60 % diopside shows $2V = 42°$, $c:\gamma = 34°$.

[2]) N. V. Ussing: Medd. om Grønland, *14*, 1894, 181—184.

pyroxene. They mainly consist of small deep-green biotite scales (pleochroism: deep-green—light yellow) which have replaced the pyroxene, especially its central parts. Sometimes fine ore particles are also segregated. Besides there occur relatively large flakes of brown biotite which probably originally were intergrown with the pyroxene and left unaltered. In some cases fine needles of secondary ægirine radiate from the edge of the pyroxene remnants. The original inclusions of apatite and ore grains in the pyroxene are unaltered.—But in most cases the aggregates show no rest of pyroxene.

Strongly altered foyaite. In the above (p. 43) mentioned specimens of rather strongly altered foyaite the main part of the dark coloured minerals consist of similar aggregates of fine scaled deep green biotite as those last described; they may therefore be supposed to derive from the pyroxene. But in this rock segregations of iron ore play an essential role so that the inner part of the pseudomorphs most often is filled with an opaque porous mass of ore intermingled with the biotite scales. In reflected light the ore grains show a brownish metallic lustre; possibly they consist of ilmenite. Apatite crystals are common in the pseudomorphs.

Besides some other aggregates have undoubtedly arisen from biotite some remnants of which are left. These biotite flakes are to a great extent filled with ore grains arranged in streaks corresponding to the cleavage. Further there are numerous small new-formed deep-green biotite scales, especially in the outer zone of the aggregates.

The nepheline is completely altered in these specimens. It has undergone the same alteration to an aggregate of muscovite, analcime and needles or skeleton-crystals, perhaps pycnite, etc. as described above under the biotite-foyaite (p. 39). Some muscovite flakes in these pseudomorphs may reach a length of up to 2.5 mm. In several cases the pseudomorphs have retained the outer form of the nepheline. The feldspar is relatively well preserved, but alteration products from the other minerals have proceeded along cracks into the crystals. Small grains of calcite are common. A few small colourless isotropic grains with high refraction index consist, perhaps, of garnet.—Fine-grained albite occurs as filling substance in fissures.

In **locality 7** where the nepheline syenite is injected into a narrow fissure the rock consists of a reddish grey nepheline syenite porphyry which nearest the wall is fine-grained or dense and 'schlieric'. On the weathered surface the rock is brownish. Most of the phenocrysts consist of tabular feldspars which reach a length of abt. 10 mm and a thickness of only 1 mm. A few phenocrysts consist of nepheline up to 5 mm in length; they are to some extent altered to gieseckite. Besides several other nepheline crystals reach almost the same size but are greatly poikilitic, intergrown with the feldspars of the groundmass so that at first sight they seem to form part of the groundmass. On the whole poikilitic intergrowths are very common in this rock and also characteristic of the dark coloured minerals. The main constituent of the groundmass is feldspar. Further small grains of black amphibole and greenish black pyroxene, biotite and numerous small ore grains are macroscopically distinguished. Under the microscope are further seen apatite, zircon, and a little fluorite. Cancrinite is scarce. Quite a small amount of analcime and calcite is observed.

The *feldspar* differs in structure from that just mentioned in the rock from loc. 8. The phenocrysts are as usually tabular parallel to (010) and twinned on the Carlsbad law. They consist of perthitic soda-orthoclase intergrown with albite which forms a very fine network being a little coarser in the outer layers of the crystals. In the inner parts of the crystals the perthitic structure often grades into cryptoperthite, and numerous small patches are totally homogeneous. These parts of the feldspar show in sections parallel to M an extinction angle of about 12° which according to H. E. Johansson's above mentioned diagram (cf. p. 38) corresponds to a composition of $Or_{40}Ab{+}An_{60}$. As will be seen below (p. 51) the average composition of the feldspar can from the rock analysis be calculated at this value. Sections $\perp$ MP show extinction parallel to trace M, a large optic angle 2V and negative character. Structurally this feldspar is thus closely related to that of the mica foyaite (see above p. 37—38) and moreover it resembles the feldspar of the foyaite from Korok described by Ussing (Medd. om Grønland *38*, 1912, 233).

The feldspar of the groundmass shows the same structure as the phenocrysts and, as far as may be ascertained, it agrees with those in all microscopic properties. Usually the grains show an elongated form and a very irregular jagged contour so that adjoining grains are often intergrown.

The feldspar is on the whole fresh and clear, especially in the cryptoperthitic parts, still the albite intergrowths may be somewhat dusty or turbid, particularly in the border zone of the crystals.

The *pyroxene* always appears as rather small irregularly formed grains; sometimes it is poikilitically intergrown with other minerals of the groundmass. It consists of intensely green ægirine-augite without zonar structure. Optically it closely agrees with the pyroxene without zonar structure in the main foyaite (see p. 32—33). The optic angle 2 V is large, nearly 90°, and in this instance it has been possible to determine the optic character as positive. Dispersion of the optic axis B is distinctly $\varrho < v$. Furthermore this pyroxene is closely related to the ægirine-augite of the Korok foyaite (Ussing l. c. p. 232) which also—though not mentioned by USSING—shows a very large optic angle 2 V and positive character.

The *amphibole* occurs in very irregularly formed grains, usually poikilitically intergrown with the other groundmass minerals. Very often several amphibole grains lying near each other show the same optical orientation, thus being parts of the same crystal. Inclusions of ægirine-augite are rather common.

The amphibole of this rock is a *hastingsite* which in almost all of its optical properties corresponds with the hastingsite of the umptekite, Almunge, described by PERCY QUENSEL[1]) and the hastingsite of the nepheline syenite of Dungannon, Ontario, first decribed by FRANK D. ADAMS[2]) and later by P. D. GRAHAM[3]).

The hastingsites show the following optic properties:

Hastingsite, Ekaluit.	*Hastingsite, Almunge.*
Birefringence low.	Birefringence low.
Axial plane normal to the plane of symmetry.	Axial plane normal to the plane of symmetry.
$b = \gamma$	$b = \gamma$
β lying nearest the vertical axis c.	β lying nearest the vertical axis c.
$c:\beta$ is abt. 36°.	$c:\beta$ is 35°—41°.
2 E is abt. 80° (2 V abt. 50°).	2 E not over 25°—30°.
Optically negative.	Optically negative.
Axial dispersion considerable, $\varrho < v$.	Axial dispersion strong, $\varrho < v$.
Pleochroism strong:	Pleochroism strong:
α light yellowish green,	α yellowish green,
β deep bluish green,	β bluish green,
γ olive green.	γ olive green.
Absorption: $\beta > \gamma > \alpha$.	Absorption: $\beta > \gamma > \alpha$.

In all these properties except the relatively large optic angle the amphibole from Ekaluit closely agrees with the hastingsites from Almunge and Dungannon. As will be shown below (p. 52) the chemical composition which may be calculated from the analysis, also resembles those hastingsites. The Greenland hastingsite shows a strong dispersion of the bisectrices, the extinction angle $c:\beta$ is about 36° being greater for blue light than for red.

Besides the hastingsite appears in the umptekite from Almunge as well as in the nepheline syenite from Dungannon another katophoritic hornblende with different optical properties. In the nepheline syenite

[1]) QUENSEL, PERCY: Bull. Geol. Inst. Univ. Upsala, Vol. *12*, 1914, p. 145.
[2]) ADAMS, FRANK D.: Am. Journ. of Science, 3. Ser. Vol. *48*, 1894, p. 13.
[3]) GRAHAM, P. D.: Am. Journ. of Science, 4. Ser. Vol. *28*, 1909, p. 540.

porphyry from loc. 7, Ekaluit, the hastingsite is the only occurring amphibole. In a border rock from another locality in the vicinity there occurs, however, a somewhat different katophoritic hornblende (see below p. 57).

The *biotite* is a greenish lepidomelane, strongly pleochroic: light yellow—very dark olive green. Its form is as irregularly fringed as the pyroxene and the amphibole. It is always intergrown with ore grains.

Under the microscope the *ore grains* appear with quite irregular forms, but seen through a lens in the rock specimens a few of them seem to possess an octahedral form. Most often they include smaller grains of feldspar; pyrite is rarely found included. Ore is present in this rock in unusually great quantities. The grains are strongly magnetic and may be extracted from the rock powder by means of a magnet.

Chemical composition. An analysis of the nepheline syenite porphyry

	2 %	Mol. Prop. of **2**	Norm of **2**		NIGGLI'S System of **2**		**A**	
SiO_2	55.65	9275	Or	31.14	si	178.1	SiO_2	53.53
TiO_2	0.15	19	Ab	39.30	ti	0.37	TiO_2	0.44
ZrO_2	tr.	—	An	5.84	p	0.29	ZrO_2	—
Al_2O_3	19.79	1940	Ne	11.93	co_2	1.24	Al_2O_3	19.69
Fe_2O_3	4.98	311	Nc	0.64	al	37.5	Fe_2O_3	5.09
FeO	3.03	421	Σ sal	88.85	fm	23.0	FeO	2.83
MnO	0.15	21			c	5.0	MnO	0.24
MgO	0.52	130	Di	0.46	alk	34.5	MgO	none
CaO	1.40	250	Ol	1.86	k	0.31	CaO	1.87
BaO	0.09	6	Mt	7.19	mg	0.11	BaO	—
Na_2O	7.60	1226	Il	0.30	c/fm	0.21	Na_2O	9.61
K_2O	5.27	561	Ap	0.31	o	0.52	K_2O	5.23
H_2O — 110°	0.04	—	Σfem	10.12	section II		H_2O — 110°	0.25
H_2O + 110°	0.82	456	H_2O	0.82			H_2O + 110°	0.34
P_2O_5	0.22	15	S	0.03	al—alk	3.0	P_2O_5	0.31
CO_2	0.28	64		99.82	al—fm	14.5	CO_2	0.40
S	0.03	9			qz	— 60.0	Cl	0.04
	100.02							99.87
							Cl = O	0.01
								99.86

Quantitative System I(II). 6(5). 1″. ′4.
NIGGLI'S Type: Normalfoyaitic.
Sp. G. 2.713.

2. Nepheline Syenite Porphyry, Ekaluit, S. Greenland. E. KLÜVER, analyst.
A. Foyaite, Korok Type, Korok. S. Greenland. C. WINTHER, analyst.
(N. V. USSING: Medd. om Grønland, *38*, 1912, p. 235).

		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	BaO	Na_2O	K_2O	H_2O	P_2O_5	CO_2	S
26.02	Or	16.85	—	4.77	—	—	—	—	—	—	—	4.40	—	—	—	—
0.22	Ba-feldspar	0.07	—	0.06	—	—	—	—	—	0.09	—	—	—	—	—	—
38.62	Ab	26.53	—	7.52	—	—	—	—	—	—	4.57	—	—	—	—	—
2.02	An	0.87	—	0.74	—	—	—	—	0.41	—	—	—	—	—	—	—
13.00	Nepheline	5.67	—	4.47	—	—	—	—	—	—	2.13	0.52	0.21	—	—	—
2.00	Cancrinite	0.72	—	0.60	—	—	—	—	0.06	—	0.38	—	0.11	—	0.13	—
3.91	Pyroxene	2.05	—	0.16	0.70	0.21	0.04	0.11	0.26	—	0.36	0.01	0.01	—	—	—
4.38	Amphibole	1.53	0.09	0.49	0.60	0.90	0.07	0.20	0.23	—	0.13	0.04	0.10	—	—	—
4.17	Lepidomelane	1.36	0.06	0.68	0.75	0.56	0.04	0.21	—	—	0.03	0.30	0.18	—	—	—
0.47	Apatite	—	—	—	—	—	—	—	0.25	—	—	—	—	0.22	—	—
0.34	Calcite	—	—	—	—	—	—	—	0.19	—	—	—	—	—	0.15	—
4.25	Magnetite	—	—	—	2.93	1.32	—	—	—	—	—	—	—	—	—	—
0.07	Pyrite	—	—	—	—	0.04	—	—	—	—	—	—	—	—	—	0.03
0.55	Rest	—	—	0.30	—	—	—	—	—	—	—	—	0.25	—	—	—
100.02		55.65	0.15	19.79	4.98	3.03	0.15	0.52	1.40	0.09	7.60	5.27	0.86	0.22	0.28	0.03

of locality 7, made by the engineer, Emil Klüver, Oslo, Norway, gave the following figures (analysis **2**).

For comparison is added the analysis of foyaite from Korok, Julianehaab district (analysis **A**), which as mentioned above also mineralogically shows considerable similarity with this rock. Both analyses are of the type common for foyaite and both are remarkable for a relatively high iron content which in the nepheline syenite porphyry appears in an uncommonly high content of iron ore; whereas iron ore in the coarse-grained foyaite from Korok occurs in small quantities only.

From the mineral composition found by the microscopical examination the analysis may be calculated as shown in the table on page 50.

In consideration of the uncertain and complicated composition of the femic silicates the calculation could give approximate results only; but the calculation was carried through to try if it was possible by this means to obtain fairly probable chemical compositions of the amphibole, pyroxene, and biotite.

In the calculation the little BaO-content is calculated as Ba-feldspar and added to the orthoclase. P_2O_5 is calculated as apatite, and as in the calculation of the analysis **1** (p. 36) it has been assumed that the compositions of the cancrinite and the nepheline are like those from Litchfield.

The percentic average composition of the feldspar should thus be about $Or_{39}Ab+An_{61}$ which agrees very well with the optical determination.

The calculated mineral composition of the rock agrees very well with the microscopic observations. It may further be checked by a calculation of the specific gravity of the rock:

		Sp. Gravity	Sp. Volume
26.24	Or	2.55	0.10290
40.64	$Ab_{95}An_5$	2.62	0.15511
13.00	Nepheline	2.60	0.05000
2.00	Cancrinite	2.448	0.00817
3.91	Pyroxene	3.487	0.01121
4.38	Amphibole	3.433	0.01276
4.17	Lepidomelane	3.151	0.01323
0.47	Apatite	3.22	0.00146
0.34	Calcite	2.72	0.00125
4.25	Magnetite	5.20	0.00817
0.07	Pyrite	5.18	0.00014
99.47		Sum = sp. volume of the rock	0.36440
		Calculated to 100 %	0.36634

From this the specific gravity of the rock: 2.730; found 2.713.

The percentic composition calculated for the *hornblende* should amount approximately to the values in column a:

	a	b	c
SiO_2	34.93	34.18	37.49
TiO_2	2.05	1.53	0.86
Al_2O_3	11.19	11.52	10.81
Fe_2O_3	13.70	12.61	7.52
FeO	20.55	21.98	25.14
MnO	1.60	0.63	0.95
MgO	4.57	1.34	1.34
CaO	5.25	9.87	9.77
Na_2O	2.97	3.29	2.06
K_2O	0.91	2.29	1.91
H_2O	2.28	0.35	2.01
	100.00	99.60	99.86
Sp. G.		3.433	3.475

For comparison is added in column b the analysis of hastingsite from Dungannon, and in column c the analysis of hastingsite from Almunge.

For the *ægirine-augite* the following composition was calculated:

$Na_2O. Fe_2O_3. 4 SiO_2$	51.15
$Na_2O. Al_2O_3. 4 SiO_2$	16.37
$CaO. MgO. 2 SiO_2$	6.65
$CaO. FeO. 2 SiO_2$	21.74
$MgO. SiO_2$	3.84
H_2O	0.25
	100.00

which corresponds to the percentic composition given below in column a:

	a	b	c
SiO_2	52.44	51.56	49.32
TiO_2	—	0.19	1.25
Al_2O_3	4.09	2.26	4.88
Fe_2O_3	17.90	19.95	16.28
FeO	5.37	7.07	5.65
MnO	1.02	0.76	—
MgO	2.81	2.66	4.28
CaO	6.65	6.60	9.39
Na_2O	9.21	8.39	8.68
K_2O	0.26	0.39	0.68
H_2O	0.25	0.32	—
	100.00	100.15	100.41
Sp. G.		3.487	

For comparison is added in column b the average analysis for alkaline pyroxenes of the ægirine series from alkaline granites, grorudites and alkaline syenites (average of 9 analyses) given by PETER TSCHIRWINSKY[1]), and in column c the analysis of ægirine-augite of särnaite, Särna, Älfdalen, Sweden, made by P. MANN[2]).

The rest of the silicates left is calculated as *biotite*. In this rest an essential part of all the mistakes in the calculations is summed up both with regard to the quantity and the compositions of the other minerals. The average composition of the biotite, shown in column a, corresponds fairly well with a lepidomelane.

	a	b	c
SiO_2	32.61	33.07	32.09
TiO_2	1.44	3.84	—
Al_2O_3	16.31	16.32	18.52
Fe_2O_3	17.99	5.97	19.49
FeO	13.43	22.46	14.10
MnO	0.96	—	1.42
MgO	5.04	5.85	1.01
CaO	—	0.26	—
Na_2O	0.72	0.87	1.55
K_2O	7.19	7.92	8.12
H_2O	4.31	3.87	4.62
	100.00	100.43	100.92
Sp. G.		3.151	

For comparison is added in column b the analysis of lepidomelane from Miask, made by W. KUNITZ[3]), and in column c the analysis of lepidomelane from Litchfield, given by F. W. CLARKE[4]).

At **locality 6**, immediately to the east of locality 7, O. B. BÖGGILD in the year 1900 found the border facies of the nepheline syenite. Within this exposure the border rock is rather varying in composition. Moreover it is mixed with pegmatitic and aplitic lumps in an irregular manner.

At a distance of 2 m from the junction with the gneiss the rock is medium-grained and light coloured reddish grey. Macroscopically the nepheline content is seen to be very considerable and distinctly greater

[1]) PETER TSCHIRWINSKY: Durchschnittliche chemische Zusammensetzung der wichtigen Mineralien der Eruptivgesteine und der Meteorite. Mémoires de l'Institut Polytechnique du Don. *11.* 1928. Nowotscherkassk, 1929, 141—165. Quoted after account in Neues Jahrbuch f. Min. 1931, II, p. 165.

[2]) P. MANN: Neues Jahrb. f. Min. 1884. II.

[3]) W. KUNITZ: Neues Jahrb. f. Min. B-B. *50*, 1924, 413.

[4]) F. W. CLARKE, Amer. Journ. of Sc. *31*, 1886, 262.

than the content of feldspar. Some small irregularly formed parts of the rock, in size of about a cubic inch, consist almost entirely of nepheline. The feldspar as usual is thin tabular and twinned on the Carlsbad law. Dark coloured minerals make up a considerable part of the rock; most conspicuous is black biotite but also pyroxene is abundant, and in one specimen some grains of a black poikilitic amphibole are seen. Under the microscope there further appear cancrinite, apatite, a little zircon, iron ore, pyrite and quite small quantities of sodalite and calcite.

The *feldspar* is a microcline microperthite containing considerable albite. The albite shows about 5 % An. As usual it mainly appears in the border zone of the feldspar. The microcline cross-hatching is often distinct.

The *nepheline* is quite fresh and clear or a little altered to gieseckite. On the whole it is idiomorphic but very often it forms micrographic intergrowths with *cancrinite*; sometimes the whole crystal consists of such intergrowths; more frequently the cancrinite appears in the outer parts of the nepheline only. Besides the cancrinite surrounds the feldspar and the dark coloured silicate minerals; the feldspar sometimes may be idiomorphic against the cancrinite. On the whole cancrinite is present in considerable quantity.

The *pyroxene* is an intensely green coloured ægirine-augite without zonar structure. Its form is quite irregular, crystal faces are totally lacking. Along the edges it sometimes shows a fringed intergrowth with neighbouring feldspar. Optically it closely agrees with the before mentioned pyroxene of the nepheline syenite porphyry of loc. 7 (p. 47). As inclusions there are apatite and biotite, more seldom feldspar, cancrinite and a few grains of iron ore. Moreover small crystals of calcite frequently occur which certainly are of primary origin, the surrounding pyroxene being totally fresh and unaltered.

The biotite is a brown or green *lepidomelane*, strongly pleochroic: light coloured greenish or reddish yellow to totally black. Its form is very irregular. Macroscopically some large flakes, 1.5—2 cm in diameter, are seen including the other minerals of the rock in a poikilitic manner. Under the microscope inclusions of apatite, pyroxene, cancrinite, nepheline and feldspar are found in the biotite. Segregations of iron ore are common, especially in the border zone of the flakes from where they penetrate along the cleavage into the biotite.

Amphibole is very rarely present. Only in one hand specimen a few relatively large grains are found the cleavage flakes of which are strongly pleochroic: γ' deep bluish green to almost black, α' light olive or yellowish. Dispersion of the bisectrices is strong. This amphibole seems to be almost identical with an amphibole mentioned below (p. 57).

Some specimens collected only 1 dm from the contact line consist of nepheline syenite which is a little more coarse-grained than the rock at a distance of 2 m. The rock is grey in colour and rather altered.

The main constituent is *feldspar* which distinctly exceeds the nepheline in quantity. It is the same microcline microperthite, here and there showing a distinct microcline twin structure, as in the rock variety last mentioned. It is relatively fresh but most of the grains are more or less filled with muscovite scales.

The *nepheline* is totally altered to gieseckite. In a few cases the pseudomorphs are included in biotite and feldspar and then they show an idiomorphic form, but more frequently they fill out spaces between the feldspars. From the pseudomorphs muscovite scales proceed into the feldspar.

Of the dark coloured silicate minerals only remnants of *biotite* are present. They are more or less discoloured and a little chloritised. The biotite encloses a few black ore grains and some red brown hematite like segregations which are partly translucent and double refracting with a deep red colour.—Pyroxene and amphibole are totally lacking. *Zircon* occurs in relatively large crystals. *Apatite* is very scarce. A little secondary *calcite* is found in the spaces.

In the coast gneiss in loc. 6 Ussing found a small apophysis of nepheline syenite about 0.5 m wide. The rock is very fine-grained, light grey or a little reddish. It shows a thin platy parting and at least two diverging subjoints which form acute angles with the main joint. Phenocrysts are lacking. On the fresh surface appear a great number of small black ore grains.

Under the microscope it is seen that *feldspar* is the main constituent. It shows a very irregular form and a perthitic structure. *Pseudomorphs after nepheline* consisting of *gieseckite* are abundantly present and like the nepheline from loc. 7 they are poikilitically developed. *Pyroxene* is very scarce, only a few quite small grains are found intergrown with iron ore. *Biotite* occurs but in small quantities. A few plates are seen coating the sides of some rather uneven fractures cutting across the main joints, and it further appears in banded or 'schlieric' parts of the rock with a slightly coarser-grained structure. It is strongly decomposed and partly replaced by porous segregations of iron oxides in the cavities of which remnants of biotite are seen. It is strongly pleochroic: deep green to light yellow or almost quite colourless. *Iron ore* is present in relatively large amount. It occurs in very irregularly formed grains poikilitically intergrown with feldspar and nepheline. Apatite is scarce. Quite small *zircon* crystals occur in relatively large amount.

On the southern slope of Ekaluit, about 300 m above the sea, USSING has collected some specimens of the nepheline syenite border rock. Unfortunately he has not stated the place in the map, but it appears from his diary that these specimens are collected at certain intervals near the upper, southern border of the great gneiss wedge. Most of the specimens are labelled "nepheline syenite near the junction with the gneiss" but in the case of one specimen it is stated that it is obtained from a "small dyke or apophysis, about 1 m wide, in gneiss near the junction with the nepheline syenite."

This border rock is light reddish grey, porphyritic, and somewhat 'schlieric'. Phenocrysts of nepheline are abundant reaching a length of up to 1 cm. Feldspar phenocrysts about 1.5 cm in length occur in somewhat smaller amount. In the groundmass medium- or fine-grained feldspar is predominant. Besides there are nepheline, pyroxene, and biotite in considerable amounts; furthermore apatite and a little cancrinite. Ore grains are only found as inclusions in pyroxene.—The rock from the apophysis differs from this mineral composition by containing amphibole.

The *feldspar* is of the usual habit and twinning. It is a microperthite consisting of microcline and albite; at a rough estimate the latter is present in somewhat greater amount than the microcline. In a few cases the microcline shows a slightly developed cross-hatching.

The *nepheline* is partly fresh and clear, partly altered to muscovite.

Biotite and *pyroxene* are abundantly present and often form inclusions in each other. The pyroxene is a deep green coloured ægirine-augite which in all respects closely corresponds to the pyroxene of the main foyaite (see p. 32—33). The biotite is brown and strongly pleochroic: light yellowish brown—totally black. Often it is so filled with segregations of iron oxides that in slices it is totally opaque. It is poikilitically intergrown with all the other minerals of the groundmass enclosing idiomorphic feldspar and nepheline and irregularly formed grains of pyroxene. The biotite is intergrown with feldspar in the same characteristic way as often occurs between neighbouring feldspars (cf. pl. 1, fig. 2) so that small parts of the black biotite are lying within the feldspar along the edge.

The rock of the apophysis in gneiss is macroscopically quite like that just mentioned. Under the microscope it shows the same structure, only a little more fine-grained. But the mineral composition is in so far different as amphibole is the predominant dark coloured mineral and iron ore is present in relatively large quantity.

The *amphibole* shows, like the hastingsite from loc. 7, a very irregular form being poikilitically intergrown with all the groundmass minerals. But optically it differs from the hastingsite in showing an extraordinarily strong absorption which together with a strong dispersion of the bisectrices prohibit a closer determination of the optic properties. Polarized parallel to β and γ the sections are practically black and only a little translucent at the edges. The optical properties, as far as can be stated, are:

Axial plane in the plane of symmetry, b = β.
The axis γ lying nearest the vertical c.
The extinction angle c:γ' was measured up to about 40°, it is greater for blue light than for red.
Absorption colours:
α light yellowish brown,
β greenish black with a faint olive tint,
γ greenish black with a faint bluish tint,
$\beta = \gamma > \alpha$.

According to these properties this amphibole belongs to the katophorite group.

Pyroxene occurs in much smaller amount than amphibole. Most of the grains are small inclusions in the amphibole; they consist of green strongly pleochroic ægirine-augite. Besides some greater pyroxene grains are present which show similar zonar structure and optic properties as the pyroxene from loc. 8 (see p. 44—45). The central parts of the crystals consist of light coloured diopside, the outer layers of deep green ægirine-augite; an ægirine border is not observed. These pyroxene grains show a characteristic intergrowth with each other and with the amphibole. Plate 2, fig. 2 shows such a complex in which the inner part consists of two pyroxene crystals. It appears from the cleavage cracks that their vertical axes are perpendicular to each other. The pyroxene which is cut approximately parallel to the vertical c shows a deep green outer zone of ægirine-augite which surrounds the other pyroxene crystal. In the figure this ægirine-augite zone appears as very dark. Further the pyroxenes are surrounded by amphibole, and this amphibole is in parallel position to the greater fringed amphibole crystal seen in the uppermost part of the figure. In this case the cleavage cracks of the amphibole are perpendicular to those of the neighbouring pyroxene, but in other cases the two minerals are in parallel position. At the lower end of the complex the amphibole-coating is replaced by black biotite.

As inclusions in pyroxene and amphibole occur small crystals of calcite, probably primary, and further apatite, biotite, and ore grains.

Iron ore is abundantly present. The grains show the same poikilitic intergrowth with other groundmass minerals as described for the ore grains of loc. 7 (p. 49).

On the southern slope of Grønne Dal O. B. BÖGGILD found the junction between the nepheline syenite and the gneiss and collected some specimens which do not in any essential respect differ from those just described. Immediately at the contact the nepheline syenite is porphyritic with phenocrysts of feldspar and pseudomorphs after nepheline. The dark coloured minerals are ægirine-augite and strongly decomposed biotite. On the whole the rock is rather altered.

The *feldspars* show a more or less distinct perthitic structure graduating into cryptoperthite. Frequently they enclose numerous small pseudomorphs after nepheline. *Nepheline* is totally altered into gieseckite; the pseudomorphs which often show the crystal form of nepheline are present in great quantities as well as phenocrysts as in the groundmass. The *ægirine-augite* is quite like that of the main foyaite.

THE IKA AREA

Along the greater part of the about 12 km long narrow Ika Fjord the steep cliffs on both sides of the fjord are built up of light grey gneiss with a very conspicuous banding. The strike is about N—S, and the bedding dips at large angles in western direction. Numerous black diabase dykes run irregularly up through the gneiss.

Along the interior, barely 4 km of the fjord the light brownish coarse foyaite appears in the cliffs. On the NW-side of the fjord the foyaite forms steep slopes of 500—600 m height. On the SE-side of the fjord the cliffs consist over a distance of about 2 km of foyaite. On this side of the fjord the ground rises less steeply, the cliffs are low without any vegetation and almost quite free of debris.

THE IKA-FOYAITE

The Ika—foyaite is a magnificent very coarse-grained rock of a light reddish grey colour. On weathered surfaces it is light brownish. The tabular feldspar crystals reach a length of about 4 cm, a width of about 2 cm, and owing to repeated twinning on the Carlsbad law, a thickness of up to 1 cm; the single crystal individuals of the twins may reach up to 0.5 cm in thickness. But the grain size varies considerably and often rather rapidly from place to place. It has not been possible to prove any regularity in the distribution of the more or less coarse-grained parts. Locally the coarse foyaite becomes pegmatitic or aplitic.

Generally the foyaite crumbles easily and usually the surface is covered with debris. But in the low clean cliffs on the SE-side of the fjord the rock is rather fresh and cohesive. In some parts of the cliffs a very conspicuous structure in the foyaite is observed. The close lying tabular feldspar crystals are placed on edge and resemble short rules running parallel over short distances. Over somewhat larger surfaces (2—4 m) they spread out fanlike or form wavy irregular patterns on the rock surface. Corresponding features are not observed in the rocks of the Grønne Dal area where the parallel texture, when present, for instance in the pulaskite, most frequently is fairly horizontal.—Parallel texture is, however, not by far a constant feature in the Ika-foyaite; in certain places, especially within the northern part of the foyaite, it is totally lacking.

The mineral composition is also somewhat varying. Most often the content of dark minerals decreases in the upper parts of the foyaite about 250 m or more above the sea. Some specimens of this foyaite further show a very small nepheline content so that the rock in these cases becomes pulaskitic. But neighbouring parts or 'schlieren' may consist almost entirely of nepheline or its alteration products. The rock as a whole must therefore most probably be considered a foyaite. Owing to the irregularly dispersed distribution of the mineral components and the coarseness of the rock it is impossible to give any exact information of the average composition of this rock. Structurally it is characterised by relatively thin feldspar crystals, about 1—2 mm in thickness. Most frequently the feldspars are divergent, but in certain 'schlieren' or bands a parallel texture is very pronounced.—Also at lower levels here and there varieties are met with characterised by a more thin-tabular feldspar and a very slight content of dark coloured minerals, but usually they show a rather considerable amount of nepheline.

The Main Foyaite

The foyaite from a lower level is considered the main type containing a considerable amount of nepheline and dark minerals. This variety is widely distributed on both sides of the fjord and has besides been found at a rather considerable height. The specimens analysed were collected slightly SW of loc. 13 (see map fig. 2, p. 19). It is a very coarse-grained light reddish grey rock. The tabular feldspar crystals show a marked tendency towards parallel arrangement. Besides reddish nepheline, biotite and pyroxene are macroscopically to be seen.

Under the microscope the *feldspar* is seen to consist of microcline microperthite with a considerable content of almost pure albite with less than 10 % An. Sometimes the feldspars are bordered with small crystals of albite in parallel position to the perthitic albite bands. The potash feldspar, seen in the meshes between the finely branched albite bands, shows a very fine twin structure on the albite law closely resembling that of the microcline microperthites of the nepheline syenites from the Julianehaab district described by USSING[1]). In basal sections the extinction angle is 15°—16°. More infrequently microcline cross-hatching occurs.

The *nepheline* is rather abundantly present. Most frequently it is idiomorphic against the feldspar, and it also occurs included in feldspar. It is partly quite fresh and clear, partly altered to gieseckite.—*Cancrinite* occurs in small amounts only.

The predominant dark coloured mineral is *ægirine-augite* which in all its properties agrees so closely with that of the main foyaite of the Grønne Dal area (see p. 32—33) that the description need not be repeated.

The biotite is a brown *lepidomelane* with pleochroism light yellow or yellowish green to almost totally black. It is partly discoloured and altered into opaque ferriferous products intermingled with small grains of iron ore.

Accessorily a few small grains of a brown *katophoritic amphibole* occur. *Iron ore* occurs but sparingly apart from the recently mentioned secondary segregations. When present it often shows a core of pyrite. Other accessories are *apatite* and *zircon*.

The *sequence of crystallisation* is the same as in the Grønne Dal—foyaite. The accessories, apatite and zircon, are first crystallised. Then come nepheline and feldspar, mostly in this order, but in some specimens the nepheline is later than the feldspar. Last comes the main portion of ægirine-augite and biotite, though some grains of these minerals are inclosed in the feldspar.

Chemical composition. An analysis of the Ika—foyaite was made by the engineer, EMIL KLÜVER, Oslo, Norway. It yielded the following figures (analysis **3**, p. 61).

For comparison is added the analyses of foyaite from Naujakasik (analysis **A**) and of foyaite from Korok (analysis **B**). It will be seen that

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[1]) N. V. USSING. Medd. om Grønl. Vol. *14*, 1894, p. 21 ff.

the three analyses are rather similar and that they all belong to a common type of foyaite.

	3 %	Mol. Prop. of **3**	Norm of **3**		Niggli's System of **3**		**A**		**B**
SiO_2	56.65	9442	Or	38.92	si	188.2	SiO_2	53.53	56.31
TiO_2	0.21	26	Ab	29.87	ti	0.52	TiO_2	0.44	} 2.82
ZrO_2	0.06	5	An	4.45	p	0.18	ZrO_2	—	
Al_2O_3	20.98	2057	Ne	17.89	co_2	0.46	Al_2O_3	19.69	20.11
Fe_2O_3	2.58	161	Nc	0.21	al	41.0	Fe_2O_3	5.09	3.93
FeO	2.19	304	Σ sal	91.34	fm	15.5	FeO	2.83	1.45
MnO	0.09	13			c	5.0	MnO	0.24	0.60
MgO	0.53	132	Di	1.40	alk	38.5	MgO	—	0.36
CaO	1.41	252	Ol	1.72	k	0.37	CaO	1.87	0.62
BaO	0.12	8	Mt	3.71	mg	0.17	BaO	—	—
Na_2O	7.54	1216	Il	0.46	c/fm	0.34	Na_2O	9.61	8.76
K_2O	6.64	706	Ap	0.31	o	0.42	K_2O	5.23	4.65
H_2O — 110°	0.11	—	Σ fem	7.60			H_2O—110°	0.25	—
H_2O + 110°	0.83	461			section III		H_2O+110°	0.34	1.13
P_2O_5	0.13	9	H_2O	0.83	al—alk	2.5	P_2O_5	0.31	0.13
CO_2	0.10	23	ZrO_2	0.06	al—fm	25.5	CO_2	0.40	—
Cl	—	—	S	0.02	qz	—66	Cl	0.04	0.15
S	0.02	6		99.85			S	—	—
	100.19							99.87	101.02
							Cl = O	0.01	0.03
								99.86	100.99

Quantitative System I''. 6''. 1''. (3)4.
Niggli's Type: Normalfoyaitic.
Sp. Gravity 2.686.

3. Foyaite, Ika, Ivigtut, S. Greenland, E. Klüver analyst.
A. Foyaite (Korok Type), Korok, S. Greenland. C. Winther analyst (Medd. om Grønl. *38*, p. 235).
B. Foyaite, Naujakasik, S. Greenland, C. Detlefsen analyst. (Medd. om Grønl. *38*, p. 132).

According to the mineral composition found by the microscopical examination the quantitative proportions of the minerals were approximately calculated from the analysis as quoted in the table on page 62.

In the calculation the BaO-content is calculated as Ba-feldspar and added to the orthoclase. P_2O_5 is calculated as apatite. As for the preceding analyses it has been assumed that the compositions of the nepheline and the cancrinite are like those from Litchfield.

The average composition of the feldspar should thus be about $Or_{50}Ab{+}An_{50}$ and that of the albite about $Ab_{91}An_9$.

		SiO$_2$	TiO$_2$	ZrO$_2$	Al$_2$O$_3$	Fe$_2$O$_3$	FeO	MnO	MgO	CaO	BaO	Na$_2$O	K$_2$O	H$_2$O	P$_2$O$_5$	CO$_2$	S
31.46	Or	20.37	—	—	5.77	—	—	—	—	—	—	—	5.32	—	—	—	—
0.29	Ba-feldspar	0.09	—	—	0.08	—	—	—	—	—	0.12	—	—	—	—	—	—
29.81	Ab	20.48	—	—	5.80	—	—	—	—	—	—	3.53	—	—	—	—	—
2.98	An	1.29	—	—	1.09	—	—	—	—	0.60	—	—	—	—	—	—	—
19.01	Nepheline	8.31	—	—	6.53	—	—	—	—	—	—	3.15	0.86	0.16	—	—	—
0.60	Cancrinite	0.21	—	—	0.18	—	—	—	—	0.03	—	0.12	—	0.02	—	0.04	—
7.69	Pyroxene	4.07	—	—	0.40	1.22	0.49	—	0.22	0.55	—	0.69	0.03	0.02	—	—	—
5.51	Lepidomelane	1.80	0.21	—	0.88	0.32	1.21	0.09	0.31	—	—	0.05	0.43	0.21	—	—	—
0.28	Apatite	—	—	—	—	—	—	—	—	0.15	—	—	—	—	0.13	—	—
0.14	Calcite	—	—	—	—	—	—	—	—	0.08	—	—	—	—	—	0.06	—
1.51	Magnetite	—	—	—	—	1.04	0.47	—	—	—	—	—	—	—	—	—	—
0.04	Pyrite	—	—	—	—	—	0.02	—	—	—	—	—	—	—	—	—	0.02
0.09	Zircon	0.03	—	0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
0.78	Rest	—	—	—	0.25	—	—	—	—	—	—	—	—	0.53	—	—	—
100.19		56.65	0.21	0.06	20.98	2.58	2.19	0.09	0.53	1.41	0.12	7.54	6.64	0.94	0.13	0.10	0.02

The calculated mineral composition has further been checked by a calculation of the specific gravity of the rock:

		Sp. Gravity	Sp. Volume
31.75	Or	2.55	0.12451
32.79	$Ab_{91}An_9$	2.629	0.12474
19.01	Nepheline	2.60	0.07311
0.60	Cancrinite	2.448	0.00245
7.69	Pyroxene	3.487	0.02205
5.51	Lepidomelane	3.151	0.01749
0.28	Apatite	3.22	0.00087
0.14	Calcite	2.72	0.00051
1.51	Magnetite	5.20	0.00290
0.04	Pyrite	5.18	0.00008
0.09	Zircon	4.7	0.00019
99.41		Sum = sp. volume of the rock	0.36890
		Calculated to 100 %	0.37109

From this the specific gravity of the rock: 2.695; found 2.686.

For the *ægirine-augite* was calculated the following percentic composition which agrees fairly well with the composition of ægirine-augite calculated from analysis No. **2** (p. 52):

SiO_2	52.93	per cent.
Al_2O_3	5.20	—
Fe_2O_3	15.87	—
FeO	6.37	—
MgO	2.86	—
CaO	7.15	—
Na_2O	8.97	—
K_2O	0.39	—
H_2O	0.26	—
	100.00	per cent.

The average composition of the *lepidomelane* given below in column a was assumed to be like the analysis of lepidomelane from Miask made by W. KUNITZ[1]) (column b).

	a		b	
SiO_2	32.67	per cent.	33.07	per cent.
TiO_2	3.81	—	3.84	—
Al_2O_3	15.97	—	16.32	—
Fe_2O_3	5.81	—	5.97	—
FeO	21.96	—	22.46	—
MnO	1.63	—	—	
MgO	5.63	—	5.85	—
CaO	—		0.26	—
Na_2O	0.91	—	0.87	—
K_2O	7.80	—	7.92	—
H_2O	3.81	—	3.87	—
	100.00	per cent.	100.43	per cent.

[1]) W. KUNITZ: Neues Jahrb. f. Min. B-B. *50*, 1924, 413.

THE BOUNDARY ZONE

In the Ika area the contact between the foyaite and the gneiss is exposed at several places, and it is found that in the vicinity of the gneiss the foyaite is developed in various ways.

In the area SE of the fjord the foyaite is still coarse and sometimes slightly porphyritic nearest the gneiss. Blue sodalite frequently occurs as filling in small fissures. At the contact about 400 m S of loc. 13 (see map fig. 2) the foyaite is coarse, poor in nepheline, and of dark coloured minerals only biotite is present. About midway between localities 13 and 14 the contact is at a height of about 220 m. The contact surface is vertical and its direction is NNE. The foyaite is coarse and some large tabular feldspars give it a slightly porphyritic appearance. Gieseckite pseudomorphs after nepheline are present in abundance, biotite in smaller quantities. But directly below this place at about 150 m's height the foyaite is considerably less coarse; the mineral composition being the same.

In the cliffs 400—500 m NNE of loc. 14 the rock is fine-grained dark grey within a small area. This rock encloses irregular lumps, or 'schlieren', of the common coarse-grained foyaite. It is chiefly composed of microcline microperthite which shows a tendency towards cryptoperthite. The nepheline is mostly altered to cancrinite. Ægirine-augite is abundantly present, mostly as small slender grains without crystal faces. It shows a very irregular zonar structure with diopsidic core and sometimes an outer coating of ægirine. Further brown biotite, iron ore, apatite, and calcite occur in rather considerable quantities.

Pyroxene-rich foyaite occurs in loc. 14. The rock is coarse-grained, yet considerably less coarse than the main foyaite. The feldspar is microcline microperthite showing a rather conspicuous microcline cross-hatching. Nepheline is abundant; mostly it is quite fresh or only slightly altered to gieseckite. Frequently it is idiomorphic. Ægirine-augite is abundantly present, and locally it appears as 'schlieric' segregations in the foyaite. In the normal rock it shows a very irregular form and occurs in the spaces between feldspar and nepheline, often enclosing crystals of nepheline. Biotite is almost totally altered to opaque dark coloured products. A katophoritic amphibole occurs in very small amounts.

Pyroxene-rich foyaite of quite the same habit and the same mineral composition occurs near the contact with the gneiss at loc. 10, N of the Ika Fjord. Still segregations of pyroxene are not found in this rock.

On the north side of the fjord marginal facies of the foyaite are found in a gully (loc. 15) running from NW to the fjord. The contact line is badly exposed as the bottom is covered with a great deal of blocks rolled down from the slopes.

Uppermost in the gully, about 500 m NW of loc. 15 a medium-grained, light reddish marginal facies of the foyaite is found. The main constituent is microcline microperthite, most often with an outer zone of pure albite. The microcline is somewhat dusty; the albite fresh and clear.

The dark coloured minerals are greatly altered to black opaque products, iron ore and redbrown ferric oxydes. They enclose feldspar crystals in an ophitic manner. It is not possible to recognize the original minerals with certainty, but fresh remnants of ægirine-augite and small scales of brown biotite occur. Most probably the originally predominant dark mineral was ægirine-augite and the biotite is perhaps an alteration product of this mineral.

Nepheline pseudomorphs occur in considerable amount. They consist partly of common gieseckite, partly of light mica in somewhat larger flakes, which show optic properties much like those of lepidolite, i. e relatively low index of refraction and a small optic angle 2 V.

At loc. 15 another light coloured, medium-grained rock variety is found *in situ*, probably a syenitic border facies of the foyaite. On the surface and along joints it is brownish. The rock is considerably altered and strongly impregnated with carbonates. As usual the feldspar is microcline microperthite rich in albite. The tabular crystals reach a length of 2—3 mm. The microcline shows a beginning alteration to sericite. Gieseckite pseudomorphs after nepheline occur in the spaces between the feldspars. The original amount of nepheline cannot have been very considerable. The carbonates consist of siderite and calcite in about equal quantities. Dark coloured minerals are totally lacking. Apatite is not observed.

Near the last mentioned rock a rather fine-grained aplitic grey rock occurs with trachytic texture. The main constituent is microcline microperthite. The tabular crystals reach a length of about 2.5 mm; they show no traces of crystal faces. Nepheline and its alteration products are totally absent. The predominant dark mineral is a hastingsite-like amphibole which appears as small slender crystals. It has a very strong absorption which prohibits any closer determination. Usually it encloses some iron ore, partly pyrite. Brown biotite is sparse. Besides there are some fluorite and relatively much iron ore.

Around loc. 15 some faulting has taken place. In the just mentioned aplitic rock well polished slickensides occur, and in the neighbouring gneiss a finely crushed breccia is found. Besides a pneumatolytic metamorphism took place by which the foyaite as well as the adjacent gneiss were impregnated with fluorite, carbonates, phosphates, etc. In the gneiss breccia for instance crocidolite and dahllite are met with.

Immediately at the contact quite a particular rock is found. It is fine-grained and light brownish. The main constituents are siderite and calcite. Also feldspar plays a considerable role; it consists of an extraordinarily albite-rich microperthite. Then follow, after quantity, dahllite which under the microscope is very conspicuous owing to its thin columnar form, its strong refraction, abt. 1.6, and its very weak double refraction. Further a chemical test showed that the mineral is a phosphate. In small quantities are further found: green biotite, muscovite, fluorite, and iron ore. Presumably this rock has arisen by metamorphosis of the foyaite.

Carbonates are on the whole found in several places, mostly near the border of the foyaite. A small vein occurs for instance filled with calcite and siderite in the gully just below loc. 12. In the next gully at loc. 11, some meters from the contact, the gneiss is traversed by a siderite vein about 20 cm wide. The siderite is here and there a little altered to limonite, and in a few cavities small crystals or aggregates of quartz occur. No other minerals are observed.

Ijolite

At loc. 9 (see map fig. 2, p. 19) between the Ika Fjord and Grønne Dal BØGVAD and GRY found the contact between the foyaite and the gneiss. From here the contact line curves westward and then runs in northern direction.

The rock nearest the gneiss is dark grey or reddish grey. It is rather fine-grained with a few phenocrysts of feldspar and of pseudomorphs after nepheline. The microscopic examination has shown that the rock is closely related to ijolite. The main constituents are *gieseckite-pseudomorphs after nepheline* and *ægirine-augite*. The form of the pseudomorphs indicates that the nepheline mostly was rather fine-grained. The pyroxene has a very irregular form; it encloses numerous grains of nepheline, which usually are allotriomorphic. Besides there occur a few grains of *feldspar*, some of which show a microperthitic structure but they are chiefly cryptoperthitic. Usually they are somewhat dusty and brownish. As inclusions in the feldspar occur idiomorphic ægirine-augite and gieseckite pseudomorphs with the crystal form of nepheline. *Iron ore* is relatively abundant. *Biotite* and *apatite* occur in very small quantities. A few isolated grains of *analcime* and *cancrinite* have been noticed. *Calcite* appears in small amounts; no doubt it is an infiltration product as it chiefly occurs in small fissures in the rock.

A measurement of this rock on the Leitz integration stage gave the following values:

	Vol. per cent.	Weight per cent.
Nepheline (pseudomorphs)	59.3	54
Ægirine-augite	35.3	40
Feldspar	2.4	2
Iron ore	1.3	2
Calcite	1.3	1
Biotite	0.2	—
Apatite	0.2	—
	100.0	99

Sp. gravity of the rock 3.06.

Other specimens represent a transition form from this rock to the ordinary foyaite rich in pyroxene. They are of a somewhat lighter grey colour and show a porphyritic texture. The phenocrysts consist of light grey feldspar and of reddish coloured, rectangular pseudomorphs after nepheline. The feldspar is microperthite frequently graduating into cryptoperthite. It is the main constituent of the rock. Nepheline, too, was originally present in considerable amount; now it is totally altered to gieseckite. Most often the pseudomorphs show the crystal form of nepheline. Ægirine-augite occurs rather abundantly, but in essentially lesser amounts than in the ijolitic rock. Biotite and calcite are not observed.

The ijolitic border rock is intersected by 'schlieric' diabase dykes. The diabase is an ordinary olivine diabase with ophitic texture. The banded appearance is due to alternation of pyroxene-rich parts with such parts which are poor in pyroxene and rich in olivine. Here and there in the diabase are found segregations of magnetite, partly crystallised in rhombic dodecahedrons, which reminds of the fact that this place cannot lie far from the iron ore occurrence (see above p. 21) discovered by N. O. Holst and Bøgvad. Furthermore fissures in the diabase are filled with calcite.

BASIC SEGREGATIONS

Basic segregations are by far not common in the nepheline syenite. Only in one place a small distance SW of loc. 8, I have found a number of fine-grained dark greenish coloured lumps in the foyaite near the contact with the gneiss. They consist mainly of pyroxene and nepheline.

On the rock surface numerous white or reddish spots are seen, 1 to 2 mm in diameter. Under the microscope they have proved chiefly to consist of cancrinite with relics of nepheline. In one particular rock specimen a very irregularly branched aggregate is found consisting of comparatively coarse-grained white feldspar; but the feldspar content of the rock is on the whole slight.

It is seen under the microscope that the *feldspar* is microcline without cross-hatching. It shows a particularly fine irregular twin structure. Perthitic albite is not observed.

The *nepheline* has no crystal form. The grains reach a size of about 2—3 mm in length. They enclose numerous pyroxene crystals. The nepheline is rather strongly altered to *cancrinite*.

The *pyroxene* chiefly consists of intensely green coloured *ægirine*. It appears as slender crystals, about one mm in length, bounded by the prism (110) and by the first pinacoid (100); no other crystal faces are observed. The extinction angle is quite small; double refraction strong. In a few cases a pyroxene with zonar structure has been observed; and in these crystals the core is light coloured greenish or, more infrequently, of a faint redbrown tint. The extinction angle reaches 40°—50° in the core and decreases to a few degrees in the outer ægiritic zone. The pyroxene is almost free from inclusions, only a few small grains of iron ore and biotite are found here and there.

Titanite is relatively abundant. It mostly occurs as rather large, well developed crystals which usually enclose a number of pyroxene crystals.

Brown *biotite* and *apatite* are present in small quantities; the latter occurs as numerous small crystals.

It is not possible to state the exact mineral composition of the rock, as the feldspar is so irregularly distributed. But a measurement of the dark green, rather uniform rock which forms the main part of the lumps was made on the LEITZ integration stage and yielded the following values:

	Vol. per cent.	Weight per cent.
Pyroxene	60.8	67.8
Nepheline	17.5	27.3 (Nepheline + Cancrinite)
Cancrinite	17.3	
Titanite	2.7	3.0
Biotite	0.7	0.7
Apatite	0.7	0.7
Iron ore	0.3	0.5
	100.0	100.0

Mineralogically these segregations have a great likeness with the ijolite just mentioned.

PEGMATITE AND APLITE

Pegmatite is not by far common within this region; it is only found in small amounts at some places. Mostly it appears as pegmatitic segregations of irregular form reaching a size of about 20—30 cm, or somewhat more, in diameter; usually it is associated with aplite. It is already mentioned (p. 53) that such a mixture of pegmatite-aplite occurs in the border rock of the nepheline syenite at Ekaluit, loc. 6, and in a similar way pegmatite-aplite-segregations may be met with all over the foyaite. Pegmatitic veins are found in a few places, for instance at loc. 2 (see map fig. 3, p. 23); they are small only, up to 25 cm in width. They cut through the foyaite in an irregular way.

The mineral composition is much like that of the foyaite. Rare minerals are not observed. The *feldspar* consists chiefly of microcline microperthite, the larger grains of which correspond closely to the feldspar of the foyaite. The smaller feldspars usually are very rich in albite, and in some cases they consist of pure albite. In the aplitic parts the feldspar is microcline microperthite. The dark coloured silicate minerals differ somewhat from those of the foyaite. In the Grønne Dal area *ægirine* is predominant, *biotite* is but sparsely present.—In the Ika area pegmatite-aplite-masses are found irregularly spread in the foyaite, for instance at loc. 12, where the most conspicuous constituent is a *katophoritic amphibole*. The black crystals reach a length of about 4—5 cm. Under the microscope it shows the following properties:

Double refraction weak.
The axial plane is normal to the plane of symmetry.
b = γ.
β lying nearest the vertical axis c.
c : β about 15°—20°. Cannot be exactly determined owing to the strong dispersion of the extinction.
Pleochroism:
α light yellow brownish,
β deep green or bluish green,
γ olive greenish or greyish.
Absorption: $\beta > \gamma > \alpha$.

The amphibole crystals are often intergrown with ægirine. Some of them enclose small grains of primary calcite and a great many apatite crystals which reach up to 3.5 mm in length. Biotite is sparse. The feldspar, as well of the pegmatitic as the aplitic parts, is microcline microperthite rich in albite; microcline cross-hatching sometimes occurs. Further there are pseudomorphs after nepheline consisting of gieseckite or "spreustein."

From a boulder of nepheline syenite found in the ravine near loc. 15 a small pegmatite vein, about 10 cm wide, was obtained. The pegmatite nearest the contact consists almost entirely of large biotite crystals with a diameter of up to 5 cm. The middle part of the vein consists chiefly of microcline microperthite occurring as larger and as quite small crystals. In some of the crystals the structure grades into cryptoperthite. Further there are brown or greenish biotite, gieseckite pseudomorphs after nepheline, and rather large zircon crystals sometimes showing a zonar structure.

Pegmatite veins are found not only in the foyaite, but also penetrating the surrounding gneiss. Some of them are built up symmetrically. A pegmatite vein in gneiss from the Grønne Dal area yields a fine instance of this. It is only abt. 12 cm wide. At the contact on both sides the gneiss consists of very finely granulated microcline, plagioclase, and quartz mixed with some fine-grained ægirine. In the next zone ægirine crystals, 2—3 cm in length, are predominant, they settle in the contact zone as slender crystals growing larger and broader towards the middle of the vein. In the spaces between the ægirine crystals there are albite, partly in the shape of slender crystals, and microcline perthite.

A special case is met with at Laxenæs (see map fig. 3) where 5—6 narrow pegmatite veins occur as sills running along the schistosity of the gneiss. The veins are built up symmetrically. Slender pyroxene crystals of an outer habit common for ægirine are arranged perpendicular to the contact. Macroscopically they are dark greenish. Under the microscope they are seen to be strongly altered under segregation of fine-grained iron ore which in reflected light shows a metallic lustre. The remaining pyroxene is discoloured, almost colourless, and partly filled with a brownish dust which makes it intransparent. Besides the pyroxene crystals enclose numerous small grains of albite and quartz. In the spaces between the pyroxene albite and quartz appear side by side with microcline microperthite closely agreeing with that of the foyaite. The microperthite is more or less corroded and replaced by quartz and albite. Some quite irregularly formed, not sharply bounded remnants of microperthite are entirely enclosed in quartz. Further a great number of albite crystals are enclosed in the quartz. Also a few aggregates of quartz with the equigranular mosaic texture characteristic of the gneiss are seen. These quartz grains show a slightly undulatory extinction. It is thus evident that the pegmatitic fluid has reacted with the gneiss wall rock and assimilated silica which caused the formation of free quartz.

SUMMARY AND CONCLUSIONS

The present description of the alkaline rocks and their occurrences in the Grønne Dal—Ika region does not claim to be exhaustive. Interesting discoveries may be made on each fresh visit. Yet the observations here advanced may give an idea of the geology of the region.

Already the irregular shape of the massif, the 'roof-pendants', and the small outcrops of nepheline syenite in fissures in the gneiss indicate that this massif represents the uppermost part of a stock, possibly of a batholite.

The contact phenomena are those usual for igneous rocks. On approaching the contact the size of the grains most often decreases, porphyritic development is common, nearest the junction the rock is often fine-grained, but also rather coarse-grained rocks are found. Apophyses occur. The contact is sharp wherever it is observed and the contact surface vertical. Gradual transition between the nepheline syenite and the gneiss is nowhere observed.

Effects of contact metamorphism on the gneiss wall rock are small only and limited to the replacement of the dark coloured minerals of the gneiss with crocidolite and to impregnation of the gneiss with fluorite, carbonates, especially siderite, and smaller amounts of phosphates. The same changes are found in the foyaite near the contact. Veins of carbonates, mostly siderite, are met with in the southern part of the region.

In a few places the gneiss is brecciated in the vicinity of the massif; at loc. 15 it is brecciated and faulted at the very contact.

The chemical alteration which the eruptive rocks of the Grønne Dal—Ika region have undergone seems—apart from some limonitic products—to have taken place in the pneumatolytic-hydrothermal stage and to a small extent only to be due to weathering.

In the Grønne Dal area the uppermost part of the stock at about 250—400 m height mainly consists of pulaskite or rocks closely related to pulaskite. In these rocks the feldspar tables show a pronounced tendency to parallel arrangement; the parallel texture on the whole being horizontal. The pulaskite rests on foyaite rich in nepheline and dark coloured minerals. But no exact limit exists between the two rocks. On the contrary transition rocks are found in several places, and in some cases the rocks shade almost imperceptibly into each other. Thus a gradual transition between the pulaskite and the foyaite must be assumed. On the other hand a wide dyke of foyaite is found traversing the pulaskite; thus it is evident that the pulaskite has consolidated earlier than the foyaite.

In the Ika area no sheet of pulaskite has been found, but it may perhaps exist somewhere in the upper parts of the massif.

As pointed out in the preceding chapters feldspar and nepheline are the first minerals to crystallise in the foyaitic rocks; last come the main masses of pyroxene and biotite though small pyroxene crystals sometimes are enclosed in the feldspar showing that the crystallisation of the pyroxene extended over almost the whole consolidation period. In this respect these rocks remind of the 'agpaïtes', the peculiar subdivision of nepheline syenites, viz. sodalite-foyaite, naujaite, lujavrites and kakortokites, described by USSING[1]), in which rocks several of the minerals which are characteristic of agpaïtes, especially ægirine and arfvedsonite under magmatic conditions have exceptionally wide temperature ranges of crystallisation.

The agpaïtic sequence of crystallisation is known from several other nepheline syenites, among others the foyaite of the Julianehaab district. But it must be noted that the latest crystallisation products of the foyaites are not usually ægirine and arfvedsonite, but ægirine-augite and biotite, and in some cases katophoritic hornblende.

An attempt to explain the main feature of the variation within the Grønne Dal—Ika massif according to the above recapitulated facts is tempting, though it must be purely hypothetical. But I shall not enter into a general discussion about the origin of alkaline magmas; this small massif does not, indeed, yield material enough for that.

The simplest assumption is that the origin of the rock types and their mode of occurrence is due to gravitational differentiation in connection with some assimilation of the country gneiss.

It seems probable that the magma has first consolidated along the sides of the magma chambre and formed the marginal facies. This is supported by the chilled borders and further by the fact that most of the border rocks, even those from the higher situated occurrences, are of foyaitic composition corresponding fairly well with the rock in lower parts of the massif.

On this assumption the average composition of the intruding magma must have corresponded to a considerable content of nepheline.

[1]) N. V. USSING: Medd. om Grønl., Vol. *38*. 1912. pp. 338 and 348.

It was then to be expected that on the cooling of the first consolidated upper part of the magma nepheline and feldspar would crystallise almost simultaneously giving rise to a foyaitic rock. This did not take place; instead a pulaskite resulted. The formation of pulaskite demands a change of the presumed composition of the magma. The simplest supposition would be that the top-magma has assimilated fragments of the country gneiss. An assimilation would lower the temperature and change the composition of the magma which may have caused the crystallisation of the feldspar and accelerated the consolidation of the pulaskite. This view would be well in accordance with the irregular distribution of the pulaskite and the presence of transition rocks. But it cannot be proved by the observation of more or less dissolved gneiss xenoliths. No other inclusions than the above mentioned gneiss wedges have hitherto been found, and these, as will be remembered, show chilled contacts with the foyaite. Yet it is possible that assimilation may have taken place at the top, now denudated, as the volatiles of the magma would rise to the top and increase the thermal energy of the magma. In this connection it must be remembered that the narrow quartz-bearing pegmatite sills at Laxenæs (see p. 70) have assimilated a relatively considerable amount of gneiss material.

Further it may be assumed that during and after the consolidation of the pulaskite a gravitational differentiation took place in the still fluid magma. This is supported by the observations that the amount of dark coloured minerals generally increases downward in the massif and further by the presence of felsic, even almost pure nepheline rocks in the upper parts of the Ika—foyaite (see p. 59). But besides the irregular occurrence of more or less mafic parts of the foyaite shows that the differentiation has not reached any high degree of separation before the consolidation of the visible parts of the foyaite.

Only one particular point shall further be dealt with. Ussing in his memoir on the Julianehaab rocks[1]) discussing R. A. Daly's assimilation hypothesis, says: "The complete absence of carbonate-rocks in the whole country around the very large nepheline-syenite areas of south Greenland is inconsistent with the hypothesis recently set forth by Daly relating to a genetic connection between carbonate-rocks and nepheline-syenites (Origin of the Alkaline Rocks. Bull. Geol. Soc. of America XXI, p. 87, 1910). The only carbonate bearing formation of South Greenland is the Arsuk group (p. 9). The possibility that dolomites of this group have once existed at Julianehaab cannot be denied. But the late-Algonkian igneous series (Julianehaab granite etc.) which is later than the Arsuk group consists of sub-Alkaline rocks. Thus, actual observations tell against the hypothesis in every way."

[1]) N. V. Ussing: Medd. om Grønl., Vol. *38*, 1912, p. 297, foot-note.

Also WEGMANN[1]) has dealt with the scarcity of carbonate rocks in southern Greenland. Among the few known occurrences he mentions Tayler's Harbour on the west coast of the Ivigtut peninsula where the following series occurs (in ascending order): migmatitic gneisses, thick beds of quartzites, gneissic schists with a dolomite horizon, which are overlain by dark schists with pyrites, graphite pigment, and layers of quartzitic slabs. The dark schists, again, contain a carbonate horizon. "The carbonatic rocks occupy some few meters, at the most." About almost the same series of schists etc. occurring at the sound of Ikerasak, at the north-eastern corner of Arsuk Island he remarks that carbonates are present in small quantities. "They are only remarkable, because carbonate rocks are absent over wide stretches of southern Greenland."

However, small occurrences of carbonate-rocks are found here and there. Thus it seems possible that the small occurrence of ijolite (loc. 9) at the eastern border of the massif may have originated by reaction of the foyaite with some carbonatic rocks.

[1]) C. E. WEGMANN: Medd. om Grønland, Vol. *113*, Nr. 2, 1938, pp. 16—20.

Færdig fra Trykkeriet den 29. September 1943.

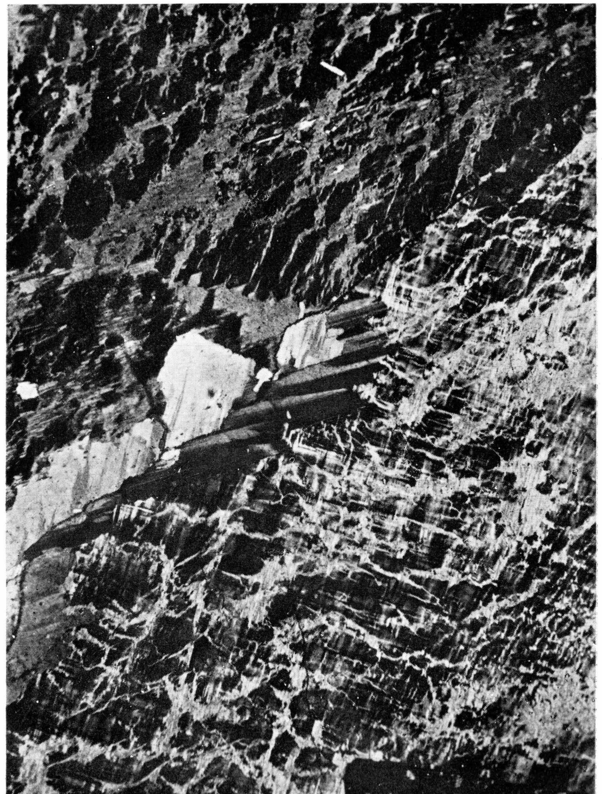

Fig. 1. Microcline microperthite showing cross-hatched microcline of the main foyaite, loc. 1, Grønne Dal. Nicols +. Magnif. × 38. (See p. 30).

Fig. 2. Intergrowths of neighbouring feldspars of the foyaite, Grønne Dal. Showing one light and three dark feldspar crystals. Nicols +. Magnif. × 26. (See p. 38).

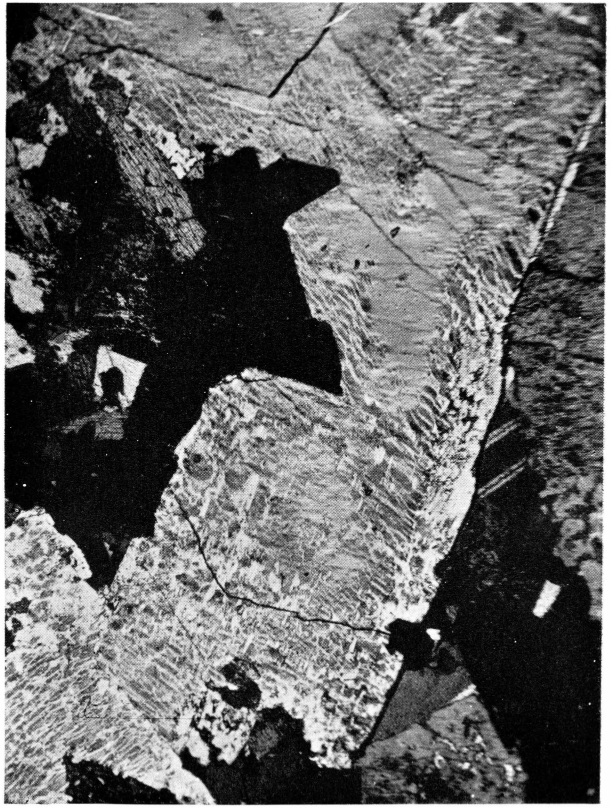

Fig. 1. Microperthite graduating into cryptoperthite in the foyaite, Grønne Dal. Nicols +. Magnif. × 28. (See p. 40).

Fig. 2. Intergrowth of two pyroxene crystals surrounded by amphibole in the porphyritic border rock of the nepheline syenite. Grønne Dal. Ord. light. Magnif. × 28. (See p. 57).