GRØNLANDS GEOLOGISKE UNDERSØGELSE
BULLETIN No. 16.

ON SAND SAMPLES FROM THE WEST COAST OF GREENLAND I

AN EXAMINATION OF THE CONTENTS OF MINERALS IN A NUMBER OF SAND SAMPLES FROM THE NORTHERN PART OF THE HOLSTEINSBORG DISTRICT

BY

BRUNO THOMSEN

WITH 3 FIGURES IN THE TEXT AND 1 PLATE

Reprinted from
Meddelelser om Grønland Bd. 157, Nr. 2

KØBENHAVN
BIANCO LUNOS BOGTRYKKERI A/S
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CONTENTS

Abstract.

Forty one samples of sand from rivers and beaches from three fjords north of Holsteinsborg were analysed. On the basis of the minerals of the heavy fractions the samples may be divided into three groups: group E derived from enderbitic gneiss with the main minerals, hornblende, hypersthene, and diopside, while garnet plays a secondary rôle only; group G chiefly derived from granulitic rocks where garnet is dominating with sillimanite and rutile as characteristic components, while the content of hornblende, hypersthene, and diopside is relatively low and, finally, group M that with the main minerals, hornblende, hypersthene, diopside, and garnet and a slight content of sillimanite and rutile shows that the sample material derives from enderbitic as well as granulitic rocks.

INTRODUCTION

The material for this paper was collected during the summer of 1949 under the field work undertaken by the Geological Survey of Greenland (Grønlands geologiske Undersøgelse, G.G.U.) by the northern party under the leadership of Professor ALFRED ROSENKRANTZ. The work was carried out from the motor-ketch "K. J.V. Steenstrup" from the G.G.U. whose skipper, Mr. E. PETERSEN as well as his crew I thank for good assistance. The examinations were made at the Mineralogical and Geological Institution of the University of Copenhagen. I thank Professor, Dr. phil. ARNE NOE-NYGAARD and my chief, Professor ALFRED ROSENKRANTZ for pleasant working conditions. I also wish to thank dr. phil. HELGE GRY and dr. phil. AXEL NØRVANG because they have gone through the manuscript and suggested some alterations. Mrs. GUDRUN THOMSEN has been in charge of part of the laboratory work. Mrs. HARRIET OPPENHEJM has translated the Danish manuscript into English and Mr. M. E. KNOP from the Geodetic Institute has prepared the maps and curves.

The material derives from three fjords north of Holsteinsborg of which the 26 km long fjord, Søndre Kangerdluarssuk (Kangerdluarssuk tugdleq) was the southernmost, while the 27 km long fjord, Nordre Kangerdluarssuk (Kangerdluarssuk ungatdleq), was situated between the former and Nordre Isortoq farthest to the north that stretches as far as to the ice-cap, but the outermost third of which (60 km) is navigable only. The material consists of forty one samples from thirty nine localities and is composed of thirty four samples of delta sand, five samples of beach sand, and two samples from the glacial drift (sandy till) one of which (No. 111) is very fine-grained. Further a sample (No. 141) was collected consisting of stratified brecciated clay. Its grain-size was, however, less than 60 μ and I have therefore made no attempt at determining its contents of heavy minerals.

Most of the samples are samples of delta sand, i. e. they have been taken from the alluvial cones of the rivers a few meters above high water level. The sample material has been collected with a view to obtain recent unweathered sediments of a grain-size well suited for the purpose.

Particularly coarse, as well as particularly fine, sediments have as far as possible been avoided. On the other hand a sample always consists of material collected in different places within the alluvial cone, so that local differences are thus eliminated. In a few cases where delta samples could not be taken, I have collected samples from beaches that within this region generally cover very small areas only. The samples have been collected above, as well as below, high water level. In order to obtain an average sample of the mineral assemblage I have at each locality collected sand in several places and always transversely to the dark layers containing garnet and other minerals. In two cases I have taken samples of till in places where the river cuts through the glacial drift, partly to examine the mineral content, partly to ascertain whether the differences in the mineral content can be traced in the corresponding alluvial cones.

To make the collections I have visited all, or at least most, places where rivers were found. To cover the area as well as possible I have taken samples from quite small brooks with a very limited "distributive province" as well as from larger rivers. On account of the numerous lakes in the mainland even the distributive provinces of the large rivers are generally not so large as might be expected. The parts of the rivers that cut through the distributive provinces are indicated by heavy lines in the map. The localities in the map are further listed by the same numbers as in the tables. The samples 103—115 are taken from Søndre Kangerdluarssuk, samples 116—124 from Nordre Kangerdluarssuk, and 125—144 derive from Nordre Isortoq.

Geologically the area from which the samples have been taken belongs to the Nagssugtoqides, a pre-Cambric mountain range the main axes of which strike in WSW—ENE direction. This anticlinorium stretches from Itivdleq south of Holsteinsborg and northward, at any rate to Jakobshavn; it may be subdivided into three zones, a southern and a northern zone of amphibolitic and epidote-amphibolitic gneisses as well as a middle zone belonging to the granulite facies with highly metamorphosed rocks. The area treated in this paper is located in the middle zone.

The purpose of the examination was to register which minerals were found in the sand samples, and on the basis of the percentage composition of minerals to conclude which rock or rocks one might expect to find within the distributive provinces of the rivers examined.

METHOD OF INVESTIGATION

The samples collected that each weighed half a kg. to 1 kg. were divided in such a way that c. 50 g were selected for further analysis. To begin with grains larger than 250 μ were sieved out; the remaining sample was thereafter boiled in water to which was added a few drops of ammonium hydroxide; then particles of less than 60 μ were removed by decanting. The sample was then heated to boiling point, first with 5 % and then with 15 % hydrochlorid acid to remove any bits of shale and to clean the grains of iron oxide coating. The method is as a rule so moderate that such easily soluble minerals as olivine and apatite are scarcely affected; indeed it is sometimes found that minerals from the calcite group have survived the process. After a renewed division of the sample 5—10 grammes were selected for the mineral separation, that was undertaken by means of a mixture of acetylene tetrabromide and benzene (specific gravity 2,9). After weighing the light and heavy mineral crops in order to determine the weight percentages permanent slides were made of both. For the heavy crop a mounting medium with a refractive index of 1.66 (Clearax from George T. Gurr, London) was used; certain minerals like, for instance, actinolite, andalusite, apatite, barite, biotite, celestite, glaucophane, topaz, tremolite and wollastonite may easily be determined in this way owing to lower refringence than that of the mounting medium, while others, like for instance hornblende, olivine, sillimanite, and sometimes tourmaline, have a refractive index equal to or very close to that of Clearax, while a number of others have higher refractive indices. Further, Clearax is practically speaking colourless and usually very easy to work with.[1]) The light fraction was embedded in Canada balsam. To facilitate the work to determine the minerals in the light fraction (quartz, potassium feldspar and plagioclases) I further made use of the method developed by R. Dana Russel (11) and A. Gabriel and E. P. Cox (3) in a modified form: a suitable number of grains was placed in a small vessel of poly-ethylene and first hydrofluoric acid was poured over them for one or two minutes, then an aqueous solution of sodium cobalt nitrite, and at last an aqueous solution of eosine was used; also these chemicals were to act on the grains for c. one—two minutes. After all three processes were performed the grains were thoroughly washed in water. The principle of the method is that quartz is not affected by hydrofluoric acid while the surfaces of the feldspars gelatinate and become dyeable. Quartz thus remains perfectly clear and colourless, while the potash feldspars become intensely yellow and the plagioclases appear in a red colour.

[1]) A small paper concerning the optic qualities of Clearax will later be published.

The counting of the heavy fraction was done in the usual way: by means of a mechanical stage each slide was moved in a single direction through the field of vision; all grains that touch the centre of the cross-hair of the ocular were classified and counted. As it proved difficult under an ordinary petrographic microscope with certainty to determine the ore grains they were assembled in one group: the opaques. The counting was performed in the following way: of the first 100 grains opaque as well as non-opaque grains were counted. The opaque grains were then noted down as per cents, and the counting was continued without considering the opaque grains till 100 non-opaque grains had been determined. In samples 103—124 I have counted only 100 transparent grains, but in order to learn how large the source of error was by counting 100 only I have in samples Nos. 125 to 144 counted 400 non-opaque mineral grains in four groups of each 100 grains and calculated the average which in the tables has been given in whole percentages. The result of this examination—not listed here—was that the counting of 200 grains provided a reasonable accuracy and will of course save considerable time. In the slides of the light crop I have found quartz and feldspars only; it has therefore been sufficient in this case to count 100 grains.

DESCRIPTION OF MINERALS OBSERVED

Actinolite-tremolite: Not a common mineral. Found in several samples as scattered grains. In outline it resembles hornblende, but the refractive index is always somewhat lower than that of the mounting material. Furthermore, it differs from hornblende by having a higher birefringence. The colour of actinolite is light green with a slight pleochroism; tremolite is colourless. Actinolite is more common than tremolite in the samples.

Apatite: This mineral has been found in a few samples only, and in very small quantities. It is always colourless and has a refractive index somewhat lower than 1.66; birefringence weak, and the sign of elongation negative. It is irregular in shape and the surface is always corroded, probably owing to the treatment with acids. The apatite may for the same reason have disappeared from other samples if the acid treatment has been too intense.

Augite appears extremely rarely in the samples from Søndre and Nordre Kangerdluarssuk; generally a single grain only is found. In the samples from Nordre Isortoq it generally appears in c. half the number of samples, but here, too, in very small quantities. The colour is brownish-green, in a few cases with a violet tint (Ti-augite).

Biotite is present in all the samples. In sample No. 131 it is the commonest but one of the heavy minerals. The mineral always appears as large flakes with an irregular outline. The colour is brownish-yellow to brown; green coloured biotite is sometimes observed. The biotite always seems fresh and unweathered.

Brookite is found in one sample only (No. 111) twice in one counting line. The grains are tabulary with straight edges, the surface closely striated. The grains have an almost total extinction in white light. In one of the grains the interference figure shows a position nearly normal to one of the optic axes. Irrespective of the strong dispersion the grain is in a position where the interference colour distribution shows few anomalies. In the smaller grain the interference figure did not allow of any conclusions.

Cassiterite. In samples 111 and 112 there are a few irregular, slightly rounded grains. The colour that is irregularly distributed is reddish-brown to a lighter brown, or greyish-green.

Corundum is found in samples 105 and 112 only, and it occurs but once in both. The grain in No. 105 is worn and rounded, the one in 112 angular and the outline determined by fracture and cleavage. The grains are almost colourless, very weak pleochroism is observed, colourless to light yellow.

Diopside. Very common mineral to be found in all samples; most frequently it occurs in samples from the southern area; less frequently in samples from Nordre Isortoq. From Søndre Kangerdluarssuk the content varies in the heavy fraction from 12 % to 37 %, in Nordre Kangerdluarssuk from 16 % to 37 %, apart from a single sample (No. 123) with 1 % only. In Nordre Isortoq the content varies between 1 % and 21 %. In the samples very strongly coloured diopsides may be found with strong pleochroism, grass-green to paler green, and paler green to almost colourless forms with weak to very weak pleochroism. Between these two extremes are numerous transition forms. All of them exibit strong birefringence. The grains are sometimes beautifully prismatic, but the shape is as often as not very irregular owing to poor cleavage; cleavage cracks are frequently seen. The grains with the deep green colour have a refractive index, that is much higher than that of Clearax; it is probably a question of the diopsides mentioned by Pauly (8), belonging to the diopside-hedenbergite series. The refraction of the slightly coloured to colourless grains is little above 1.66 and rather resembles common diopsides. Diallage with prominent parting is found in almost all samples from Søndre and Nordre Kangerdluarssuk, while it is only registered in three samples from Nordre Isortoq.

Enstatite appears in a few samples. It is distinguished by its refractive index, which is close to that of the mounting material, and further, it is colourless, and has straight extinction.

Epidote occurs in less than half the samples, and in small quantities only. The grains are irregular, greenish-yellow and slightly pleochroic; sometimes strongly coloured epidotes (curry yellow) are found. Clinozoisite and zoisite rarely occur, they are included in the figure for epidote.

Garnet is present in all samples but one, though in greatly varying quantities. The grains are always angular and irregular due to lack of cleavage; they never show trace of transportation. In very rare cases idiomorph grains occur. Corrosion is sometimes observed in a few grains. Large inclusions of rutile, quartz and biotite are not rare. Slight birefringence is seen in some grains. The mineral may be colourless, pink or brownish-red; in rarer cases pale yellow.

In the southernmost fjord the pink garnet is the most common one; in the fjords further to north the colourless garnet is more frequent than the two other varieties.

Hornblende is found in all sand samples. It always occurs in the usual prismatic elongated cleavage fragment and shows no trace of disintegration. In counting I have distinguished between common, bluish-green, and brown hornblende. The common hornblende is brownish-green with normal pleochroism; to the common hornblende I have also counted a hornblende with somewhat deviating pleochroism: light straw-yellow to black or almost black, possibly the same hornblende that is mentioned by PAULY (8). It is observed in almost all samples from Søndre Kangerdluarssuk and in a single sample from Nordre Kangerdluarssuk. As bluish-green I have counted such grains that have pleochroism from bluish-green to green; the discrimination between common and bluish-green hornblende is sometimes pretty difficult as transition forms occur between these two varieties. The brown hornblende is not very common; the colour is light brown to dark brown with distinct pleochroism. The extinction angle generally lies between 6° and 10°.

Hypersthene is a very common mineral; sometimes the dominant one. It generally occurs as truncated or elongated prismatic grains the shapes of which are determined by the conspicuous cleavage of the mineral. Pleochroism is very marked and varies from an intensive beautiful red, reddish-brown or yellow, to a strong green or dark-green colour; the very marked colour variety indicates a large Fe-content. Slightly coloured hypersthene sometimes occurs. Grains showing Schiller-structure are not uncommon.

Kyanite. This mineral has been observed in two samples (Nos. 131 and 143), and at each locality in a few specimens only. The grains are cleavage fragments and colourless. The extinction angle is 32°.

Olivine is observed in half the number of samples, but as scattered grains only (in No. 128 it is, however, 6 $^0/_0$ of the heavy crop). The grains are angular and irregular. They are colourless with a slightly yellow or green tinge; strong birefringence. The refractive index is almost equal to that of the mounting medium which shows that it may also be a question of forsterite. The surface of the grains is generally corroded owing to the acid treatment. The olivine presumably derives from the ultrabasic rocks in many places occurring as smaller bodies in the gneiss rocks.

Rutile is found in almost all samples from Nordre Isortoq, while the mineral occurs scattered only in the southern area. The grains are usually very small in proportion to other minerals. They are always angular or fragments of crystals, never rounded. The colour is dark red-brown, sometimes almost opaque. Most often weak pleochroism, dark red-brown to light red-brown. Striations in two directions are often seen on crystal faces. Even if rutile is not a common mineral it is very characteristic in its occurrence, as it is found in greatest quantity in the samples where garnet and sillimanite form the main part of the minerals.

Sillimanite is found as scattered grains in most samples from the two southernmost fjords; in certain samples from Nordre Isortoq it is a very characteristic constituent. The shape is most often very remarkable: long, narrow, or short prismatic grains with oblique cleavage cracks and obliquely terminated; the refractive index is very close to that of the mounting medium. The grains are always colourless. Curved grains with undulous extinction are observed. The fibrous form never occurs.

Titanite is a mineral rarely occurring. It is almost always irregular in shape and angular in outline. The colour is brown-yellow, and the mineral slightly pleochroic. Extinction is incomplete in white light owing to the very strong dispersion.

Zircon is present in many of the samples, but in small quantities only. In contrast to most other minerals it almost exclusively occurs as strongly worn or rounded grains, generally of small sizes. Sometimes idiomorph forms with zone-structure are found. The colour is brown-red or pink, sometimes with slight pleochroism.

Opaque minerals. The ore minerals are counted in one group, as it has proved impossible to classify them with certainty. It is presumably as often as not a question of magnetite, easily recognizable owing to the magnetic qualities of the mineral. Further, I have in two samples (Nos. 103 and 115) found pyrrhotite characterized by a silver-white colour in reflected light and very ragged in form.

DESCRIPTION OF THE MINERAL ASSEMBLAGE OF THE HEAVY FRACTIONS

The content of heavy minerals forms a large part of the samples; the weight percentage of the heavy and the light fractions is given in the two first columns in the tables and apply to the grain-size 60—250 μ. In Søndre Kangerdluarssuk the heavy fraction forms 25 to 45 %, in Nordre Kangerdluarssuk 20 to 44 %, and in Nordre Isortoq 13 to 42 % of the examined part of the samples. The beach sand sample No. 133 has an extremely large content of heavy minerals (83 %) in spite of the fact that the sample has been taken in the same way as the other beach sand samples.

The examination of the content of heavy minerals in the 41 samples shows that half of these mineral species generally occur in quantities of less than a few per cent, or are sporadically distributed in the region in such a way that they cannot be used for classification of the material. That applies to zircon, titanite, kyanite, epidote, actinolite, enstatite, augite, olivine, and apatite; other minerals like brookite, cassiterite and corundum occur in one or quite few samples only. Carbonate, presumably magnesite, which I have found in a smaller number of samples, is thus not without significance for the localization of skarn lenses, because veins of calcite have not been observed within this area. Its significance is, however, somewhat reduced on account of the acid treatment necessary to clean the grains.

Of greatest interest is the distribution percentage in the samples of hornblende (common, blue-green and brown), hypersthene, diopside, garnet, sillimanite, and rutile. In the term hornblende are in the following included all three varieties. Bluish-green and brown hornblende, namely, occur much more rarely than common hornblende, and apparently these two varieties are without importance for the classification of the samples. Further, it is not possible with certainty to discriminate between common and bluish-green hornblende in the samples.

Of the above minerals hornblende, hypersthene, diopside, and garnet are always present; both hornblende and hypersthene always appear in greater quantities than diopside. On the other hand the proportion between quantities of hornblende and hypersthene does not apparently vary in any way regularly as in some samples hypersthene and in others hornblende is the abundant mineral.

Garnet is, however, always present (still sample No. 120 is always free of garnet); the content of garnet percentage compared to the content of sillimanite varies in the following way. In the samples where sillimanite is lacking, or is found in quantities of less than 1 $^0/_0$, the percentage of garnet is often low, i. e. less than 10 $^0/_0$; with an increasing content of sillimanite the garnet content is increasing, too. In samples where sillimanite occurs in more than a few per cent garnet forms more than half of the heavy fraction.

Rutile only appears in half the number of samples. Even if it cannot be called a diagnostically important mineral it is worth noticing that there is a connection between the occurrence of sillimanite and rutile; a large content of sillimanite gives rutile a per cent larger than 1, while samples where sillimanite is either absent or is only found as scattered grains rutile is also missing.

When we consider the content of amphibole and pyroxene in the samples on one hand, and the content of garnet and sillimanite on the other, it is clear that the material may be classified round two extremes: one group rich in amphibole-pyroxene, and another rich in garnet-sillimanite. Between these two extremes we have a number of samples the mineral content of which deviates from that of the latter two, and which must be considered mixture groups: we may here distinguish between a "pure" intermediate group and samples that are fairly closely related to one or other of the main groups.

As mentioned above the area belongs to the Isortoq-granulite-facies complex; the main rock consists of a fairly dark metamorph hypersthene-antiperthite-quartz-carrying gneiss or hypersthene-bearing quartz-diorite, i. e. an enderbitic gneiss (RAMBERG 1948, 1951, NOE-NYGAARD, BERTHELSEN 1952). The next common rock is granulite: a sillimanite and garnet bearing metasediment; this rock is found as layers of several hundred meters thickness, but it may also alternate with the main rock in layers of 10—30 meters thickness. Further, bands or inclusions of hypersthene-amphibolite, marble layers, skarn lenses and -bands, some quartzite, "rust zones" (sulphide-bearing zones), and ultrabasic

Table 1.
Mineralogical composition of samples from Søndre Kangerdluarssuk.

Number of samples	Percentage by Weight		Light fraction percentages by number of grains			Heavy fraction percentages by number of grains																					
	Light fraction	Heavy fraction	Quartz	Potash feldspar	Plagioclase	Opaque	Zircon	Rutile	Brookite	Titanite	Garnet	Kyanite	Sillimanite	Epidote, clinozoisite, zoisite	Hornblende, "common"	Hornblende, "blue-green"	Hornblende, brown	Actinolite	Enstatite	Hypersthene	Diopside, Diallage	Augite	Olivine	Corundum	Apatite	Calcite group	Biotite
103 D	71	29	26	12	62	8	×	..	..	×	10	..	×	2	23	2	2	..	..	32	29	..	..	..	..	..	1
104 D	63	37	15	12	73	6	..	..	..	..	4	..	..	..	29	2	×	..	..	30	35	..	×	..	..	..	8
105 D	55	45	14	8	78	21	×	..	..	..	13	..	..	×	24	2	..	..	..	46	15	..	×	×	..	..	10
106 D	64	36	17	4	79	12	×	×	..	1	8	..	..	..	22	×	2	..	..	40	27	..	×	..	..	..	4
107 S	62	38	17	8	75	3	..	..	..	..	1	..	×	1	24	4	..	..	..	46	24	..	..	..	..	..	10
108 D	63	37	22	5	73	7	×	..	..	..	2	..	×	×	32	3	×	2	..	33	28	..	×	..	..	..	9
109 D	72	28	16	4	80	12	×	..	..	×	4	..	×	..	45	×	..	..	..	30	21	..	..	..	..	..	5
110 M	67	33	28	10	62	19	1	..	..	1	10	..	×	..	40	1	1	..	..	29	17	..	..	..	..	..	5
111 M	67	33	30	4	66	11	..	..	2	1	7	..	×	3	33	4	1	..	..	28	21	..	×	..	×	..	×
112 D	71	29	22	4	74	8	1	..	..	×	5	..	×	×	33	×	2	1	..	28	29	..	1	×	..	..	1
113 D	74	26	24	6	70	6	..	..	..	×	3	..	..	..	27	..	4	..	..	28	37	..	1	..	..	..	2
114 D	74	26	36	3	61	7	..	..	..	1	6	..	1	..	37	2	2	..	1	27	22	..	1	..	..	..	1
115 D	75	25	39	3	58	3	..	..	..	..	6	..	..	..	31	2	2	..	..	47	12	..	..	..	..	..	4

D: Delta Sand Sample. S: Beach Sand Sample. M: Till sample. ×: present in percentages under 1.

rocks (RAMBERG 1948, 1951, NOE-NYGAARD, BERTHELSEN 1952). Further granitic augengneiss is found in the innermost part of Nordre Kangerdluarssuk. This rock is not described in the papers quoted above.

Samples belonging to the same main group vary a little in mineralogic composition owing to the location. The description of the mineral assemblage of the samples therefore falls in three groups, each dealing with its fjord area.

From the rivers in the southernmost fjord, Søndre Kangerdluarssuk, 13 samples derive; the mutual relationship of the heavy minerals vary in all samples within pretty narrow limits and must be referred to one of the main groups: the amphibole-pyroxene rich one. The mean figure for all 13 samples is 34 % hornblende, 34 % hypersthene, 24 % diopside, 6 % garnet and 2 % variae (see table 4).

To show the variations in the mineralogic composition the per cents

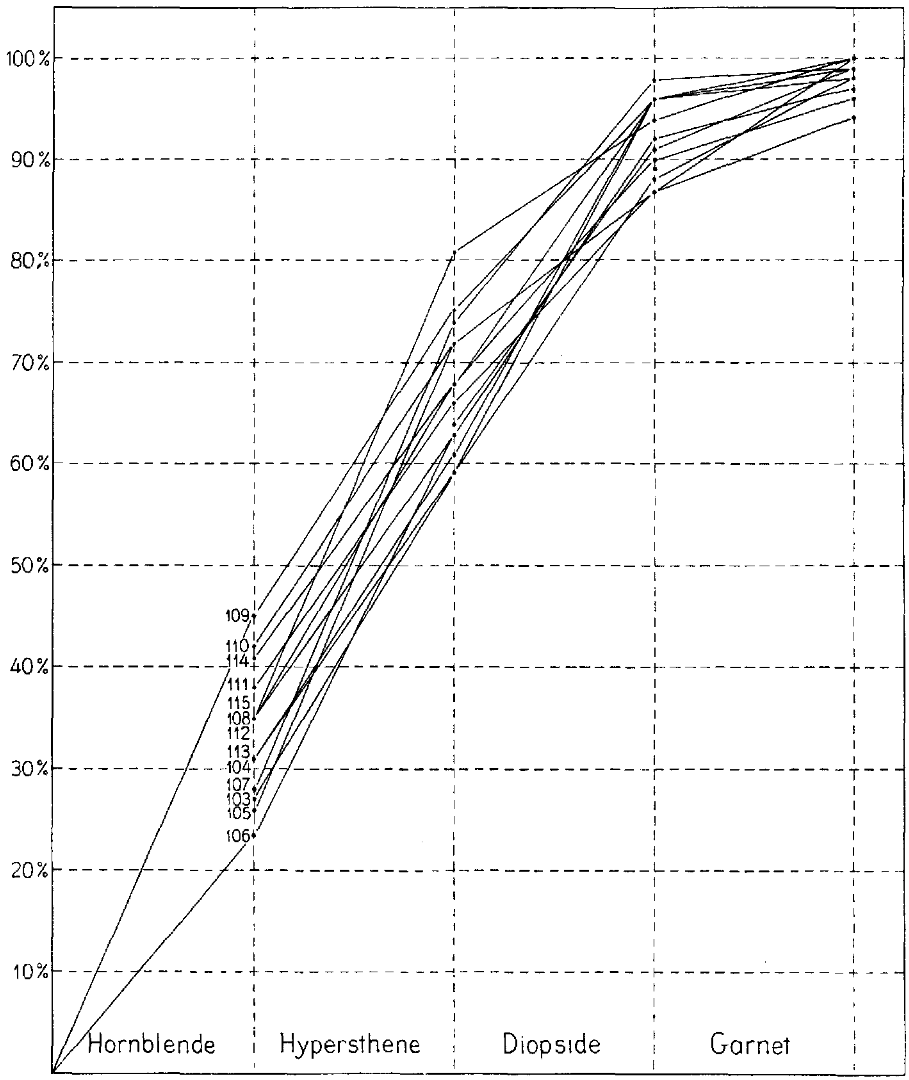

Fig. 1. Cumulative percentages of hornblende, hypersthene, diopside, and garnet, Søndre Kangerdluarssuk (Nos. 103—115).

of the four most commonly occurring minerals in the samples: hornblende, hypersthene, diopside, and garnet are plotted in cumulative curves; the minerals are entered on the abscissa with equally great distances in the said succession, while the per cents are entered on the ordinate. The curves for the samples 103—115 show little dispersion only (fig. 1).

The uniform character of the samples indicates that all the samples are disintegration products of the same rock type chiefly, the enderbitic

Table 2.
Mineralogical composition of samples from Nordre Kangerdluarssuk.

Number of samples	Percentage by Weight		Light fraction percentages by number of grains			Heavy fraction percentages by number of grains																					Biotite
	Light fraction	Heavy fraction	Quartz	Potash feldspar	Plagioclase	Opaque	Zircon	Rutile	Brookite	Titanite	Garnet	Kyanite	Sillimanite	Epidote, clinozoisite, zoisite	Hornblende, "common"	Hornblende, "blue-green"	Hornblende, brown	Actinolite	Enstatite	Hypersthene	Diopside, Diallage	Augite	Olivine	Corundum	Apatite	Calcite group	
116 D	61	39	18	21	61	6	..	..	..	..	12	..	1	..	53	..	1	..	..	14	16	..	..	..	3	..	22
117 D	80	20	42	9	49	3	..	1	..	..	24	..	×	1	15	4	2	..	..	32	21	..	..	..	..	..	12
118 D	58	42	22	9	69	6	1	..	..	..	14	..	..	..	28	..	1	..	..	20	31	1	..	..	4	..	22
119 D	65	35	34	9	57	17	2	..	..	..	13	..	..	..	24	..	1	..	..	34	26	..	..	..	×	..	25
120 D	70	30	44	1	55	11	1	..	..	..	..	..	..	..	14	..	..	..	..	48	37	..	..	..	..	..	11
121 D	63	37	45	2	53	9	..	..	..	..	2	..	..	..	17	..	..	..	..	49	32	..	..	..	×	×	6
122 D	77	23	47	2	51	7	×	..	..	..	9	..	3	1	22	..	..	..	..	48	17	..	..	..	..	..	7
123 D	56	44	34	11	55	1	..	1	..	..	53	..	12	..	8	..	..	..	..	25	1	..	..	..	..	..	8
124 S	57	43	19	15	66	6	..	..	..	..	4	..	..	..	15	1	1	..	..	53	26	..	..	..	×	×	4

D: Delta Sand Sample. S: Beach Sand Sample. ×: present in percentages under 1.

gneiss. The hypersthene-amphibolites found are partly embedded as small and thin bands everywhere in the rock, partly as thicker layers at a few localities. None of these modes of occurrence seem to influence the mineral content of the samples. This may be due to the fact that the material from these bands is small compared to the main constituent. Otherwise the mineral content of the said bands may be very similar to the content of the heavy minerals of the main rock; the latter possibility is certainly the most probable one. Interesting are samples Nos. 110 (till sample) and 111 (also a sample of fine-grained till); if the material from these deposits is transported from far afield the heavy mineral per cents lie so close up to the locally marked delta samples that we must conclude that the land towards the ice-cap consists of rocks with a similar composition as that of the coast. There is, however, another possibility, that the material derives from till composed of minerals of local origin. In none of the cases does it, however, look as if the glacial drift—if it forms part of the delta samples—influences the composition of the latter. But it must be noted that a few brookite grains have been found in the most fine-grained sanded till.

Biotite occurs in all the samples, but the variations are small. The

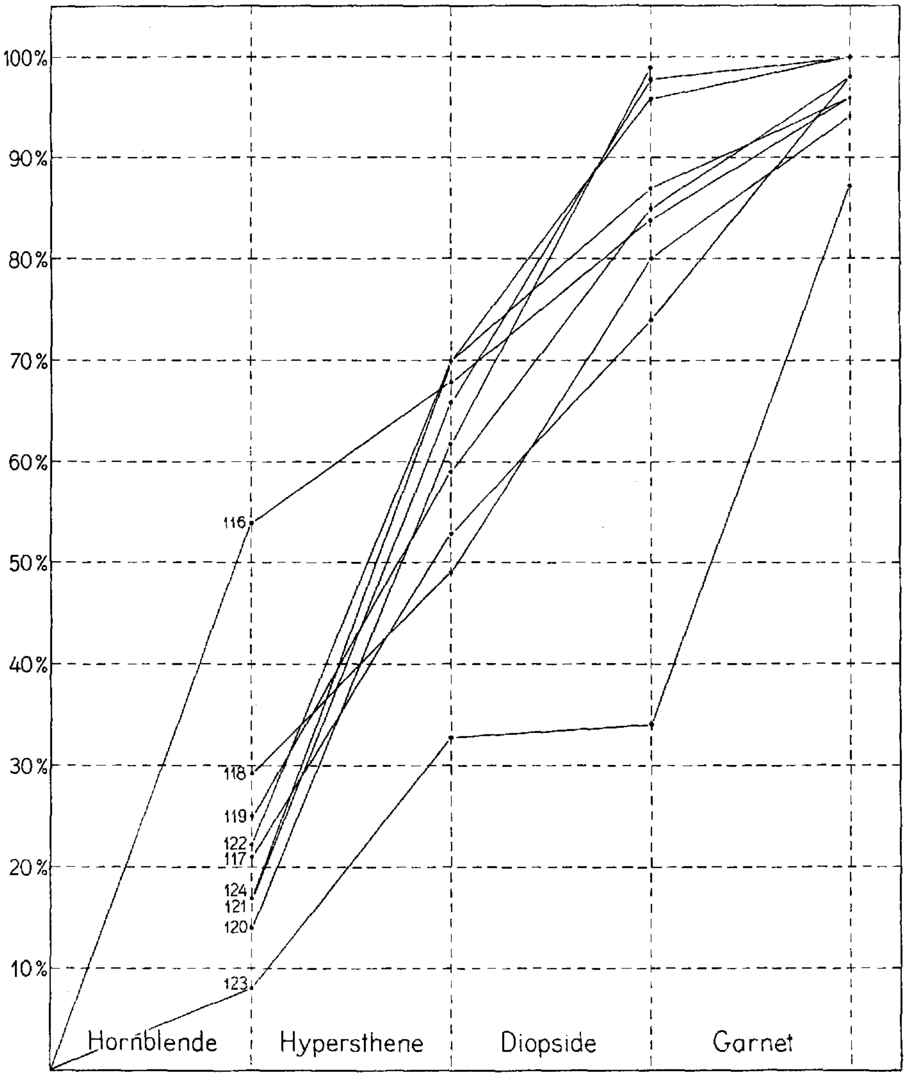

Fig. 2. Cumulative percentages of hornblende, hypersthene, diopside, and garnet, Nordre Kangerdluarssuk (Nos. 116—124).

percentage number of biotite grains in the individual samples is to be found in a special column last in tables 1, 2 and 3. If one lets biotite enter as ten per cent in the countings the fact cannot be disregarded that it may appear with too high per cents in comparison with the other heavy minerals. Biotite, namely, easily splits in several small particles under the cleaning process owing to the strong cleavage after the basal plane. The figures stated are thus an approximate expression only of the frequency of the minerals in the samples. The figures have been

Table 3.
Mineralogical composition of samples from Nordre Isortoq.

Number of samples	Percentage by Weight		Light fraction percentages by number of grains			Heavy fraction percentages by number of grains																					
	Light fraction	Heavy fraction	Quartz	Potash feldspar	Plagioclase	Opaque	Zircon	Rutile	Brookite	Titanite	Garnet	Kyanite	Sillimanite	Epidote, clinozoisite, zoisite	Hornblende, "common"	Hornblende, "blue-green"	Hornblende, brown	Actinolite	Enstatite	Hypersthene	Diopside, Diallage	Augite	Olivine	Corundum	Apatite	Calcite group	Biotite
125 D	81	19	38	6	56	2	..	×	..	..	15	..	×	..	16	×	1	..	..	51	16	..	1	..	×	..	2
126 D	80	20	39	5	56	7	×	×	..	×	14	..	1	1	26	2	1	1	×	42	12	×	×	..	..	..	1
127 D	86	14	40	4	56	4	..	..	..	..	3	..	×	×	21	1	..	×	..	58	17	..	..	..	..	..	6
128 D	70	30	48	16	36	3	..	1	..	×	48	..	7	..	11	1	1	×	×	19	6	..	6	..	×	..	2
129 D	76	24	27	2	71	5	×	×	..	..	6	..	1	×	19	×	1	×	..	52	21	..	×	..	..	..	9
130 D	84	16	65	×	35	7	..	..	..	..	12	..	1	..	12	×	×	×	..	65	10	..	×	..	×	..	9
131 D	87	13	47	7	46	3	..	×	..	..	5	×	1	..	26	4	1	..	..	48	15	×	×	..	..	×	42
132 D	74	26	64	3	33	2	..	2	..	..	41	..	14	..	9	×	1	×	..	20	11	1	1	..	..	×	3
133 S	17	83	42	4	54	12	×	4	..	..	74	..	4	×	4	×	..	..	..	10	4	×	..	..	..	×	×
134 S	58	42	49	9	42	×	..	2	..	..	57	..	18	..	5	2	×	..	..	14	2	×	..	..	..	..	5
135 D	80	20	57	1	42	4	×	×	..	1	25	..	4	×	24	4	2	×	..	26	13	..	1	..	..	..	1
136 D	75	25	81	0	19	×	..	1	..	..	40	..	11	..	5	×	3	..	×	30	7	1	2	..	..	×	7
137 D	60	40	66	4	30	1	×	3	..	..	69	..	20	..	1	..	..	..	..	6	1	..	×	..	..	..	1
138 D	67	33	47	6	47	2	×	3	..	..	50	..	20	..	4	1	×	×	..	19	3	×	..	..	..	..	2
139 D	77	23	53	6	41	9	×	1	..	×	27	..	3	3	28	4	2	×	..	22	9	1	×	..	..	..	1
140 S	79	21	65	3	32	17	×	×	..	×	27	..	4	1	30	7	3	×	..	17	9	2	×	..	..	..	2
142 D	79	21	47	×	53	2	×	×	..	1	23	..	3	1	26	7	2	×	..	22	13	2	×	..	..	..	×
143 D	77	23	62	2	36	5	×	1	..	×	22	×	3	1	22	3	1	×	..	33	11	2	1	..	..	×	3
144 D	73	27	61	5	34	6	1	1	..	..	37	..	8	..	9	2	1	..	..	31	9	1	×	..	×	..	2

D: Delta Sand Sample. S: Beach Sand Sample. × : present in percentages under 1.

arrived at in the following way: to begin with 100 grains were counted inclusive of biotite, and then the counting was continued up to 100 grains exclusive of biotite.

The samples from Nordre Kangerdluarssuk are not so uniform in composition as those previously mentioned. Seven of nine samples (116, 118—122, and 124) are rich in amphiboles and pyroxenes. The mean figures are 25 % hornblende, 38 % hypersthene, 26 % diopside, and 8 % garnet, while sillimanite is found in two samples only, and rutile is completely lacking. Compared with the mean figures for the samples from Søndre Kangerdluarssuk the variations are rather small: 9 % less

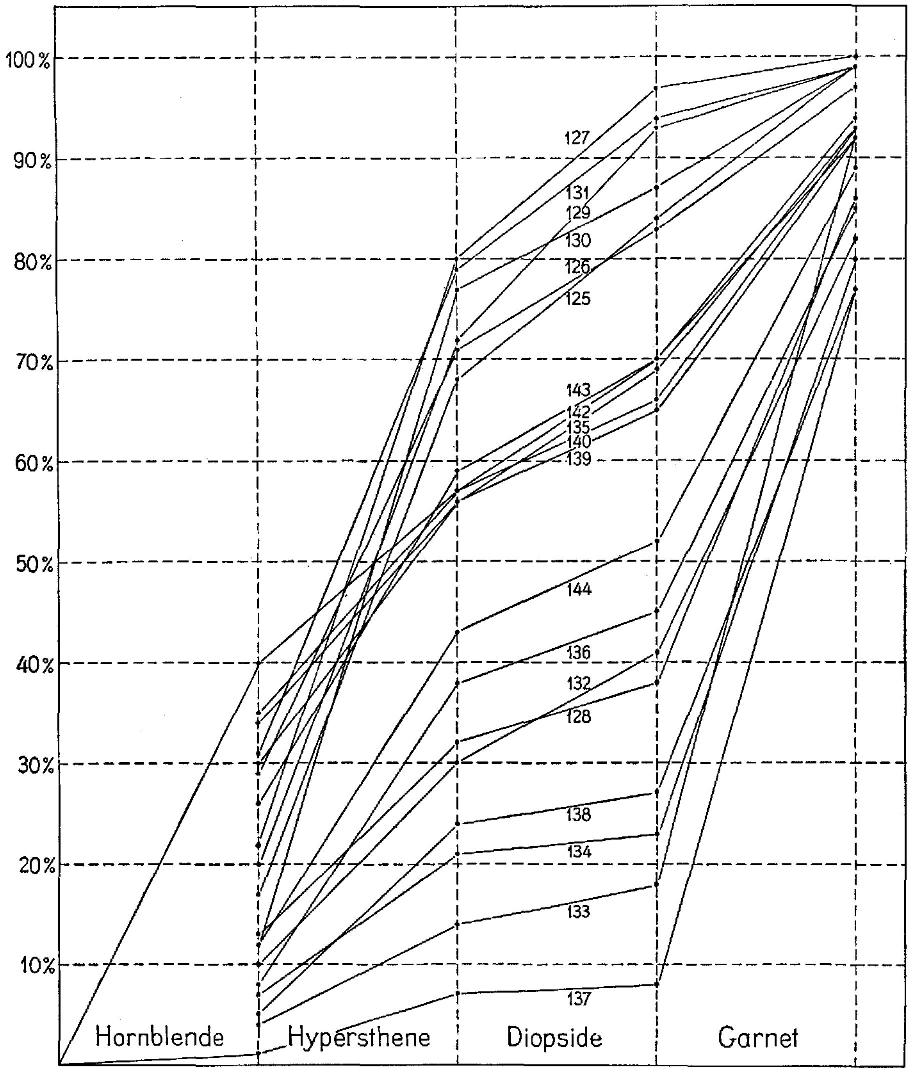

Fig. 3. Cumulative percentages of hornblende, hypersthene, diopside, and garnet, Nordre Isortoq (Nos. 125—144).

hornblende, 4 % more hypersthene, 2 % more diopside, and 2 % more garnet, but within the individual samples there are pretty great deviations from the mean figures. Thus sample No. 116 has 54 % hornblende, while the others vary between 14 and 29 %, i. e. a somewhat lower percentage than is the case in the samples from Søndre Kangerdluarssuk. The per cents for hypersthene and diopside on the other hand correspond very closely to those found before. The garnet per cents vary in the following way: one sample is free of garnet; two have low per cents (2 and 4 %), while four have from 9 to 14 %. Sillimanite is lacking, or is found in very small quantities only; sample No. 122 forms an exception, it contains 3 % in spite of the not very high garnet per cent (9 %). Rutile is completely lacking. The content of heavy minerals shows that the main source is hypersthene gneiss (quartz-dioritic gneiss); the higher garnet or sillimanite per cents of certain samples show that layers of garnet- and sillimanite-bearing granulite occur in some places. This is more conspicuous in sample No. 117 that contains 24 % garnet; even if sillimanite does not occur in the sample it must be referred to the mixed group (see below under the description of the samples from Nordre Isortoq).

The previously mentioned granitic augengneiss which occurs in the innermost part of this fjord (see the map) evidently does not form disintegration products that with certainty can be distinguished from the enderbitic gneiss.

Sample No. 123 is essentially different from the others; only one third of the heavy fraction consists of amphiboles and pyroxenes, while garnet (53 %) and sillimanite (12 %) dominate. The material chiefly derives from granulitic rocks.

The curve (fig. 2) clearly shows that the original material is not homogeneous; some samples (Nos. 120, 121, and 124) have the same curvature as the samples from Søndre Kangerdluarssuk, while the curves of other samples (Nos. 117, 118, 119, and 122) are distinguished by a larger content of garnet. This applies to sample No. 116 in spite of the large content of hornblende. On the other hand the curve in the case of sample No. 123 is distinctly different from the others.

Biotite is found in all samples and in greater quantities than in the material from Søndre Kangerdluarssuk. More than 20 % biotite is found in Nos. 116, 118, and 119.

Nordre Isortoq covers the largest area; 19 samples derive from it. They fall in three groups determined by the heavy mineral: 1) one rich in amphiboles and pyroxenes, 2) one mixed group, and, 3) one rich in garnet and sillimanite. The mean figures for these three groups appear from table 4.

The group rich in amphiboles and pyroxenes consists of six samples; it is fairly closely related to those described before. The hypersthene content is, however, somewhat higher at the cost of hornblende and diopside; further sillimanite and rutile are found in small quantities in almost all samples. The composition shows that the main rock is the enderbitic gneiss, but the small quantity of sillimanite and rutile indicates the presence of secondary layers of granulite.

The group rich in garnet and sillimanite is represented by eight samples, whose mean composition is seen above (in table 4); the con-

Table 4.
Mean figures of the most important minerals occurring in groups E, G, and M.

Locality	Group	Number of samples	Hornblende	Hypersthene	Diopside	Garnet	Sillimanite	Rutile	Variae
Søndre Kangerdluarssuk	E	103—115	34	34	24	6	0	0	2
Nordre Kangerdluarssuk	E	116, 118—122 & 124	25	38	26	8	0	0	3
	M	117	21	32	21	24	0	1	1
	G	123	8	25	1	53	12	1	0
Nordre Isortoq	E	125—127, 129—131	22	53	15	9	1	0	0
	M	135, 139, 140, 142, 143	33	24	11	25	3	1	3
	G	128, 132—134, 136—138 & 144	8	19	5	52	13	2	1

E: Enderbitic group. G: Granulitic group. M: Mixed group.

stituents may be traced back to granulite, while the part played by enderbitic rocks is non-essential or nil. Sample No. 137 must particularly be noted as amphibole and pyroxene form 8 % only, while garnet, sillimanite and rutile together form the remainder (92 %). Sample No. 123 mentioned above has a composition exactly like the mean figure of this group.

The remaining samples from this fjord area have a mineral assemblage intermediate between these two groups (see the mean figures in table 4). The origin of the material is obviously both rock types.

The curves in fig. 3 show the subdivision of the material in three groups: at top the samples rich in amphiboles and pyroxenes, at the bottom those rich in garnet and sillimanite, and in the middle the mixed samples.

Biotite occurs in all samples, generally in quantities under 10 %. Remarkable is, however, No. 131 where it forms 42 % of the heavy minerals.

DESCRIPTION OF THE MINERALS OF THE LIGHT FRACTIONS

The examination of the light fraction has been undertaken by means of the abovementioned staining method. The following minerals have been found: quartz, that remains unstained, potash feldspar that appears in a yellow colour, and plagioclase known by its red staining. Cordierite and skapolite which no doubt both are found as component parts of the rocks of the area have not been found in the slides. Cordierite—probably because it greatly resembles quartz—may have been overlooked, skapolite because it probably occurs in very small quantities only.

The per cent distribution of the minerals within the light fraction does not offer the same possibilities for classification of the samples as the heavy one. Still, there are certain indications. Material that derives from areas that chiefly consist of granulitic rocks or have considerable layers thereof have much quartz (over 45 $^0/_0$) and correspondingly small quantities of plagioclase. Transversely the enderbitic material is frequently poor in quartz, though rich in plagioclase. It is worth noting that potash feldspar in by far the most samples occurs in quantities of less than 10 $^0/_0$.

RESULTS AND CONCLUSIONS

The analyses of 41 samples of sand thus show that the mineral content in the heavy fraction varies so much that a division into two main groups is possible, and that some samples have an intermediary position closer to one or the other group. The mineral assemblage of the light fraction does not offer the same possibilities.

It is only the main rocks, the enderbitic gneisses and granulites that characterize the mineral assemblage.

The other rocks that are observed in the area: skarnlenses, amphibolites, ultrabasic rocks, quartzites and rustzones have small extension only. The finding of carbonate in some of the samples may perhaps indicate the presence of skarn rocks; on the other hand the non-presence of this mineral does not indicate any lack of skarn lenses or skarn layers. The distribution of the amphibolites and the difficulty as to their identification by means of the mineral contents in the heavy fractions is previously mentioned (p. 16). In this connection the attention is drawn to the fact that the sample (No. 116) containing most amphiboles has 54 $^0/_0$ hornblende and is derived from augengneiss. Whether this rock is particularly rich in amphiboles or contains schlieren of amphibolite is unknown. 6 $^0/_0$ olivine in No. 128 suggests the presence of ultrabasic rocks. Pyrrhotite, found in Nos. 103 and 115 presumably derive from rustzones. On the other hand the samples offer no basis for proving the presence of quartzite.

No geological maps of the area have as yet been published, but a survey map over the west coast of Greenland from the mouth of the Buksefjord to Jakobshavn is under preparation. By the kindness of the responsible leader of the geological mapping, Professor, dr. phil. ARNE NOE-NYGAARD, I have obtained permission to copy the working maps from the said areas. They are printed to the scale of ab. 1:5000.000.

A good conformity is found in most occurrences (namely in 26 samples) between the analyses of the mineral content in the heavy fraction of the samples compared with the theoretical possibilities, i.e. the mineral composition of the material from the recent deposits from the individual rivers appears to be in accordance with the rocks observed. Four samples derive from "terra incognita", while eleven samples differ more or less from the supposed source material.

The reason of this is due to several facts: 1) the maps at disposal for geological mapping were sketchy in character with consequent difficulties for the perfectly accurate drawing of the borders observed between the rock types, 2) the mapping is in the case of most of the areas dealt with carried out in such a way that only the coast-areas are covered; in a number of cases it is not known which rocks are found in the upper course of the rivers, 3) if a river cuts through several different rock-types it theoretically carries material from all of them. How much it carries along depends a) on the length of each layer through which it flows, b) the velocity of the flow in the layer, c) the situation of the layer with regard to that of the area of accumulation, in extreme cases whether it lies in the upper or lower course of the river, d) whether the disintegration velocity (erosion and weathering) in the various rocks is high or low.

All the said factors—mostly unknown—are of the greatest importance for the composition of the minerals and particularly affects the classification of the mixed samples. Other unknown factors are the surface soils; the glacial drift is, however, very thin or completely lacking in most places, so that the contamination from it at any rate in the regions with main rock enderbite is quite insignificant (see the analyses of samples Nos. 110 and 111). Contamination from local weathering products may be eliminated, apart from the loss of certain easily weathering minerals like apatite and olivine.

As previously mentioned the mineral contents of the rocks observed in the distributive provinces are usually in good agreement with the heavy mineral contents in the recent samples. In a few cases, however, smaller discrepancies have been observed. Thus the two samples (Nos. 125 and 129) contain less garnet and sillimanite than expected, as both enderbitic and granulitic rocks are present in the mainland. On the other hand several samples (Nos. 128, 132, 136, and 138) are so rich in these two minerals, that they have been referred to the G group, i. e. that the material is derived from granulitic rocks. The geological field map, however, shows that both types of rocks are present in the distributive provinces of the respective rivers. Sample No. 143 is of a mixed character (M group) and thus deviates from the composition expected, as the contents of garnet and sillimanite are large compared to the rocks observed (enderbite and amphibolite).

In a few cases, only, the results of the present investigation are at variance with the composition expected according to the preliminary geologic map of the area. Thus sample No. 119 from Nordre Kangerdluarssuk contains 25 % hornblende, 34 % hypersthene, 26 % diopside, 13 % garnet, but no sillimanite and rutile, and seems to be derived from enderbitic rocks only. Nevertheless, according to the map the river traverses granulitic rocks only. Contrary to this the heavy fraction in sample No. 144 from Nordre Isortoq indicates largely a derivation of the sediment from granulitic rocks as it contains 12 % hornblende, 31 % hypersthene, 9 % diopside, 37 % garnet, 8 % sillimanite and 1 % rutile. However, according to the map enderbitic rocks only are present in the distributive province.

In spite of these few discrepancies between the heavy mineral contents of the recent samples and the rocks in the corresponding distributive provinces it may be concluded that the present investigation shows close agreement in most cases. In my opinion the heavy mineral analysis of recent sediments from Greenland may be well suited to estimate the kind of rocks to be expected in the various distributive provinces.

It is thus considered safe to draw the following conclusions from the four samples collected in areas which are not yet geologically mapped. Judging from the analyses only enderbitic rocks should be present in the distributive province of sample No. 120, while samples Nos. 117, 139 and 140 seem to be derived from enderbitic as well as granulitic rocks.

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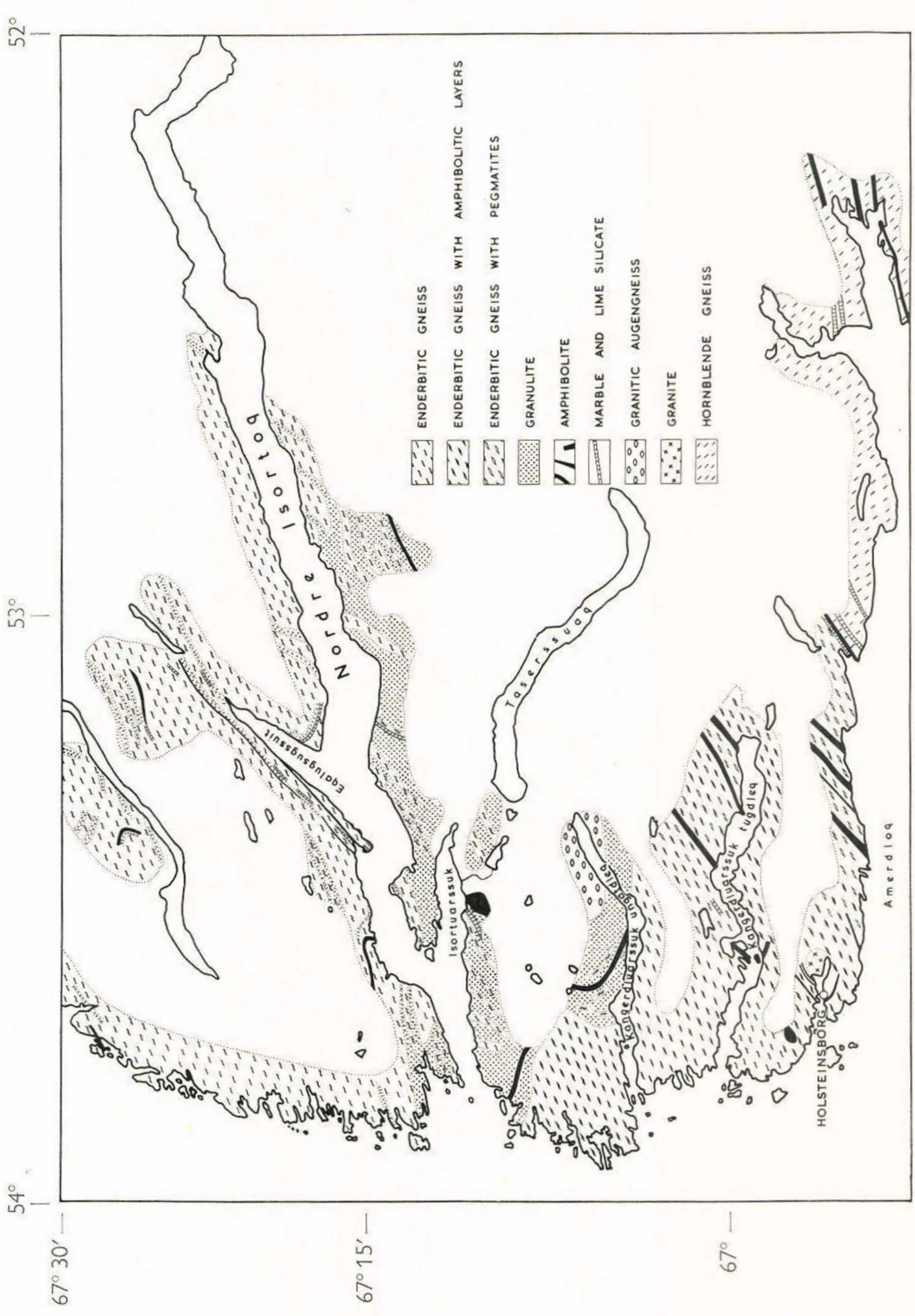
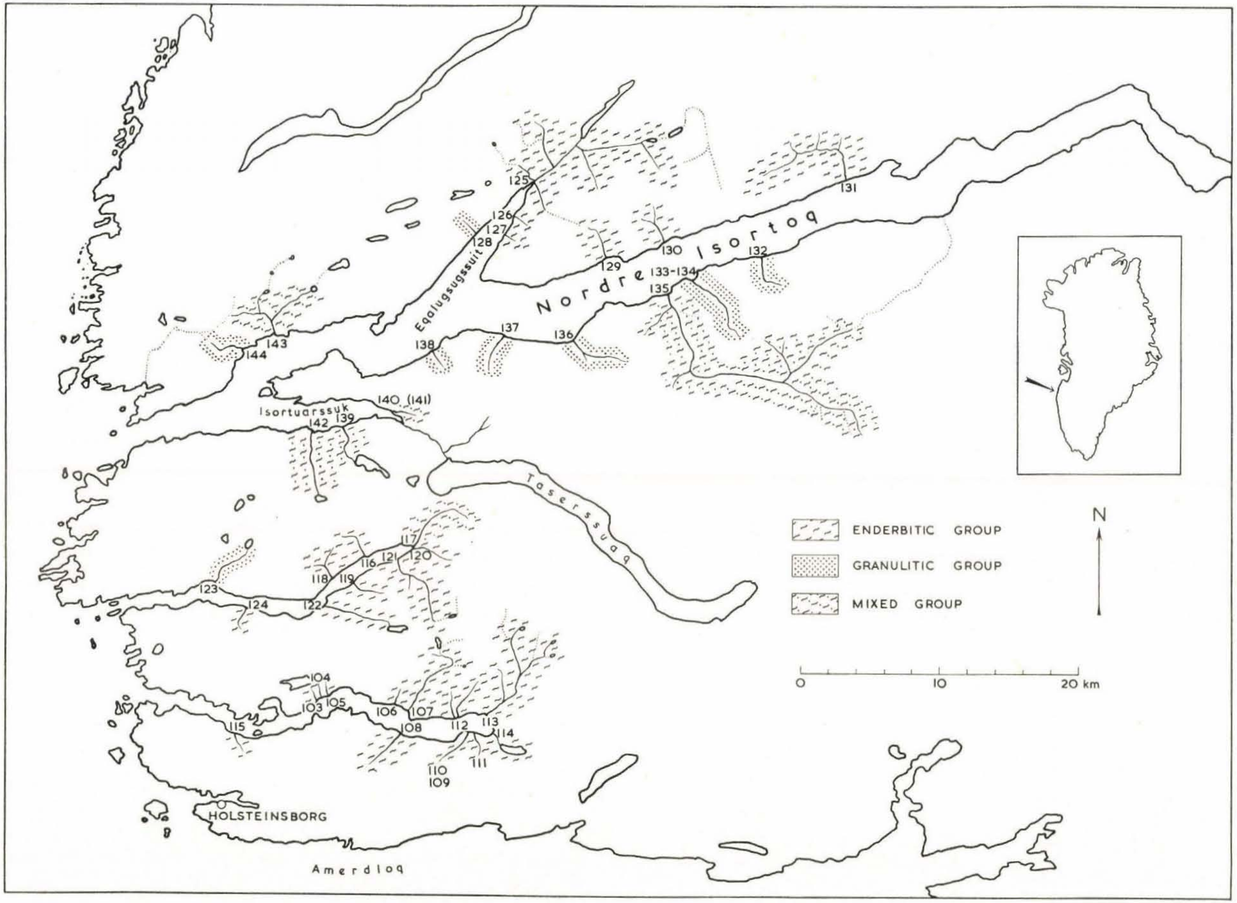
Færdig fra trykkeriet den 6. juni 1957.

PLATES



Provisional geological map of the area investigated, chiefly mapped by Hans and Marie-Louise Ramberg.



Map showing the results of the analyses and the distribution of the sand samples in the area investigated.