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UNDER LEDELSE AF LAUGE KOCH

A SEDIMENTARY PETROLOGICAL INVESTIGATION OF A NUMBER OF SAND SAMPLES

FROM THE SOUTH COAST OF GREENLAND BETWEEN IVIGTUT AND FREDERIKSDAL

BY

R. D. CROMMELIN

WITH 4 FIGURES IN THE TEXT AND 1 MAP

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
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SUMMARY

In studying a collection of sand samples from the south coast of Greenland an attempt was made to give further information:

1. about the hitherto little-known so-called newer abyssal rocks;
2. about the possible occurrence of other nepheline syenite areas in the examined area than the 3 known ones;
3. about the nature of the moraines and the possible occurrence of specific minerals in them.

By the side of the macroscopical examination a microscopical examination, was necessary which was done according to the method used at the geological laboratory at Wageningen (see lit. EDELMAN, BAAK) in which 2 fractions are made of each sand, respectively with specific weight > 2.9 and < 2.9. Fixed preparations were made of the fractions. The results of the countings of the preparations of the heavy and the light fractions are given in the tables. According to the descriptions of the sands 2 groups may be distinguished:

1. group of sands consisting of local material;
2. group of sands in which moraine material plays an important part.

After the discussion of the 2 groups some particulars are given about the minerals found, among others eudialite, astrophyllite, aenigmatite, which may be considered as new in the literature of sedimentary petrology. In one sample *piedmontite* was found, probably a new mineral for Greenland.

Summing up, we find that

1. the newer abyssal rocks are characterized as to their heavy fractions by the combination titaniferous augite — diopside with or without green hornblende, which together with other data e. g. absence of natronamphiboles and natronpyroxenes points to rocks of the potassiumsuit of the alkali series;
2. no indications were found for the existence in the examined area of more than the 3 known nepheline syenite masses;
3. the examined sands come from local moraines and no single indication for a regional moraine with a more or less constant composition was found in the whole area;
4. it appeared that hypersthene has a more regular distribution in the examined area than would be expected from the available data.

CONTENTS

1. Introduction.

In the autumn of 1936 the Geological Laboratory at Wageningen, Holland, received a collection of sand samples from South Greenland made by Dr. WEGMANN during an exploring expedition by order of Dr. LAUGE KOCH. It was agreed with Professor Dr. C. H. EDELMAN, Director of the Geological Laboratory, that the present writer would undertake to examine these sands which form an exceedingly interesting object of study for the sediment-petrologist. For these sands come from one of the finest areas of alkali rocks in the world, where, moreover, owing to the relatively dry and cold climate the chemical disintegration progresses slowly, so that as a rule the minerals are still clean, which can only have a favourable influence on the examination of them. So from the point of view of sedimentary petrology alone it would already be interesting to describe sands which to my knowledge have not yet been mentioned in the literature, but from that of geology, too, some problems arose here, which, as was to be hoped, might be solved together with the sand-examination.

Before stating the object of the present investigation a short survey may be given of the geological situation of the source of the sands.

2. Geological Survey and Object of the Investigation.

According to the most recent views on the geology of the examined area, which I derive from data of Dr. C. E. WEGMANN, two geological formations can be distinguished. The oldest formation is called the *Ketilides*, an old sediment series, in the upper part of which is the *Arsuk group* with thick greenstone formations, in the lower part a pelitic-psammitic formation: the *Sermilik group*. This series has been folded and migmatitised and some part of the *Julianehaab granite* of USSING (lit. 15) was thus formed. So the crystalline schists on USSING's map in lit. 15 are connected with the real Julianehaab granite by various transitions and they are equally old. In the Arsuk group also occur gabbroid and ultrabasic rocks.

The second formation, the probably young-precambrian *Gardar*-formation, lies on the old eroded body of the Ketilides and begins with the Igaliko sandstone which covers an extensive area north east of Julianehaab. Above it volcanic eruptions have caused a cover of *porphyries*. The youngest phase of the Gardar formation is represented by the as yet little known younger *granite*, *syenite* etc. (newer abyssal rocks of Ussing) and the better known series of the *nepheline syenites*. To the latter belong the igneous masses of Ilimausak, Igaliko and Ivigtut of which the first and the second were amply described in the classical work of Ussing (lit. 15).

It may be pointed out that the Julianehaab granite is a resistent rock with in general smooth, round forms, the newer abyssal rocks on the other hand are miarolitic in structure and easily disintegrate to waste. We may now sum up the above in a table:

<table>
<tr><td rowspan="2">Scheme by
Dr. C. E. Wegmann
(Cf. M. o. G. in
this volume
and lit. 18, 19).</td><td colspan="2">Gardar formation
a. younger alkali rocks
1. younger granite, syenite with prevalence of potassium
2. series of the nepheline syenites with prevalence of natrium.</td></tr>
<tr><td>b. porphyritic formation
c. Igaliko sandstone</td><td>both partly changed by the younger alkali rocks</td></tr>
<tr><td></td><td>Ketilides
a. Arsuk group
b. Sermilik group</td><td>both folded and granitised (Julianehaab granite)</td></tr>
</table>

Now the geological object of the present investigation was:

1. to give further information about the nature of the hitherto little-known newer abyssal rocks;

2. to find whether by means of the sand examination others than the 3 known nepheline syenite areas might perhaps be traced;

3. to obtain further data about the nature of the moraine and about the possible occurrence of specific minerals, as they might in certain respects be characteristic of the rocks under the inland ice.

3. Method of Investigation.

In order to arrive at comparable results, first of all an idea had to be obtained about the average mineralogical composition of each sand. For this purpose, besides a macroscopical examination under the binocular, a microscopical examination is necessary. For even with the use of a greatly magnifying binocular it is not always possible to distinguish the minerals that are important for the determination of a sand, and therefore it is absolutely impossible to get at all quickly an idea of the proportion in percentages, which is always of paramount importance to the sediment-petrologist. Thus e. g. greenish quartz and greenish sodalite which are full of mikrolite-like hornblende inclusions cannot with any degree of certainty be distinguished from each other under the binocular. The same may be said of orthoclase and nepheline. Likewise this may be the case with the distinction between rather thick grains of arfvedsonite, titaniferous augite and aegirine. Titanite and hypersthene are difficult to distinguish under the binocular, if the grains lack their morphological habitus. More examples might be given to make clear that besides a macroscopical examination a microscopical method must be used in order to give the geologist in a quicker and more accurate way an impression of the composition of the sand, at the same time removing the mentioned doubtful cases. A similar method was introduced by EDELMAN and DOEGLAS (lit. 6) and it is here applied in a slightly modified way. Briefly, with this method the sand, after having first been washed and sieved, is divided with bromoform into two fractions, a heavy one with spec. weight > 2.9 and a light one with spec. weight < 2.9. Mostly, the sand is first heated with hydrochloric acid and nitric acid, in order to remove the troublesome iron films round the grains. In this process, however, minerals such as olivine and apatite are then dissolved, likewise in the light fraction nepheline and sodalite. Now this is exactly what had to be avoided in our examination, so of the heavy fraction of each sand 2 preparations were made, 1 heated with acids and 1 heated with 10 % KOH (for some minutes). In the latter case the iron films disappear owing to peptisation without the minerals dissolving to any extent. With a certain content of olivine or apatite in a sand the percentages of these minerals may be determined from the fraction heated with KOH and then interpolated into the composition in percentages of the preparation heated with acids. The composition in percentages is obtained by shifting the preparation lying on the cross-table vertically through the field of vision. Each grain passing the point of intersection of the cross-lines of the ocular is then noted down. Thus of each preparation 50 grains, inclusive the opaque ones, were counted and the percentages of the heavy fraction were rounded off to 5. For the less frequently occurring minerals together 5 % was preserved. The proportions given are therefore not so accurate as with the EDELMAN method, which is not necessary, because in the examined sands the mutual differences in composition are much greater than in a regional sedimentary petrological area, such as e. g. Holland, to which the EDELMAN method is applicable.

Of the light fraction, which had to be spared as much as possible with a view to discovering minerals such as nepheline and sodalite, only if necessary preparations were made of which the fraction had for a moment been heated with KOH, in cases of clean sands a preparation was immediately made. For the certain distinction between nepheline on the one hand and quartz and orthoclase on the other the Fedorow apparatus model UT 2 was used. With this apparatus, by means of some simple manipulations, it can at once be settled whether we have to do with a uniaxial or a biaxial mineral, and in the first case whether the mineral is positive or negative, so that any doubt if we have to do with nepheline is at once removed.

The light fraction can in general not be counted with the same accuracy as the heavy fraction. For by far the greater part we have here to do with the combination quartz-felspar, so that the typical variations in optical properties, as e. g. pleochroism, birefringence and average refractive index, are lacking. Moreover, a hindrance is formed by the frequent occurrence of turbid felspars that cannot be determined any closer, which have been indicated in the table as *turbid felspar*. Finally, another difficulty is formed by the fact that if felspars in the preparation lie on the plane (010) the twinning according to that plane is not visible. In such a case a confusion between albite and orthoclase is not impossible. The conduct of these two minerals with regard to the Becke line mutually corresponds to a large extent. In the light fraction a distinction is made with the aid of the Becke line between albite-oligoclase on the one hand and oligoclase-anorthite on the other; oligoclase of which the refractive index is about equal to that of the canada-balsam is counted now on the acid side, now on the basic. A rough idea about the proportion acid-(intermediate + basic) plagioclase is thus obtained, although the content of basic plagioclase will always be found to be slightly too high. For the above-mentioned reasons the composition of the light fraction was not given in percentages, but in relative proportions of much or little.

Before passing on to the discussion of the results given in the tables we may first give a survey of the 47 samples collected by Dr. C. E. Wegmann, together with his slightly abridged descriptions.

4. Survey of the Localities according to Dr. C. E. Wegmann.

1. Sand from Tunuarmiut on the northern beach near the river-mouth. The valley is cut in the Igaliko sandstone and the porphyritic formation. The sand is locally washed. A small supply from the area of the alkali rocks is considered possible.

2. River sand, inner Kirkevig, Kakortok fjord. The river cuts partially in Quaternary sediments. The surroundings consist of granite,

diorite, migmatite, which are intersected by young basic veins. In the moraine some nepheline syenite blocks were found.

3. Beach sand from Kekertarsuak under the mine FREDERIK VII. The slope is partially covered by Quaternary, out of which the sand is washed by the waves and locally accumulated. The moraine probably comes from the Igaliko- and Kakortok fjord.

4. Beach sand from the inner Kangerdluarsorujuk fjord. The sand is washed out of river terraces consisting of moraine material deposited at the foot of the slope. The moraine comes for the greater part from the surroundings, which consist of granite and younger basic veins. Some syenite blocks were found.

5. Beach sand from the south-east side of the inner Kangerdluarsorujuk fjord. From old delta structures consisting of moraine material the sea has cut a steep wall and deposited the sand at the foot. The supplying area consists of granite, migmatite and younger basic veins.

6. River sand from the inner Akugdlek fjord. This is a sample from the river mouth, which comes from an area rich in moraines. The area consists of gneiss, granite and younger basic veins.

7. Moraine sand from the river near Imartunek. The sample comes from the bank of the river, which cuts through the moraine. This river comes from a glacier now ending farther off in the valley. The area consists of granite, migmatite and younger basic veins.

8. Beach sand from the south-east edge of the Sermilitsialik glacier. The sample comes from the beach lying closely below the front of the glacier. The supplying area consists of gneiss, migmatite and diabase, also sandstones and shales.

9. River sand from the moraine north-west of the Sermilitsialik glacier. The river runs through a moraine landscape only shortly left by the glacier. The sypplying area corresponds with that of no. 8.

10. Beach sand from the north-west end of the middle Sermilitsialik fjord. The sample comes from a bend in which a diabase vein is outcropping which will have furnished the greater part of the material. The surroundings consist of granite, migmatite and other rocks rich in amphibole.

11. Beach sand near Aurora harbour. The Quaternary is washed out by the waves and locally accumulated. The area consists of gneiss-granite with older and younger basic veins.

12. Moraine sand from the bend south of Angnikitsorsuak (the isle of Alangorsuak). The hinterland of the bend consists of younger granite and syenite. Material from the old basement rocks may also be present in the moraine, but probably to a small amount in proportion to the younger granites and syenites which easily disintegrate to sands.

13. Beach sand of Tuluvartalik (archipelago of Kitsigsut). The islands consist of syenite with veins and "schlieren" of amphibole-magnetite rocks and felspar-magnetite rocks. The darker elements of this easily disintegrating material are concentrated behind the stones on the beach. There may be an admixture of moraine material from Greenland itself.

14. Disintegration sand from the youngest diabase on the south-west part of the isle of Sanerut. There may be admixtures of Quaternary material. In the diabase fragments are found of the neighbouring rocks.

15. Disintegration sand of the young diabase from Ekaluit (Ivigtut fjord). The sand is washed out by the waves and locally accumulated. A small admixture of moraine material is possible.

16. Moraine sand of Ekaluit (Ivigtut fjord). Collected at the mouth of the river. The supplying area of the moraine mostly consists of migmatite and younger basic veins, also of a small nepheline syenite mass, but it is doubted whether much material of the latter has got into the moraine.

17. Beach sand near the Ivigtut glacier. From the moraine delta in front of the glacier. The supplying area consists of migmatite, granite and basic veins. Metamorphic rocks are also found in the moraine.

18. Beach sand from Ininguit at the entrance of the Iluat. The sand is washed by the waves out of the moraine, in which fragments of the basement rocks and of younger basic veins are mostly found.

19. Moraine sand from the inner bend of Ininguit. The supplying area of the moraine is formed by migmatite and younger basic veins.

20. Beach sand from Ekaluit (Kungnat). Derived from the disintegration of the younger granite. Rock fragments with fluorite and topaz are found in it.

21. Beach sand from Ekaluit (Kungnat). The sand is glittering-black owing to the concentration of iron ores and it comes from the Kungnat granite and its neighbouring rocks.

22. Fluvioglacial sand from the inner Arpagfik fjord. The sand is probably deposited in the sea but lies now above the sealevel. The surroundings consist of migmatite and darker younger veins.

23. Fluvioglacial sand, north beach of Patugsuk (Arsuk). The sand is washed out of the terraces. The supplying area consists of migmatite and chiefly Kungnat granite.

24. River sand and beach sand from the great delta south of Taylorshavn. The material comes from the local and the regional moraine as is shown by some nepheline syenite blocks.

25. Beach sand from the harbour at the south-east point of the Arsuk island. Washed in the bend by the waves out of a banded clay. Probably for the greater part of erratic material. On Arsuk

occur only greenstone schists and quartzites, which are intersected by diabase veins.

26. River sand from the valley north of the Ika fjord. The delta lies south of no. 24 and may be compared with it. In the Ika fjord nepheline syenites occur, further migmatite and many younger basic veins.

27. Beach sand from the harbour on the south side of the Arsuk island. The sand comes partly from local material, partly from regional moraine. In the surrounding part of the Arsuk island greenstones are chiefly found, which are intersected by diabase veins.

28. Beach sand from the north harbour on Arsuk Storö. Washed by the waves out of the moraine. In it local and regional moraine material. Arsuk Storö consists for about one-third of granite, for about two-thirds of greenstones.

29. Beach sand from the north beach of Lichtenau. Lichtenau lies on a peninsula, the Cape of which consists of amphibolite and pegmatite whereas there is Quaternary in the isthmus. The latter is washed out by the waves, the ores are concentrated in it. The sample comes from this sand. The surroundings consist of ultrabasic rocks.

30. Beach sand from Unartok. The sand is washed out of Quaternary deposits in which iron ore is concentrated. A part of the material is perhaps of aeolian nature. The supplying area consists of migmatite and granite among which much easily disintegrating younger granite.

31. Beach sand from the north bend of the inner Unartok fjord. Derived from the easily disintegrating younger granite.

32. River sand from the inner Unartok fjord. From a rockstream. The surroundings consist of migmatite and younger veins.

33. Beach sand from the bend near Niarkornat, opposite the Unartok island. The sand is washed out of a moraine. Niarkornat consists of younger granite. Probably, however, little material of it is found in the moraine.

34. Beach sand from Itivdlek, Tugtutuarsuk. Derived from the Quaternary of the bend. The surroundings consist of granite, migmatite and Rappakiwi granite.

35. Beach sand near the river mouth of the Kingua valley. The sand is washed out and partly accumulated as aeolian sand. Younger granite and migmatite partially containing garnet are found in the Quaternary.

36. Beach sand from Frederiksdal. The sand is washed out by the waves. The surroundings consist of younger granite and syenite and, a little further on, also migmatite.

37. Beach sand from Herjulfsnaes (Östpröven). The surroundings consist of younger granite. In the Quaternary migmatite also occurs.

38. Beach sand from the delta of Lakseelf, Kangerdluarsuk. Locally derived from the area of alkali rocks.

39. Beach sand from the Tupersuatsiak bend, Tunugdliarfik fjord. Like no. 38 locally derived from the area of alkali rocks.

40. Beach sand from Ipiutak, Tunugdliarfik fjord. Derived from the regional Quaternary, containing rocks from the Igaliko sandstone, the porphyritic group of the nepheline syenites and from the basement rocks.

41. River sand from the inner Tunugdliarfik fjord. The pebbles chiefly consist of gneiss, to a smaller extent of younger veins and nepheline syenites.

42. Delta sand from the delta east of the inner Tunugdliarfik fjord. The surrounding mountains consist of gneiss partially changed and intersected by many younger veins. In this zone hydrothermal minerals are found, such as fluorite, barite and pyrite.

43. Beach sand from the northern Kiagtut bend. Like no. 42, the surroundings consist of gneiss and younger veins. Along the southern bend nepheline syenite is found which probably furnishes hardly any minerals for this material.

44. Beach sand from Angmagsivik, between Kiagtut and Korok. From a delta in a steep valley cut into the nepheline syenite.

45. Beach sand near the promontory at the entrance to Tunuarmiut. From the disintegrated material from the slope. For the greater part derived from the alkali rocks.

46. Delta sand north of Siorarsuit. The sand comes from the alkali rocks of the Ilimausak mass.

47. Beach sand, bend near Igdlunguak. Like no. 46, but here porphyries also play a part.

5. Classification of the Material.

From the descriptions it appears at once that 2 main groups may be distinguished:

a. sands consisting exclusively of local detrital material,

b. sands in which moraine material plays an important part.

If, now, we consider the tables of the heavy fractions, it appears that both in the local sands and in those admixed with moraine material not only fairly great variations occur in the proportion heavy-light fraction, but also with regard to the relative proportions in the heavy fractions and in the light fractions. In other words it appears that all the sands at our disposal have a strongly local character, so that we cannot speak here of the idea "sedimentary petrological province". This idea, namely, was introduced into the regional sedimentary petrology which was developed and which is suitable for the large sedimentation basins

Table 1. Group of sands consisting of local material.

Number of sample	Light fraction in estimated amounts[1]													Heavy fraction in mutual percentages[2]															
	Percentage of		Quartz	Microcline	Orthoclase	Microperthite	Acid Plagioclase	Intermediate and Basic Plagioclase	Turbid Felspar	Eudialite	Nepheline	Sodalite	Biotite	Opaque	Ti-augite	Diopside	Aegirine	Arfvedsonite	Green Hornblende	Brown Hornblende	Aenigmatite	Olivine	Hypersthene	Epidote	Saussurite	Zircon	Apatite	Titanite	Garnet
	Light fraction	Heavy fraction																											
1	50	50	4	1	2		2	2					1	20	30	.	.	.	15	.		..	.	10	20			.	
10	90	10	3	1	2		2	2	1				2	25	30	..			25			10	.	.		.	5	.	.
13	50	50	2	1	1	4	1		2					5	5	35			40	.		5				.	5		
14	80	20						5					2	25	70				.			.	.				..	.	
15	25	75	3	1			1	3	2				2	75	20				.			..					.		
20	30	70	2		3		2	2	1				1	25	10	5			5	10		35			.	.	5		.
21	30	70	3		2	1	3	2	1				1	15	20	10			5	10		35	.	.			..		.
31	80	20	3	2	1		3						2	5					85	.		..	5		.			..	.
32	90	10	4	1	1		3	1					2	.	.				70			.		25	.	..	..	..	.
38	75	25	4	2	2		2		1	1			1	5	10	.	40	30		.		5	5	.	.	.	.	.	.
39	55	45		2	2		2			2	2	3	2		.		25	70				.				.	.		.
41	75	25	3	2	1		2	2	2				1	75	15	.			5			..	.	.		..	.	.	
42	85	15	4	2	2		2	1	1				1	10	10	20			30	.		..	15	.	5	.		5	.
43	90	10	3	1	3		2		2					5	10	5	.	.	35	10		10	10	.	10		..	.	.
44	85	15			3		2	1	4		1		1	.	.	5	40	30	.	20		.	.		.	.	..		.
45	65	35	3	1	1		1	1		1	1	1		.		.	45	25	.			.	.	15	10	.			.
46	85	15	2	1	2		2		2	1	2	1		5	5		40	40		5	..			..	..	.	.		
47	85	15					1		2	1	3	4		10	.		50	25			10	.			.				

[1]) 0—5% = 1, 5—25% = 2, 25—45% = 3, 45—75% = 4, 75—100% = 5.
[2]) . = < 5% occurring sporadically, .. = < 5% occurring regularly.

(lit. 1 and 7); as they do not occur in the examined area, we shall not speak of sand-provinces, but of *sand-types*. We may point out that our object was to trace the ever recurring minerals characteristic of the sand and that we did not especially look for the rare minerals such as rinkite, neptunite, schizolite, rosenbuschite, etc., which might undoubtedly be found in sands such as nos. 38, 39, and nos. 45—47. This would take much time, and, moreover, whether such minerals that may be expected are actually found or not would probably not give rise to any new interesting problems and it would have little to do with the object of the investigation.

a. Sands of chiefly local origin.

We may here expect mineral combinations that are in general an exact reflection of the petrology of the neighbouring areas. In sample 1 from Tunuarmiut (Ilimausak) ti-augite[1]) and green hornblende occur together (apart from epidote and saussurite which are little character-

[1]) In the future ti-augite will be used instead of titaniferous augite.

istic). The small amount of aegirine and arfvedsonite may be explained from the neighbouring alkali rocks. We must assume 2 local sand-types: the ti-augite comes from the diabase of the porphyritic formation, whereas the green hornblende cannot very well be explained from the immediately neighbouring rocks. For none of the alkali rocks of the Ilimausak mass nor the rocks of the porphyritic series from the Gardar formation contain ordinary hornblende except the foyaite and the augite-syenite, and these even little. Neither of these, however, occurs in the neighbourhood of the locality of sample 1, so that therefore it is most obvious to assume a small admixture of moraine material from the hinterland, where much Julianehaab granite is found in which green hornblende occurs as the chief dark element.

In the samples from the back of Tunugdliarfik fjord, e. g. nos. 41—44, diopside occurs besides green hornblende, so that the appearance of diopside in no. 1 may also testify to some admixed moraine. Pieces of Igaliko sandstone are numerous in this sample.

When we now take no. 13 from one of the Kitsigsut islands as an example of a local sand and when we pay attention to the composition of the heavy and the light fraction, we find that the most important components of this sand are microperthite, green hornblende and diopside. The green hornblende is explained by the "schlieren" of the syenite that are rich in amphibole and magnetite. As most important minerals of the syenite itself we find diopside and microperthite. The ti-augite is here probably connected with the diopside by transitions.

Numbers 14 and 15 from Sanerut and Ekaluit are both samples consisting of disintegration sand of diabase: the heavy fraction contains ore and the violet ti-augite. It is difficult to state why the first sample contains so much less heavy fraction than the second and why the proportions of ore and ti-augite in both are exactly the other way about. Remarkable also is the difference in the light fraction: no. 15 contains rather much quartz, whereas in no. 14 it was not found. This difference cannot be explained from the description of the localities. Further it may be stated that the diabase of no. 14 and no. 15 has furnished less olivine than for instance in the case of sample 10 for the Sermilitsialik fjord, in which a percentage of 10 was found. This greater olivine percentage of no. 10 might be explained by the presence of younger olivine bearing basic veins. The granite and migmatite that appear in the neighbourhood of the locality of sample 10 are responsible for the occurrence of green hornblende.

We skip no. 20 and no. 21 for the moment and first consider no. 31 and no. 32 from the Unartok fjord. They have high percentages of ordinary green hornblende. No. 31 is a disintegration sand of the younger granite so that for this granite we may assume the green hornblende by the side of biotite (see light fraction) as the most important dark mineral. The same holds for the migmatite from the surroundings of no. 32. Later on however we shall see that also the older granites (migmatite, Julianehaab granite) are rich in green hornblende. That moreover in no. 32 25 % epidote is found is not very important, because epidote cannot very well be used as a guide mineral.

In samples 20 and 21 from Kungnat we should likewise expect high percentages of hornblende, because the original rock in both cases is younger granite. We find for both 70 % heavy fraction and instead of hornblende, opaque minerals, ti-augite and olivine are found whereas the light fractions have 10—20 % intermediate + basic plagioclase. Evidently by the side of granites basic rocks play a part, e. g. diabase or essexite of which such combinations may be expected, so that granite minerals are even pushed on the background. An argument in favour of original granite material is the occurrence of a light green diopside which, as will appear later on, always remains restricted to the granite and syenite of the newer abyssal rocks. Fluorite and topaz which must occur in certain parts of the granite from the surroundings of no. 21 were not found.

The samples nos. 38, 39, 44—47 may be taken separately as they all come locally from the nepheline syenite areas, no. 44 from the Igaliko mass, the rest from the Ilimausak mass. As prevailing combination of minerals we find aegirine and arfvedsonite, further as accompanying minerals nepheline, sodalite and sometimes eudialite, all of them typical representatives of the nepheline syenites of these igneous bodies. Small pieces of red-brown Igaliko sandstone were sometimes also found, mainly in nos. 38, 45 and 47. They may come from rests of Igaliko sandstone occurring higher up in the mountains, or they may result from a small admixture of moraine material. With the aid of Ussing's work everybody can see that most minerals can be explained as representatives of local material. I may however point out the occurrence of 5 % hypersthene in no. 38. From the supply of local material hypersthene cannot be explained and it is nowhere mentioned by Ussing. Either rocks containing hypersthene must occur in the neighbourhood or some moraine material has been admixed. Diopside was found in no. 38, no. 44 and no. 45.

As regards no. 38, it may be explained locally from the augite-syenite of Kringlerne, in no. 44 and no. 45 according to Ussing's map no local supply of augite syenite can be assumed. Probably the diopside comes from some admixed moraine material from the Igaliko mass, where, as we shall see, the augite of the augite syenite often has a more diopside-like habitus than in the Ilimausak mass.

Finally, we may mention separately nos. 41—43 from the inner part of Tunugdliarfik fjord intersected by younger veins of which Ussing (lit.

15, p. 266) mentions: diabase, monzonite porphyry, augite syenite porphyry, hedrumite, nepheline porphyry, sölvsbergite (?), of which the augite syenite porphyry and the hedrumite are most numerous; for the greater part therefore intermediate veins of the nepheline syenitic magma. The augite syenite porphyry has, as a dark element, among others a grey-green augite that probably corresponds with the diopside-like augite we saw in the heavy fraction of no. 42 and no. 43. Brown hornblende seems to appear in the hedrumite, we see it e. g. in no. 43. As in no. 38 the hypersthene in nos. 41—43 cannot be explained from the data; it is not mentioned in Ussing's description. A closer examination of the spot will perhaps solve this problem.

In conclusion it may be said that most sands of this group do not yield any difficulties and may very well be considered as local material from the surrounding rocks except in samples no. 20 and no. 21, where the mineral composition does not correspond with what might be expected from the description. We saw that green hornblende is characteristic of the granitic rocks in general, diopside of the newer abyssal rocks, the ti-augite to a small extent of the syenite, mostly however of the basic veins, especially the diabase. A small admixture of moraine material must often be assumed in order to explain minerals, the appearance of which would otherwise be strange.

b. Group of sands in which moraine material plays an important part.

Passing on to the rest of the samples, we may take them together in a group that is characterized by the sands consisting to a greater or lesser extent of moraine material. They are the samples nos. 2—9, 11, 12, 16—19, 22—30, 33—37 and 40.

Their heavy fractions do not mutually correspond very much and we shall again try from the descriptions to find out, how far there are deviations or correspondences.

In the sands 2—9, 11 and 12 there appear in the heavy fraction as most important minerals opaque — augite — green hornblende and mostly epidote — saussurite. This combination is in accordance with the petrology of the supplying areas. The green hornblende may be explained from the appearance of granite and migmatite and opaque and ti-augite derive from the basic veins and the diabase.

In no. 12, from an area of younger granite and syenite, 45 % diopside is found besides 15 % ti-augite and 5 % green hornblende. Although it is not impossible that basic veins are responsible for the ti-augite, it is more probable to assume that, just as in sample 13, we have here to do with transition between ti-augite and diopside. Such transitions could also sometimes be stated by me. Thus we see that it appears more and more that the green diopside may be used as a guide mineral for the

Table 2. Group of sands in which moraine material plays an important part.

Number of sample	Light fraction in estimated amounts[1]													Heavy fraction in mutual percentages[2]															
	Percentage of Light fraction	Percentage of Heavy fraction	Quartz	Microcline	Orthoclase	Microperthite	Acid Plagioclase	Intermediate and Basic Plagioclase	Turbid Felspar	Eudialite	Nepheline	Sodalite	Biotite	Opaque	Ti-augite	Diopside	Aegirine	Arfvedsonite	Green Hornblende	Brown Hornblende	Aenigmatite	Olivine	Hypersthene	Epidote	Saussurite	Zircon	Apatite	Titanite	Garnet
2	80	20	3	2	2		3		2				1	10	5		.	5	45			.	.	10	5	5	..	10	
3	80	20	3	2	3		2		2				1	10	10		.	.	65	.		.	..	5	5	.	.	..	.
4	90	10	3		2		2		4					5	..			.	65				.	20	5	.	..	.	.
5	90	10	4		2		3		1					5	5				60					15	5	5		..	
6	80	20	4	1	2		3		2				1	5	5				50			.		10	15	.	.	.	10
7	90	10	4	1	2		2		1				1	.	5				90			.		.		.	.	.	
8	80	20	3	1	2		2		2					10	20				30			20	.	5	10	.	.	.	.
9	80	20	3		2		3		1					20	15				50	.		..	.	5		.	5	.	.
11	90	10	4	1	1		3	1	2				1	20	10				25			5		15	20		.	.	
12	90	10	3		2		3	2	1				1	25	15	45			5			..				.	5	.	.
16	90	10	3	1	2		2	1	2				1	35	20				35			..		5		.	.	.	
17	90	10	4	1	2		2	1	2				1	20	10	..			40			.		10	15	.			.
18	90	10	4		1		1	1	2				1	10	25				25				.	20	15		.	.	.
19	90	10	5	1	1		1	1	1				1	10	10				60			..		15		.	.	.	..
22	90	10	4		1		1	1	1				2	.	20				75			.		..	.		.	.	
23	90	10	4	1	2		2	2	1				1	5	25				45			5		10		5	.	.	..
24	90	10	4	1	2		2	2	2				2	15	5				75	.		..		.			..	.	
25	80	20	3	1	1		2	2	2					.	10				45			.	.	10	30		.		.
26	50	50	2	1	1		1	4	1				2	60	10				5			20		..			..		
27	45	55	3	1			1	4	2				1	.	10				10			..		5	70				
28	70	30	4	1	1		2		3					.	10				10			..		.	75			.	.
29	40	60	2	1	2		2	3	2					25	15				15			15	20	.	..		5	.	.
30	90	10	3	2	2		3	1	1				1	25	.				40				.	.	10	5	..	15	.
33	90	10	4	1	1		2	2	1				1	.	10	5			70				.	10	.	.	.	.	.
34	95	5	4	1	1		2	1	2				1	5	.	5			60	.		.	5	10	10	.		..	.
35	15	85	4	1	1		2	3	1				1	50		10				.			20			..	.	.	15
36	85	15	4	1	2		2	2						40		.			.				45	.		.	.	.	10
37	75	25	3	1	2		2	3	1					30		.			.	.			60		.		.		5
40	85	15	3	2	2		1	1	3					5	20	15	10	.	15	5		5	5	5	10	.	.	.	

[1]) 0—5 % = 1, 5—25 % = 2, 25—45 % = 3, 45—75 % = 4, 75—100 % = 5.
[2]) . = < 5 % occurring sporadically, .. = < 5 % occurring regularly.

intermediate newer abyssal rocks and especially for the syenite. As source of the material of no. 3 may be given Kakortok- and Igalikofjord, so that we may chiefly expect the elements of the Julianehaab granite in the sand; the heavy fraction actually contains 65 % green hornblende, moreover aegirine and arfvedsonite are to be expected in small quantities, which could also be stated.

The diabase which we already saw in nos. 14 and 15 as suppliers of opaque minerals and ti-augite have influenced the composition of nos. 8 and 9. These 2 samples clearly have a higher percentage of the 2 minerals mentioned than the rest, while at the same time olivine is found in them (especially in no. 8). Finally in nos. 8 and 9 small pieces of Igaliko sandstone were found, which is to be expected, because the sandstone seems partly to be a supplying area of these sands (see description).

In sample no. 6 we may mention as a peculiarity a content of 10 % garnet which, as we shall also see later on, probably derives from the gneiss. The garnet shows here a decidedly idiomorphic habitus, chiefly $\{211\}$ combined with $\{110\}$, of which $\{211\}$ prevails over $\{110\}$. With some restriction this idiomorphic habitus of the garnets may count as an argument for the local character of the moraine. It is striking that in the light fraction nowhere clean basic plagioclase was observed. Probably it must be found among the indeterminable turbid felspars.

In this series of samples may also be mentioned no. 40 from Tunugdliarfik-fjord, where the moraine contains aegirine and some arfvedsonite which must have come from the Igaliko mass. Pieces of Igaliko sandstone can also very well be explained locally in the moraine, likewise ti-augite and olivine from the porphyries. For the first time we see hypersthene appear considerably. We shall presently come back to the hypersthene question in general. Later we shall find hypersthene in other samples in still greater percentages. Finally 15 % diopside was found in the heavy fraction. We saw that diopside-like augite occurs much in the local material of the younger veins of the inner Tunugdliarfik fjord, so the appearance of it in the moraine that has come from the hinterland need not surprise us.

The samples 16—19 from the Ivigtut fjord show few differences as regards the heavy fractions; opaque, ti-augite, green hornblende, epidote and saussurite are again the typical components, in accordance with the occurring rocks, namely older granite, migmatite, gneiss and basic veins.

In no. 16 no minerals of the neighbouring nepheline syenite of Ivigtut were found.

In no. 17 of which the moraine must contain metamorphic rocks, metamorphic minerals were not found in the sand.

Next come the sands 22—28, likewise all from the neighbourhood of Ivigtut. They do not at all show the same composition; the content of ore varies from some percents to 60 %, green hornblende from 5—75 %, olivine from very little to 20 %; saussurite is only found in 3 sands, but in large quantities.

In no. 22 from the Arpagfik fjord 20 % ti-augite is found and 75 % green hornblende. This corresponds with the description, which gives migmatite and younger basic veins. In the light fraction mostly quartz and some biotite are found, to which may be added that naturally in the light fraction relatively more of the intermediate than of the basic rock is present.

No. 23 near Arsuk does not so much correspond with the surroundings, 25 % ti-augite can here again hardly be explained, if we do not assume that basic veins in the surroundings are found. A still stronger proof for this is the basic felspar in the light fraction.

No. 24 and no. 26 both from Ivigtut come from 2 similar deltas; it may already be seen macroscopically (no. 24 has 10 % heavy fraction, no. 26 even 50 %) that the compositions must differ considerably. The description of no. 24 mentions only moraine material with some nepheline syenite blocks. It is therefore difficult to judge how far the 75 % green hornblende corresponds with the surrounding rocks.

No. 26 lies closer than no. 24 to the Ika fjord, where, besides nepheline syenite and migmatite, also many basic veins are found. This explains the shifting of the composing minerals with regard to no. 24 in the direction opaque — olivine — basic plagioclase.

Nos. 25, 27 and 28, the first two from the Arsuk island, no. 28 from Arsuk Storö, may at first sight be compared together as regards the heavy fraction. It will be seen that the comparison holds good only partly. All three samples show a high percentage of saussurite, respectively 30, 70 and 75 %. The saussurite is however macroscopically and microscopically not the same in the three samples, which becomes sufficiently clear, when we take into consideration the fact that the greenstones in different horizons are differently metamorphic and will therefore show mineralogically great variations.

In no. 25 the saussurite consists of green turbid rounded grains which are all about the same and contain fine epidote-aggregates. This saussurite can easily be explained from the local greenstones. The diabase veins will have furnished the 10 % ti-augite and the 45 % green hornblende may perhaps be better explained from the hinterland where rocks rich in hornblende must occur, as is shown by the composition of the sands 16, 17, 24. This would be in accordance with the description which calls the material largely erratic. The same cannot be said of no. 27 with 70 % saussurite, which contains here very little epidote-like matter and very much chlorite- and serpentine-like matter and which moreover consists of schist-like sharp-edged fragments only to be explained from local material. So the greenstones have here had another composition than in the places where the material of no. 25 came from. The light fraction contains much basic plagioclase in accordance with the basic material. The small quantity of ti-augite can again be explained from the diabase veins.

No. 28 contains as saussurite-element partly the saussurite of no. 25, partly that of no. 27, so that we must here assume a mixture of two kinds of material. The material may have come from the hinterland or it may have a local origin from the greenstones which crop out on Arsuk Storö.

Finally, a number of sands between the Igaliko fjord and Frederiksdal must now be discussed, namely nos. 29, 30 and 33—37. They are again distinguished by greatly varying compositions in the heavy fraction, but also in their proportions light fraction — heavy fraction.

In no. 29 near Lichtenau the appearance of a considerable percentage of hypersthene is striking. Apart from a large quantity of ore this mineral is probably the most important element of the ultrabasic rocks, which, according to the description, are to be found in the area from which the Quaternary comes. The Quaternary is therefore very local, but further confirmation of this occurrence of hypersthene is desirable; see also the geological map in lit. 2, p. 123, where near Lichtenau an occurrence of gabbro is given but the descriptions of which does not mention hypersthene. The other elements all come from basic rocks which frequently occur in the locality of the area. In the light fraction 30 % basic plagioclase is found which has the characteristic "Bestäubung" of gabbroid rocks. This gives the grains a dullgrey lustre that is clearly visible when slightly magnified.

In nos. 33 and 34 the influence of younger granite is seen. How much of the 60 % green hornblende in no. 34 must be ascribed to the older granite and how much to the younger is difficult to decide. The same is more or less the case with no. 33 and perhaps also with no. 32 (here younger granite is not given, only younger veins).

All 3 sands have in common much light fraction, little heavy fraction in which is much hornblende and a lack of a larger quantity of minerals that point to basic rocks. Whether therefore the moraine from the Unartok fjord contains little or no local material, does not matter, but it may be said that the basic rocks in this area are of little importance and that older or younger granites rich in hornblende will have furnished the material. We may point out the occurrence of diopside in nos. 33 and 34 which here too, as before, is found where younger granite and syenite play a part. An entirely different combination of minerals is seen in the 3 samples nos. 35—37 from the surroundings of Frederiksdal in which the combination garnet-hypersthene so interesting to the sediment-petrologist appears among the transparent heavy minerals. The garnet can in all three cases easily be explained from the migmatites which probably still contain garnet in the neighbourhood, although this is only given for the migmatite in no. 35. Older granite and gneiss containing garnet are indeed very common in South and East Greenland. Already Giesecke (lit. 8 cf. the following dates: 23, 26, 27, 30 July and 6 Aug. 1806), mentions this of several places (coast of Nanortalik, Staatenhuk, the isle of Ikariut, Cap Farvel). According to Vrba (lit. 16 p. 95) the garnets in the granite near Prins Christiansund may even attain the size of a fist, see also Eberlin who describes gneiss containing garnet between Umanak on the east coast up to about 61° N. Lat. on the west coast (lit. 5, p. 386). Hypersthene will also have its origin in gabbroid rocks as in no. 29. This is confirmed by Törnebohm (lit. 13, p. 431) who describes gabbro from Frederiksdal with chiefly hypersthene and diallage, further red-brown mica, apatite and titaniferous iron. We shall presently come back to the question of hypersthene. Gabbro is not mentioned in the above sample-descriptions, younger granite is. This younger granite could not have much influence because of the large quantity of migmatite and gabbro and it manifests itself perhaps only in the light fraction, in which fairly large total quantities of quartz, orthoclase and acid plagioclase are found. So here too the moraine may be explained locally, although the composition that is found cannot be expected from the descriptions.

Summing up, we arrive here too at the conclusion that the sands may generally be explained locally, if not here by fluviatile or local disintegration material, but by moraine. Only for some cases, such as no. 24 and no. 25, where the material cannot be explained directly from the surroundings, regional material is not excluded. In by far the most cases however we conclude to local moraine. In this group, just as in the first, great variations are found of the heavy minerals (e. g. green hornblende, hypersthene, garnet, saussurite!), which would be difficult to explain for regional moraines.

6. Observations on the Minerals.

We now pass on to some particulars of the discussed minerals in general.

Quartz. Angular or rounded grains with or without iron films; sometimes, as in no. 32, wedge-like to thin plate-like fragments were found, which are sometimes faintly curved. Hitherto these forms of detrital quartz were never before found by the present writer in non-Greenlandish sands. In some cases quartz has inclusions of a kind of hornblende and macroscopically it then resembles sodalite (samples no. 3, no. 22).

Felspar. Often easily recognisable by the excellent cleavage. Strikingly red are the orthoclase and perthite in the samples nos. 41—44, especially in no. 44. Microcline is sometimes waterclear. Typical gabbro-plagioclase with dust-like inclusions occurs in no. 29 easily visible when slightly magnified. The microperthite of no. 14 is macroscopically bluish-grey and has a vitreous lustre. Under the microscope very fine fairly regular perthitic intergrowth may be observed.

Nepheline. It appeared that nepheline as grains in the sand could macroscopically not be distinguished from felspar. The determination of the percentage in a sand had to be obtained entirely microscopically. The grains then seldom appeared to be still clean, mostly they have a turbid habitus owing to zeolitisation, so that a definite determination becomes difficult. In general they could only be definitely distinguished from quartz and felspar by means of the FEDOROW-apparatus UT 2.

Sodalite. Always light green. An easily recognisable mineral, at least if confusion with quartz with hornblende inclusions is impossible. The green colour is here caused by included minute aegirine needles.

Eudialite. Macroscopically grains of this mineral are striking owing to a decidedly pink to pink-brown colour and irregular conchoidal fracture. Idiomorphic grains were found only seldom. Once in no. 38 the rhomboedric form described by FLINK (lit. 4, p. 494) was found. Although it is usually uniaxial, occasionally a biaxial character was observed with a small angle of the optic axes. In some cases an optically negative character was stated (Eukolite). The pleochroism is as a rule distinct (ε = pink, ω = yellow), but it was also found that in some cases, e. g. in no. 39, ω almost shows the same pink of ε. The reverse, that ε assumes more or less the same colour of ω, was stated in far fewer cases. In other individuals again a distinct colour is hardly recognisable; at the same time dust-like inclusions lying parallel are then found. Finally in some eudialites in no. 45 anomalous (violet and brown) polarisation colours were found. This may be the result of the fact that the birefringence is no longer the same for all colours. Can this perhaps be brought in connection with the occasional local positive and negative character in one and the same mineral described by RAMSAY (lit. 11, p. 42)?

Titaniferous augite. In larger individuals it is macroscopically as a rule pitchblack and intransparent; in thin splinters it has a conchoidal fracture and is then transparent with amethyst colour. Faint pleochroism: γ = greyish-violet, α and β pinkish violet. The average R. I. is 1.710. This violet ti-augite seems to be widely spread on Greenland. BELOWSKY (lit. 3, p. 66) also mentions it in diabase from Karajak-Nunatak (West-Greenland). A dispersion of the bisectrices on (010) was never observed. The extinction is always perfect. A confirmation of this remarkable exceptional phenomenon for ti-augite I have not yet found in the literature. Linear metallic inclusions parallel to the chief morphological directions frequently occur. They were also observed in:

Diopside. It is connected with the ti-augite by transitions. These transitions were always found in sands of syenitic origin (no. 12 and no. 13). The R. I. of diopside however is distinctly lower. No. 17 contains a malacolite-like diopside; small xenomorphic grains which are waterclear and have a bright green colour with for the rest diopside-like character. Perhaps they come from calc-silicate-hornfels, the occurrence of which in the surroundings is however nowhere mentioned. Calcareous and dolomitic inclusions in crystalline schists from western North Greenland are described by BELOWSKY (lit. 3, p. 51). Thus here too the malacolite might be an indication of analogous calcareous inclusions in the crystalline schists.

Aegirine and *Arfvedsonite.* They are in accordance with the already known data of these minerals. In thin columns aegirine is macroscopically easily recognisable by its grass-green colour. In thicker individuals it can at first sight not be distinguished from arfvedsonite or ti-augite. Only little aegirine-augite was found.

Aenigmatite, which frequently occurs only in no. 47, is fairly easily recognisable under the binocular by ruddy glittering cleavage-planes and irregular forms.

Green hornblende is very common and has the ordinary pleochroitic colours, sometimes however with a strongly bluish tint, e. g. in nos. 18, 19, 23 and 24.

Brown hornblende, with positive elongation, has a barkevikitic to basaltic habitus (extinction angle 7—8°, with a maximum of 14°).

Glaucophane-like hornblende was found in no. 17, with an average R. I. of 1.640, which showed an exceedingly dispersion of the bisectrices, such as the author has never before found in hornblende or augite. Extinction could not be obtained in any position in the FEDOROW-apparatus; on the other hand the appearance of anomalous interference colours was observed. Moreover a distinct zonal structure was found. Perhaps this hornblende corresponds with the riebeckite from Igaliko described by USSING (lit. 14). Now according to USSING its dispersion of the bisectrices is smaller than in arfvedsonite. This is however certainly not the case here.

Crocidolite with the same pleochroism as glaucophane, but with negative elongation and small extinction angle, was found in no. 24 and no. 32. In some cases a distinct stage of transition between ordinary hornblende and crocidolite could be observed in one and the same individual.

Hypersthene has a general distribution in the examined area. Its origin must be found in gabbroid rocks (see nos. 35—37), which probably have a wider distribution in South Greenland than would appear from the data at my disposal. Thus e. g. its appearance in no. 38 and no. 45 where only extreme alkali rocks were found is difficult to explain. The Fe-content is high, to judge from the striking pleochroism: orangepink-green. In no. 36 the hypersthene often contains the parallel diallage lamellae which also Törnebohm has already observed (lit. 13 p. 439). Schiller-structure is very general.

Olivine is macroscopically difficult to recognise in the sand. Owing to the ever present iron films on the cleavage planes it is probably rich in iron. The optic angle is as a rule relatively small with negative birefringence. The average R. I. was found higher than 1.740. These facts point to a fayalitic olivine.

Epidote and *Saussurite* did not offer any new particulars. It is striking that zoisite and klinozoisite with anomalous polarisation colours were practically never found.

Piedmontite was observed in no. 3 with beautiful pleochroism from wine-red to light-orange. In the Mineralogia Groenlandica this mineral is not yet mentioned, neither did I find it described in the newer literature.

Chromite was found once in no. 9 and is mentioned in the Mineralogia Groenlandica as an accessory mineral of the syenite of the Kitsigsut islands.

Titanite is a frequently occurring mineral, which however shows higher percentages in only a few sands (no. 2, no. 30). Where the titanite is idiomorphic the envelope form was always found, which points to an origin from eruptive rocks. As the titanite is not known from the area of the alkali rocks and is therefore lacking in the nepheline syenite, it will probably come from the granite. The occurrence preferably together with green hornblende is corroborated by the table. If no crystal-planes are present, a macroscopical distinction from hypersthene sometimes becomes difficult.

Microscopically the brown variety was nearly always observed, rarely the colourless.

Astrophyllite. This remarkable mineral, never before observed in sands by the author, macroscopically somewhat resembles biotite, but under the binocular it has a clearer slightly copper-like lustre and was found in no. 39 and no. 47 as a covering of light minerals. Pressed between two slides mica-like fragile (100) cleavage planes are easily separated. They have a straight extinction and contain the optic symmetry axes β and γ.

It was found that β = orange-yellow
γ = light yellow.

The data about the pleochroism of astrophyllite are widely divergent in the various handbooks. Thus Larsen gives β = yellow
γ = orange.

The red-orange colour of α can in cleavage planes only be seen with the aid of the Fedorow apparatus. The average R. I. is 1.720. Astrophyllite cannot easily be dissolved in strong nitric- and hydrochloric acid, which is in contrast to the data given in some handbooks.

Zircon is always idiomorphic and often has a pink colour.

Biotite is very common, varies in colour from brown to green and always has a small optic angle. As regards its spec. weight it belongs to the heavy fraction but gets into the light fraction owing to its tendency to floating.

Muscovite was rarely found.

Fluorite was observed in the preparations of nos. 2, 39, 46 and 47 and could be recognised not only from its relief and isotropic character but also from irregularly distributed violet patches.

Tourmaline, *rutile* as well as the parametamorphic minerals *andalusite*, *kyanite* and *sillimanite* were found only rarely, *staurolite* not at all.

7. Conclusions.

We shall now sum up our results and try to find out how far the above questions (p. 6) have been answered.

1. The first question was whether further information could be given about the newer abyssal rocks. It is quite clear from the composition of the examined sand samples that the newer abyssal rocks must not be considered to the extreme side of the natronsuit of the alkali series, therefore not at all to those rocks of which $alk > al$. Except in those cases in which small percentages of aerigine and arfvedsonite coming from the nepheline syenite area of Ilimausak were found in the moraine material, these minerals are entirely lacking in the other sands. If among the younger granite and syenite there had been representatives of the extreme side of the natronsuit, they would have been shown by aegirine and arfvedsonite in the sand. On the contrary in the local sands of the newer abyssal rocks the combination diopside — titaniferous-augite is often found. The ti-augite however points to alkali rocks, so that as to their belonging to a magmatype there remain according to the data at our disposal 2 possibilities, either the younger abyssal rocks belong to the natronsuit but have $alk < al$, so that natron pyroxenes and natron amphiboles do not appear, or they belong to the potassiumsuit of NIGGLI (lit. 9). The general occurrence of ti-augite would rather point to the natronsuit. According to written information by Dr. C. E. WEGMANN however the younger granite and syenite, as the latest examinations have shown, are partly to be compared with the Rapakiwi rocks in Finland and Sweden, partly with, among others, the Obnäs and Onasgranite of J. J. SEDERHOLM (lit. 12). Now these two kinds of granite belong to the potassiumsuit. The Rapakiwi rocks from Finland and Sweden have a k of 0.40—0.60, the Obnäsgranite has a k of 0.64, so that

these data together with the results of the present writer are indeed strong arguments in favour of the assumption that the newer abyssal rocks belong to the potassiumsuit of the alkali rocks.

Another question which presents itself in connection with the study of the mineral composition of the sands is that of *hypersthene*, especially with regard to the samples nos. 35—37 (cf. p. 25) which all come from the neighbourhood of Frederiksdal[1]). Now Ussing's map (lit. 15) gives here younger granite and syenite (so at any rate newer abyssal rocks), but the older petrologist Törnebohm (lit. 13 p. 439) found here gabbro with as chief elements plagioclase, hypersthene, diallage and redbrown mica, as accessory minerals apatite and titaniferous-iron (so certainly a rock of the calc-alkali series). With a view to the high percentages of hypersthene it seems to me without any doubt that it is at any rate a gabbroid rock which furnished this mineral and that we have not to do here with a rock of the atlantic series, as Ussing's map would suggest. The occurrence of hypersthene could in that case not very well be explained, as in general the basic abyssal rocks of the alkali series have a proportionally lower percentage of SiO_2 than the corresponding rocks of the calc-alkali series. So, instead of hypersthene, olivine would be expected. It is therefore more probable that we have here to do with a local occurrence of hyperite or norite of a calc-alkali-magma. This was corroborated by written information from Dr. C. E. Wegmann. According to this investigator, namely, basic rocks of the Sermilik series occur in the hinterland of Frederiksdal (Kingua valley). They are probably the same rocks as those described by Törnebohm.

It appears that such hypersthene rocks must occur more often in the examined area, as the table shows that hypersthene is found fairly regularly in small amounts. It is not impossible that the gneiss or Julianehaab granite locally contain hypersthene, but in accordance with the above case it must be considered probable that hitherto unknown outcrops of gabbroid rocks prove to be the suppliers of hypersthene. It is very well possible that the occurrence of gabbro near Lichtenau, where the sand no. 29 with 20 % hypersthene comes from, is a similar magma to that of Frederiksdal. As in general hypersthene is hardly ever mentioned in this area a further investigation into this question is desirable.

It may also be recommended to make a closer examination of the rocks rich in titanite which must have furnished the titanite in samples no. 2 and no. 30, respectively with 10 % and 15 %. From the available literature it appears that titanite does not occur in the extreme alkali rocks from Ilimausak.

As to the older basic veins, which have furnished material in many samples, it can only be said that they are all characterized by violet ti-

[1]) See Fig. 4.

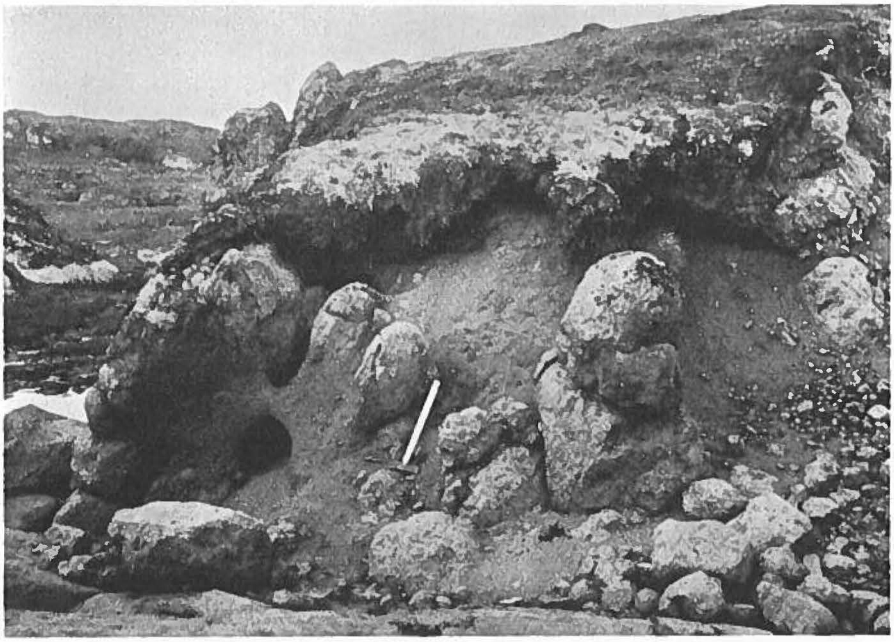

Fig. 1. Disintegrating diabase. Ipsen Harbour, Kerrortusok. July 2, 1936. (WEGMANN phot.).

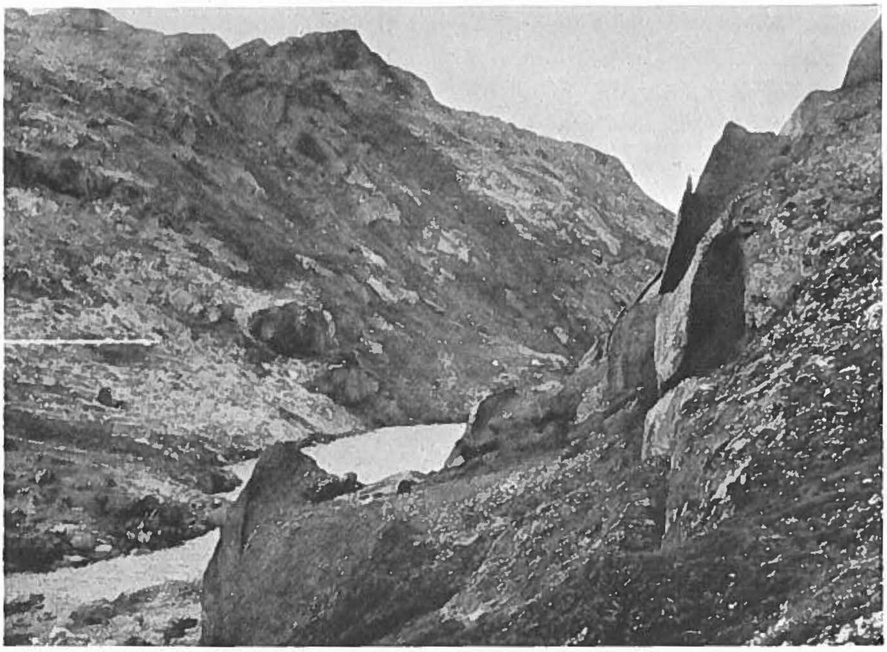

Fig. 2. Disintegrating younger granite near Helene Harbour, Nunarsuit. July 9, 1936. (WEGMANN phot.).

augite, so that it must be considered probable that they belong to the natronsuit of the alkali series. They come perhaps from the same magma as the trachydolerites and alkalitrachytes which rest on the Igaliko sandstone.

In general we find in most sands the mixture of 2 local sand types, that of the basic veins characterized by the occurrence of ti-augite, and that of the granitic rocks either of the calc-alkali series (Julianehaab granite) or of the alkali series (newer abyssal rocks) with distinctly green hornblende and with or without diopside. It may be pointed out that, as the green hornblende is common where migmatites and Julianehaab granite are found, it must be characteristic for all stages of migmatitisation in the Ketilides.

Finally it must be observed that many minerals that are characteristic or have a general distribution in numerous non-Greenlandish sands, e. g. those of the Netherlands, occur here sporadically or are lacking. They are *rutile*, *tourmaline*, *zoisite*, *clinozoisite*, *andalusite*, *kyanite*, *sillimanite* and *staurolite*. Rutile and tourmaline were each found only twice, zoisite and clinozoisite were entirely lacking, while the rest, which consists of parametamorphic minerals, was likewise found rarely; andalusite occurred most of these, sillimanite three times, kyanite once and staurolite not at all.

Any definite conclusions cannot be drawn from this, owing to the local character of the sands and the fact that metamorphic rocks, as regards their share in the sands, play only a relatively slight part. Yet it would be interesting in future investigations to pay attention to sands consisting of schist- and gneiss material, in order to find something about the division of para- and orthometamorphic rocks.

2. The reader will have noticed that the second question, whether more than the three known nepheline syenite areas could be traced, has already been dealt with in the above conclusion. For the present the answer to this question must be negative. It is to be expected that with a more systematical and more regional examination such nepheline-syenite areas may yet be found. We find indications for their occurrence in East-Greenland in NORDENSKIÖLD (lit. 10, p. 208): "We have here probably a strongly differentiated effusive analogy of the aegirine-syenite from C. PARRY, described by BÄCKSTRÖM. A block of aegirine syenite was found also inside Scoresby Sund. Similar rocks seem to occur in several areas along this coast". It must however be observed that these nepheline syenites are much younger, namely Mesozoic or Tertiary (WAGER, 1934, 1935, M. o. G. 105, No. 2, 3).

3. Finally, the third question as to the nature of the moraine is closely connected with what has already been discussed and the answer to it has been anticipated a few times. It appeared namely that practically

Fig. 3. Disintegrating granite near Helene Harbour, Nunarsuit. July 10, 1936. (WEGMANN phot.).

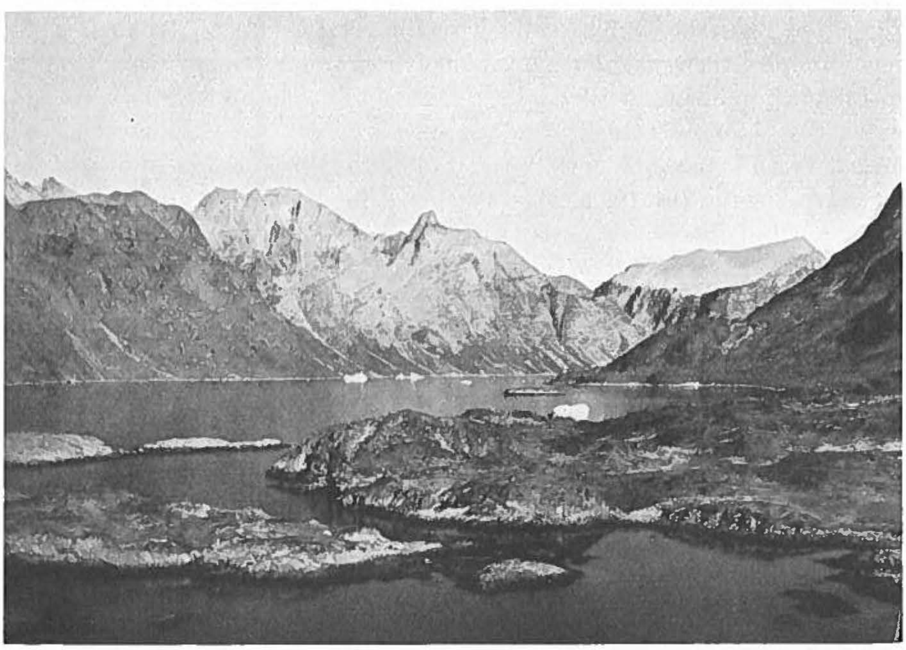

Fig. 4. Petrological situation in the neighbourhood of Frederiksdal. September 1, 1936. (WEGMANN phot.).
Looking north from Frederiksdal; the dark rocks in the foreground and on either side are younger granites and syenites; the light-coloured rocks in the background are the migmatites of the Ketilides.

all sands, not only the not quite local sands, but also those consisting of moraine material, can be explained from the petrology of the neighbouring rocks. An argument in favour of this is not only the analogy between sand and local rock, but also the fact that most sands consist of angular grains that are often still beautifully idiomorphic. A long transport under the ice is hardly compatible with the facts just mentioned. A regional moraine with a mineralogical composition constant over extensive areas and with less angular grains such as are found e. g. in the Netherlands and Germany is here entirely lacking. The explanation of this seems to lie in the fact that the regional moraines in the Pleistocene have come to be deposited much farther off the coast of Greenland, so mostly under the sea. In the course of the Holocene, when the ice withdrew and a zone of land came free along the coast, while more and more mountains emerged from the ice, the mechanical disintegration of the free rocks by means of alternate freezing and insolation could prevail over the erosion on the bottom of the glacier. Thus via lateral moraine more material from above than from under the ice could eventually get into the terminal moraine. In general it may be said that, as it is here a question of relatively short distances of transport by the glacier, the ice will have more scouring and crunching effect on the hard rockbed of granites and migmatites, whereas it is chiefly the easily disintegrating younger diabases and granites[1]) that are transported as waste and are thus represented relatively much stronger in the sand than would be expected on account of their distribution in the older granites. That the mechanical disintegration owing to alternate freezing and insolation is not slight and especially strongly attacks the younger eruptiva with their miarolitic structure and easy tendency to disintegration, becomes clear, when we compare Ussing (lit. 15, p. 24): "*The newer abyssal rocks are subjected to mechanical disintegration on the largest scale. The occurrence of numerous large screes, with heights of many hundreds of meters, is a characteristic feature in the scenery of the newer abyssal rocks*" and a little further down: "*The more gentle slopes, with inclinations varying from a few degrees to 20° or 30° are real streams of stones sometimes several kilometers in breadth*". So it will be clear that the regional moraines could with difficulty maintain themselves when, after the withdrawal of the ice, situations arose like those described above. The present author therefore thinks that the regional moraine could assert itself too little in the examined moraine sands, so that they are a reflexion in the first place of the easily disintegrating newer abyssal rocks and diabasic veins, the material of which during the regression of the ice eventually came into the local moraines via talus and to a far less degree of the older granite and migmatite. Possibly an examination of sand samples from the sea floor along the

[1]) See Fig. 1, 2 and 3.

coast will sooner give us an idea of the regional moraine and perhaps more uniform sedimentary petrological provinces coming from the areas nowadays covered by inland-ice will then come to light.

For the rest much more difficult questions are connected with the problem of sand transport by the ice and it would perhaps be interesting to compare the above-mentioned phenomena in South Greenland with analogous Fennoscandian Quaternary problems.

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April 1937.

Geological Laboratory of the Agricultural University,
Wageningen, Holland.

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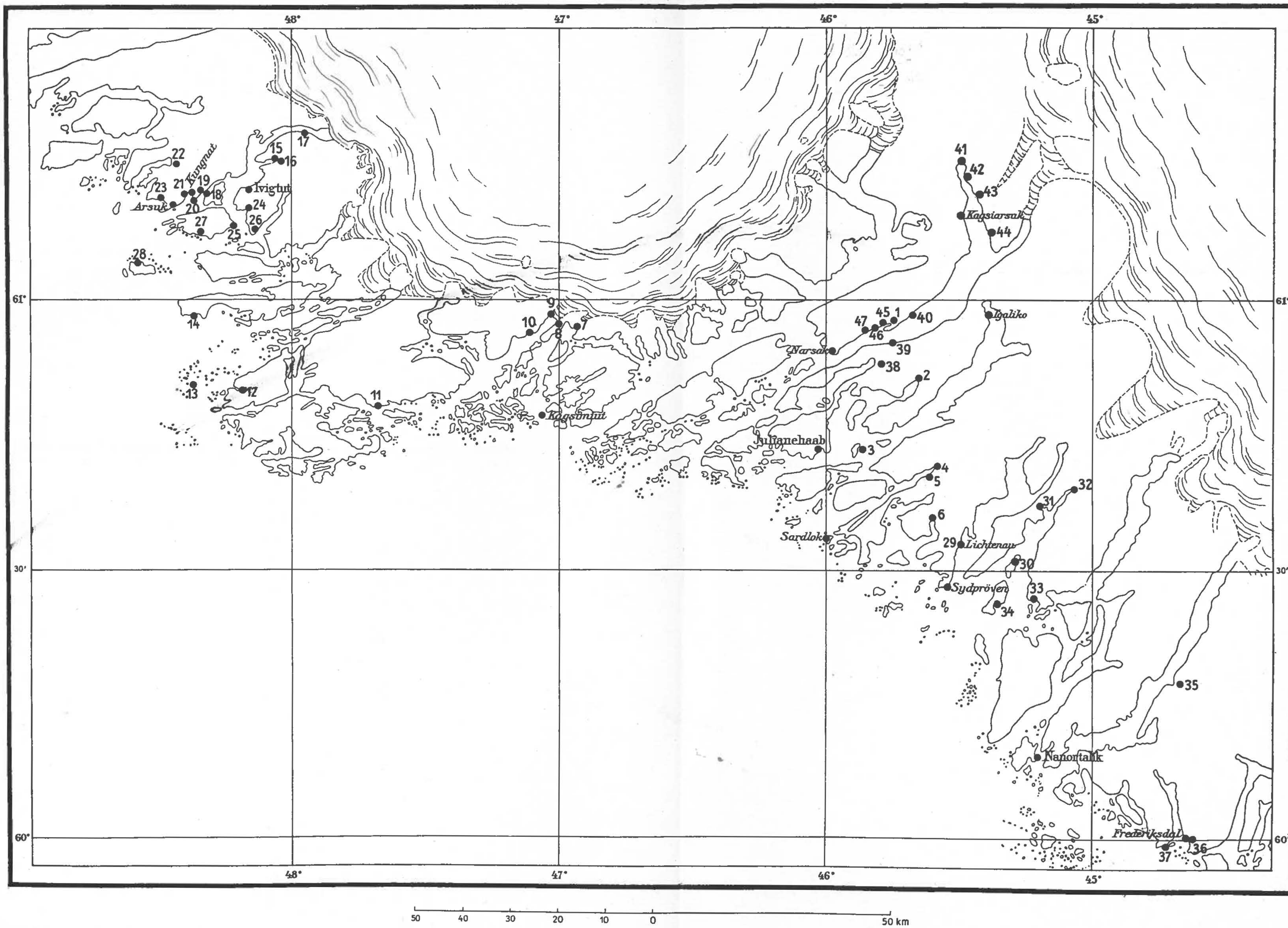

Map shoving the distribution of the sand samples in the area investigated.