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Review of the work on

The Precambrian Basement (Pre-Gardar) between Kobberminebugt and Frederiksdal, South Greenland

by

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with 1 figure, 5 tables and 2 maps

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I. INTRODUCTION

The course of the field work

The systematic geological mapping in South Greenland under the auspices of Grønlands Geologiske Undersøgelse started in 1956. The Ivigtut region was mapped in the first three years. From 1958 to 1960 a new group mapped part of the so-called Julianehåb granite in an area between Kobberminebugt and Igaliko fjord, to the south-east of the Ivigtut area. In 1961 the work was continued in the area south of Igaliko fjord as far as Frederiksdal and completed in 1963. In the Ivigtut region, as well as in the Julianehåb area, after the large groups left a few geologists continued work for one or two summers to study special problems. In this paper no results from the Ivigtut region will be described, only the different possible interpretations will be mentioned to give a comprehensible background for the treatment of the areas to the south-east.

Sincere thanks are due to Mr. K. Ellitsgaard-Rasmussen, Mag. Scient., Director of the Survey, who has given so much of his time to the practical aspects of the direction of the organisation, and has created an atmosphere in which it is possible to carry out scientific investigations with free discussion of a wide variety of view points. The author is grateful to all GGU workers for discussion and their kind cooperation, in particular T. C. R. Pulvertaft.

Development of the general ideas

Chronology of the Ivigtut area

Wegmann (1938, 1939, 1948) distinguished three, what he called, cycles in South Greenland, i. e. pre-Ketilidian, Ketilidian and Gardar. The first one appeared as gneisses (along Arsuk fjord), at least partly reactivated during the Ketilidian, and as pebbles of granite and gneiss in conglomerates of supracrustals of Ketilidian age. The second one showed up as supracrustals and also as gneisses and granites and represented a complete geological cycle. The last one was a period of sedimentation, volcanism, faulting and intrusion of alkaline rocks without plutonism (in the sense of Read, 1957).

With this background the main problem of the team mapping in the

Ivigtut area was to decide "whether the gneisses and migmatites ("Ivigtut gneisses") wholly or partly, represent reworked, original pre-Ketilidian basement rocks or whether they have been formed exclusively from formerly supracrustal Ketilidian rocks" (Berthelsen, 1960, p. 153). After the main mapping in the Ivigtut area Berthelsen favoured the interpretation that both the gneisses and supracrustals were part of the Ketilidian mountain chain, the separation of the supra- from the infrastructure having taken place during the orogeny. Thus Wegmann's suggestion (1939, p. 205) that the contact between infra- and suprastructure could well correspond to an old erosion surface was more or less dismissed. The main argument was that there were no traces of an unconformity either between the supracrustals and the gneisses or deeper in the gneiss series itself.

Another very interesting result was the discovery of the so-called Kuanitic dykes (Bondesen and Henriksen, in press), true metadolerites typically developed near the Kuánit fjord north of Ivigtut, of which five generations could be distinguished. Some of the dykes seem to continue to Ivigtut and farther to the south-east where they are migmatised and disrupted as a result of plutonic activity after the Ketilidian period. Berthelsen thus distinguished two periods of plutonic activity in the Ivigtut area, i. e. the Ketilidian period (the same as Wegmann's) and a younger one which is called the Sanerutian period. He admitted however that in the Ivigtut gneisses "the possibility of intercalations of wedges or slices of pre-Ketilidian rocks cannot be completely excluded" (op. cit. p. 157).

The work in Grænseland

In Grænseland, north-east of Ivigtut, a detailed study was made of an occurrence of Ketilidian supracrustals and their relations to the adjacent gneisses (Ivigtut gneisses) by Bondesen (1962). He collected conclusive evidence that there the almost unmetamorphosed supracrustals were lying unconformibly on the nebulitic gneisses and that this unconformity was truly basal thus separating two tectonic units of different ages. The gneisses therefore belong to an older, i. e. pre-Ketilidian, cycle. In total eventually three plutonic episodes could thus be distinguished in the Ivigtut area before the beginning of the Gardar.

These results from Grænseland started a tremendous argument about the distribution of the pre-Ketilidian basement in the Ivigtut area. Berthelsen (1962, text-table 7) only considers the presence of a relatively small

wedge necessary while the opposing group, consisting mainly of workers who have not mapped in the Ivigtut area, suggests that a relatively large part of the Ivigtut gneisses, i. e. north and east of Ivigtut, where the Kuanitic dykes are typically developed, could represent old basement. It has not yet been possible for either of the groups to produce conclusive evidence disproving one of the possibilities. This disagreement resulted in two different interpretations about the plutonic development of the Ivigtut area. The difference concerns the age of the Ivigtut gneisses and the Kuanitic dykes relative to the Ketilidian supracrustals. Berthelsen considers the Ivigtut gneisses and the Ketilidian supracrustals as belonging to the same cycle as is indicated under Ivigtut B in tables III and IV. The group of workers on the Julianehåb granite suggests the interpretation indicated as Ivigtut A in tables I and II in which most of the Ivigtut gneisses are considered to be older than the Ketilidian supracrustals and at least some of the Kuanitic dykes as possible feeders of the Ketilidian volcanic supracrustals. Further discussion of this problem is given by Watterson (in press), Bridgwater (in press) and Berthelsen (in Rankama, in press).

The work in the Julianehåb granite (DA chronology)

In the Ilordleq area, south of Kobberminebugt, Watterson (in press) showed that three periods of intrusion of basic dykes, earlier than the Gardar, could be distinguished which were separated from each other by plutonic episodes during which the basic intrusive bodies were metamorphosed, granitised and also deformed. These have been called discordant amphibolites (DA), for definition see p. 7. It has also been possible to show that this chronology could be applied on a regional scale (Allaart, in prep., Persoz, in prep., Windley, 1963). In this way it became clear that the episode between the first and the second period of intrusion represented a major event comparable with the main plutonic phase of an orogeny. This need not be the case with the plutonic episode between the second and the third period of dyke intrusion as was pointed out by Bridgwater and Walton (1964). The chronology thus established is presented in the central columns of tables I to IV.

The work in the Julianehåb area thus resulted in an improvement of the basic dyke method as originally developed by Sederholm (1923, 1926 and 1934). Watterson (in press) showed that it is possible to distinguish systematically, basic dykes directly derived from simatic material and

intruded into cold crust under tentional conditions (so-called second period dykes) from other basic and intermediate dykes intruded under "abnormal" conditions into granite which is not cold (third period dykes). The former have a chronological significance which cannot be credited in the same degree to the latter.

The Tasermiut area

In this imposing region with its alpine landscape a thick series of supracrustal rocks is exposed consisting of metamorphosed volcanic rocks, quartzites and pelitic to semi-pelitic metasediments grading downwards and westwards into gneisses and granites. Before the field work began in 1961 the two most likely possibilities of the plutonic history of the area had been suggested. After the first field season the scheme given in the Syd Sermilik-Tasermiut A column of tables I and III seemed the most probable. However, it has not been possible to find an older basement below the series of supracrustal rocks and underlying gneisses. Later it became more and more probable that the plutonic history of the Tasermiut area was longer and interrupted by an episode of intrusion of doleritic dykes, i. e. Syd Sermilik-Tasermiut B in tables II and IV.

Possibilities of correlation

It is necessary to agree upon chronologies within each of the areas treated above before attempts can be made at correlations between the areas. The widest agreement can be found in the Julianehåb granite area which conveniently is the central one. The standard chronology for this central area is in the middle column of tables I, II, III and IV (bound at the end of the paper) and alternatives A and B for both Ivigtut and the Syd Sermilik-Tasermiut areas placed on either side. The alternatives A and B for the Syd Sermilik-Tasermiut area have the same geological sequence of events and the main difficulty was in establishing a definite link between this and the central area. In tables I and III one link has been assumed by correlating the volcanic rocks in the Tasermiut area with the DA2s in the Julianehåb granite area. During the two last years a better link has become apparent i. e. correlation of the second period dykes with the dykes of the Syd Sermilik-Tasermiut area intruded before the local reactivation; this is indicated under Syd Sermilik-Tasermiut B of tables II and IV which indicates the most probable alternative.

There is a definite link between the Ivigtut and Julianehåb granite areas; this is the supracrustal series which can be followed from north of Arsuk fjord down to Kobberminebugt lying at the margin of the Julianehåb granite area. This series is linked by a double-headed arrow in the tables. In this way four possibilities of correlation can be distinguished:

Table I
Ivigtut A + Syd Serm. -Taserm. A; 3 supracrustal series (DA2, DA1 and pre-DA1 in age)+)

Table II
Ivigtut A + Syd Serm. -Taserm. B; 2 supracrustal series (DA1, pre-DA1 in age)

Table III
Ivigtut B + Syd Serm. -Taserm. A; 2 supracrustal series (DA2, DA1 in age)

Table IV
Ivigtut B + Syd Serm. -Taserm. B; 1 supracrustal series (DA1 in age)

Another link between the Ivigtut area and the Julianehåb area has been suggested by Berthelsen, when he correlated the Kuanitic dykes of the Ivigtut area with the second period DAs of the Julianehåb granite area (table III and IV). Although this alternative is not at all unreasonable it has to be admitted that there is no conclusive evidence to support it. None of the typical Kuanitic dykes has been seen to continue from the Ivigtut area into the Julianehåb granite to the south. Neither has it been possible to collect conclusive evidence showing that all Kuanitic dykes are really younger than the Ketilidian supracrustal rocks.

The alternative correlation between Ivigtut and the Julianehåb granite area is indicated in tables I and II. This implies that the Kuanitic dykes belong to two periods, the older ones being considered as the feeders of the Ketilidian volcanic rocks which only have been preserved as real dykes in the least reactivated pre-Ketilidian basement occurring north of Ivigtut. The younger generations however could possibly be of the same age as the second period DAs and might continue to the Kobberminebugt.

+) Although the pre-DA1 supracrustals have not been recognised as mappable units in South Greenland, they have still to be considered present, although in a transformed state, in the nebulitic gneisses from Grænseland.

II. CHRONOLOGY OF METAMORPHOSED BASIC DYKES

In the granites, gneisses and supracrustals of the area under consideration a large number of dykes, sheets and other bodies occurs which clearly cut through older structures present in the country rock. In most cases it could be shown that these are intrusive bodies consisting of basic or intermediate rocks which have been intruded during three different periods separated from each other by episodes during which the stiff country rocks came again under plutonic conditions.

As a field term the name "discordant amphibolite" (DA) is used to indicate all these igneous rocks composed mainly of hornblende and plagioclase to distinguish them from Gardar dykes which are unmetamorphosed and from basic remnants derived from Ketilidian and pre-Ketilidian gneisses and supracrustals (definition from Watterson, in press). The designation AD ("amphibolite discordante") has been used by the workers in the Ivigtut area to indicate the successive generations of metadoleritic dykes occurring around the Kuánit fjord, i.e. AD1, AD2, AD3 etc. (e.g. Ayrton, 1963 and Weidmann, 1964). In contrast in this paper the term DA1 is used for any dyke belonging to the first period of dyke intrusion recognised in the Kobberminebugt - Julianehåb area. In plural form it indicates all the dykes belonging to all successive generations of the first periods. The same applies to the dykes of the second and third periods (DA2s and DA3s).

The key area Ilordleq

It is necessary to begin with the treatment of the chronology of this area because there it has been possible to link the DA chronology to the history of the supracrustals, defined as Ketilidian, and to that of the Ketilidian granites.

Watterson (in press) separates his first period DAs, which only occur in the Ketilidian supracrustals, into two sub-groups, i.e. one which is earlier than the folding in the supracrustals and which is considered to have been produced by the same volcanic activity giving rise to the supracrustal metavolcanics, and another group cutting early folds in the supracrustals but being themselves affected by later folds and cut by veins of Ketilidian granite. He suggests the possibility of a single extended period of hypabyssal intrusion continuing throughout the initial folding phase.

In the Ilordleq area these DAs form the basis of the whole DA chronology. Their chronological relations to the Ketilidian supracrustals have been fixed with certainty and with them as starting point Watterson has been able to build up the DA sequence and to interweave it with the plutonic history of the area. Thus it became possible to show that the emplacement of first period dykes was followed by the folding of the supracrustals and by the formation of the Ketilidian granites.

The second period dykes have been interpreted as being derived from basaltic material and as being emplaced into cold crust, i. e. into the supracrustals and the Ketilidian granites. Watterson remarks that in the supracrustal rocks from the Ilordleq area their distinction from the DA1s is uncertain unless the relationship to the veins of Ketilidian granite can be seen. They are best preserved in the Ketilidian granites themselves and in most places they retain their original trends and intrusive features. A typical feature of most of these DA2s in the unreactivated Ketilidian granites is that shearing is internal and concentrated along their margins suggesting that during the Sanerutian reactivation they have been less competent than the country rock.

In what Watterson calls a "Sanerutian granite", which is thought to have been almost completely reconstituted by intense deformation and recrystallisation at the expense of Ketilidian granite "the second period dykes are strongly deformed and nearly all of them show some degree of replacement by granitic material. In some instances the granitic material has almost entirely replaced the amphibolites and in such cases it is often impossible to show that the remnants of the amphibolites are in fact the remains of a dyke".

Third period DAs. Watterson was the first who realised their genetic relations and he demonstrated that they were later than the second period dykes as well as the processes producing his Sanerutian granite and the granitisation of the second period dykes but before the latest Sanerutian aplites and pegmatites. He considers them to have been emplaced during the closing stages of the Sanerutian plutonic period while the country rocks were still at an elevated temperature, in contrast to the 2nd period dykes, and during the operation, at least intermittently, of strong compressive forces. He even suggests that they were emplaced along compressional shear zones; therefore they are called synkinematic dykes. However this might be, there is convincing evidence showing that after the

intrusion of the dykes and during their crystallisation movements took place along at least some of them producing a "primary foliation" with a characteristic pattern reflecting the relative displacement of the wall rocks from which an indication of the original stress pattern can be obtained.

Correlation to Julianehåb and farther east

From the beginning it seemed probable that the successive periods of basic dyking in the Ilordleq area could also be recognised farther east.

After systematic investigations made in many different localities over a large region (Allaart, in prep., Persoz, in prep. and Windley, 1963) it can be demonstrated that the basic dyke chronology established in the Ilordleq area can also be applied on a regional scale. In this way it also became possible to show that the Sanerutian plutonism was not a local phenomenon.

It was not however possible to build up the chronology with the DA1s as a starting point as has been done by Watterson because in the Julianehåb granite and the enclosed gneisses it has almost nowhere been possible to prove whether the granite and gneisses have been generated at the expense of pre-Ketilidian basement or from original Ketilidian sediments. The alternative was to recognise the second and third period DAs in each area and to show that they were separated by an episode of plutonic activity. After this it was then possible to go back and recognise the Ketilidian structures and also possible older DAs.

First period DAs. Of those basic intrusive bodies which have been correlated with the Ilordleq DA1s it can only be shown that they belong to a period of dyke intrusion older than the second period DAs. Because of the fragmentary knowledge of the structures in the area of the Julianehåb granite it has never been possible to prove that the first period DAs outside the Ilordleq area really were older than the first phase of Ketilidian folding. Only in one locality of supracrustals of probable Ketilidian age do several DAs occur which could be shown to be earlier than two phases of deformation demonstrable in the supracrustals. If both deformation phases are of Ketilidian age these DAs approach in age Watterson's first period dykes. In a few other cases (one body of metagabbro and a few other DAs, see Allaart, in prep.) occurring in gneiss and granite it can also be shown that they underwent two phases of deformation. These bodies cut across basic inclusions in the surrounding granite in a way suggesting that

the basic rocks intruded country rock which was already gneissic or granitic. It can also be considered probable that these DAs are of the same age as the Ilordleq DA1s. Therefore it is necessary to suggest that their country rock might have been derived from pre-Ketilidian basement material. Thus it would be a good thing for future workers in the Julianehåb area to look more seriously for relics of pre-Ketilidian basement than has been done hitherto.

Second period DAs. Three different types can be distinguished: 1) Plutons or plugs of gabbro or gabbro-diorite. These have usually dioritic or anorthositic margins and cores of gabbroic or ultrabasic rocks. 2) Dykes of relatively basic amphibolite, often demonstrably metadolerite, sometimes up to 20 m thick but mostly in the range 0.3 - 3 m. 3) Laccolithic bodies of diorite from which numerous flat-lying sheets can go out into the surrounding granite. The relations between these types are not always completely clear. All are influenced by the reactivation which took place on a regional scale. There is nothing that could indicate that the diorites intruded under abnormal circumstances into hot granite as some of the third period dykes did.

Another very interesting discovery has been made by Walton (in press) of a few zoned plutons consisting of a margin of hypersthene gabbro and a core of monzonitic rock. He has suggested their similarity in setting and characteristics to some members of the appinitic suite in Scotland. These rocks are earlier than the regional reactivation. Probably they also belong to the second period suite. It has thus become clear that besides such typical simatic material as doleritic dykes, dioritic and other less typical rocks have been intruded during or just after the second period.

Late-plutonic dykes or sheets (third period DAs). The synkinematic dykes, identical to those of Ilordleq, occur on the Julianehåb peninsula, Akia, Sardloq peninsula and Unartok. Three or four generations can be distinguished. Typical of these dykes, which are always schistose, is that at intersections the foliation of the older generation is cut off by that of the younger one, proving that the deformation of the older dyke took place before the emplacement of the younger one. The relations to intersecting aplites and pegmatite veins show that internal deformation and recrystallisation in the dykes may also have taken place just after their crystallisation. After these dykes a few large bodies of granite have been formed e.g. around Unartok fjord, on Sardlok peninsula and possibly on Igaliko peninsula.

Between Qagssimiut and Unartok fjord the so-called net-veined diorites occur regularly and often numerously. Usually these intrusive bodies are low-dipping sheets, although dykes have also been observed. Their thickness varies between a few decimetres and a few tens of metres. They consist of a core of diorite and usually with a mantle of aplitic or granitic material from which a rather regular network of veins penetrates deeper into the core rock forming a pattern identical to that of the net-veining in the Guernsey diorite described by Elwell et al., (1962) and of the diabase-granite composite dykes with pillow-like structure described by Chapman (1962). The granitic mantle is always seen to replace the marginal parts of the diorite bodies. The field relations suggest that the intrusive diorite and replacing aplitic material are very closely related. The net-veined diorites which are later than the synkinematic dykes will be described by Windley (in prep.).

Another category of late-plutonic basic to intermediate dykes is associated with the "New granites" described below (p. 28 - 30). These dykes penetrated the granite during the final stages of consolidation. Apparently they have no regional chronological significance, but seem to be related to the latest stages of the emplacement of the granite bodies themselves.

It will be clear that distinguishing all these different sorts of basic dykes can often be extremely difficult. Without careful and very detailed work big mistakes can easily be made. It is essential that in every small area the whole chronology be built up on the basis of conclusive intersections and other field relations. Only in this way can the succession of the different events be established with a reasonably high degree of probability.

III. THE JULIANEHÅB GRANITE AREA

Rocks and structures

Ussing (1912) introduced the name of Julianehåb granite for those granites occurring in an area between Kobberminebugt and somewhere in the neighbourhood of Syd Sermilik fjord. Now this area has been mapped in more detail during the last few years and it has become clear that Igaliko fjord forms the approximate south-eastern border of the area in which granite predominates. Gneisses become more and more predominant to the south-east of this fjord, although major bodies of granite, greatly varying in age, are still common.

In the Julianehåb granite metasediments, e. g. quartzites, tuffites and even agglomeratic rocks, have been found in many places. These form small areas either isolated or arranged in zones. The supracrustals are everywhere clearly veined by and apparently older than the Julianehåb granite. These relations hold for those areas where the granite is only metamorphosed and not reactivated during the Sanerutian period.

Gneisses are widespread. They usually form small areas or zones, but in some larger areas gneiss and granite are regularly intercalated. The amount of mafics in the gneisses varies from place to place while their composition is as a rule quartz-dioritic. A common variety is leucocratic, fine-grained and quartz-rich. Other varieties are banded and rich in biotite; hornblende-rich varieties also occur. In one place north of Bredefjord coarse-grained gabbro-anorthositic rocks have been found.

The granites are usually medium- to coarse-grained rocks, granodioritic to adamellitic in composition. The mafics consist of biotite and hornblende which are present in varying amounts. Part of this variation, visible not only on the scale of the exposure but also on a larger scale, might be derived from pre-existing material. In many places the Julianehåb granite is porphyroblastic (microcline). Basic inclusions usually occur and may be numerous. Most of them are strongly recrystallised, but in some original structures can still be recognised. Foliation is often present and marked either by the orientation of the dark minerals or by the orientation of the inclusions, or by both. Occasionally the microcline megacrysts are also orientated.

Part of the island of Tugtutôq (Upton, 1962, p. 12) and the area north

of Bredefjord is composed of a coarsely porphyroblastic granodiorite with microcline porphyroblasts ranging from 3 to 8 cm. These show a preference to crowd in and around basic patches, schlieren and inclusions. The matrix of the rock is identical to the normal varieties of Julianehåb granite. The field relations show that there are two generations of megacrysts. These phases of porphyroblastesis are separated by a phase of emplacement of aplite veins and the second generation seems to be connected with shearing. The relations to the surrounding rocks and their structures suggest that the porphyroblastic granite is of replacement origin.

The age of the porphyroblasts is difficult to determine. The following features suggest a Ketilidian age. Along the south-western contact of the body the porphyroblastic granite is cut by granite veins coming from a granite reactivated during the Sanerutian period. A possible second period dyke is seen to cut through the microcline megacrysts. Other 2nd period dykes are usually well preserved. Sanerutian deformation is seen to deform the megacrysts.

There is however also evidence that some of the porphyroblasts are of Sanerutian age and probably connected with the reactivation. Locally 2nd period dykes occur containing porphyroblasts which seem to have grown into them.

Major structures have been mapped in the area of Julianehåb granite in several places. These trend NE or NW. The foliation is predominantly trending NE-SW. In a few isolated localities a time sequence of the mesoscopic structures can be distinguished. In all cases NE-trending folds are preceded by structures whose axes vary between N and NW. In one locality the youngest phase of deformation is clearly earlier than the 2nd period dykes. There are no disharmonies between the structures in the granite and the regions of gneiss around it.

Relation to the Ketilidian supracrustals from Kobberminebugt

Along the southern shore of Kobberminebugt a zone occurs consisting of metasediments and metavolcanics at least 1500 m thick. The foliation, which is parallel to the bedding, stands vertical and trends ENE. Way up evidence suggests that younging in these rocks is towards the SE. In the lithostratigraphical column reconstructed by Berthelsen (in press) of the series of Ketilidian geosynclinal sediments the supracrustals from Kobberminebugt occur at a high level. With the rocks younging towards the SE

it might be expected that the granites immediately south of Kobbermine-bugt have been formed at the expense of Ketilidian sediments (Harry and Oen, 1964). The field observations suggest that the granitisation to a great extent has been controlled by an axial plane foliation.

Further to the south-east around Qagssimiut a major antiformal structure has been mapped and it might therefore be expected that there, and still more to the east, the younging relations are reversed and that older parts of the Ketilidian sedimentary pile, although largely granitised, will crop up. The question is whether this whole pile is still present towards the east or whether it has been wedged out so that material derived from pre-Ketilidian basement occurs in the cores of antiformal structures or as blocks. Although there is local evidence indicating that the latter is probable it does not seem that large areas of pre-Ketilidian basement have been preserved as such.

In conclusion it can be said that probably the structures in the Julianehåb granite are Ketilidian in age and that most of the gneisses and supracrustals have been derived from Ketilidian sediments, but that at least part of the granite might represent reconstituted old basement. A similar suggestion has already been made by Wegmann (1938, p. 55) so that in this respect it has not been possible to make any progress.

There is however strong evidence to suggest that the whole area of the Julianehåb granite consisted of granite before the intrusion of the second period dykes (see p. 25, 26).

Although the field relations suggest that the Julianehåb granite is a transformation product of other rocks as a result of plutonism and closely connected with the structural development in the crust, some features indicate local mobilisation resulting in allochthonous relationships on a small scale. These were first recognised as having developed during the latest stages of the Ketilidian plutonism.

IV. THE REGION AROUND SYD SERMILIK AND TASERMIUT FJORDS

Lithostratigraphy

Supracrustal rocks and gneisses form extensive exposures around the fjords of Syd Sermilik and Tasermiut and also on parts of the islands of Angmalortoq, Amitsoq, Nanortalik and Sermersoq. On the long peninsula immediately north-west of Tasermiut fjord it has been possible to unravel the sequence of this series which was given the name Syd Sermilik series by Wegmann (1948). The thickness of this pile is of the order of a few thousand metres. On the south-western part of this peninsula the following units can be distinguished (Escher, in prep., see also fig. 1).

V. Volcanic rocks. Its upper part consists mainly of tuffites, lapillis and pillow lavas with common intercalations of quartzites, quartzitic slabs and thin greenschist horizons.

In the lower part epidotised pillow lavas occur with some intercalations of pyritic epidote-hornblende schist.

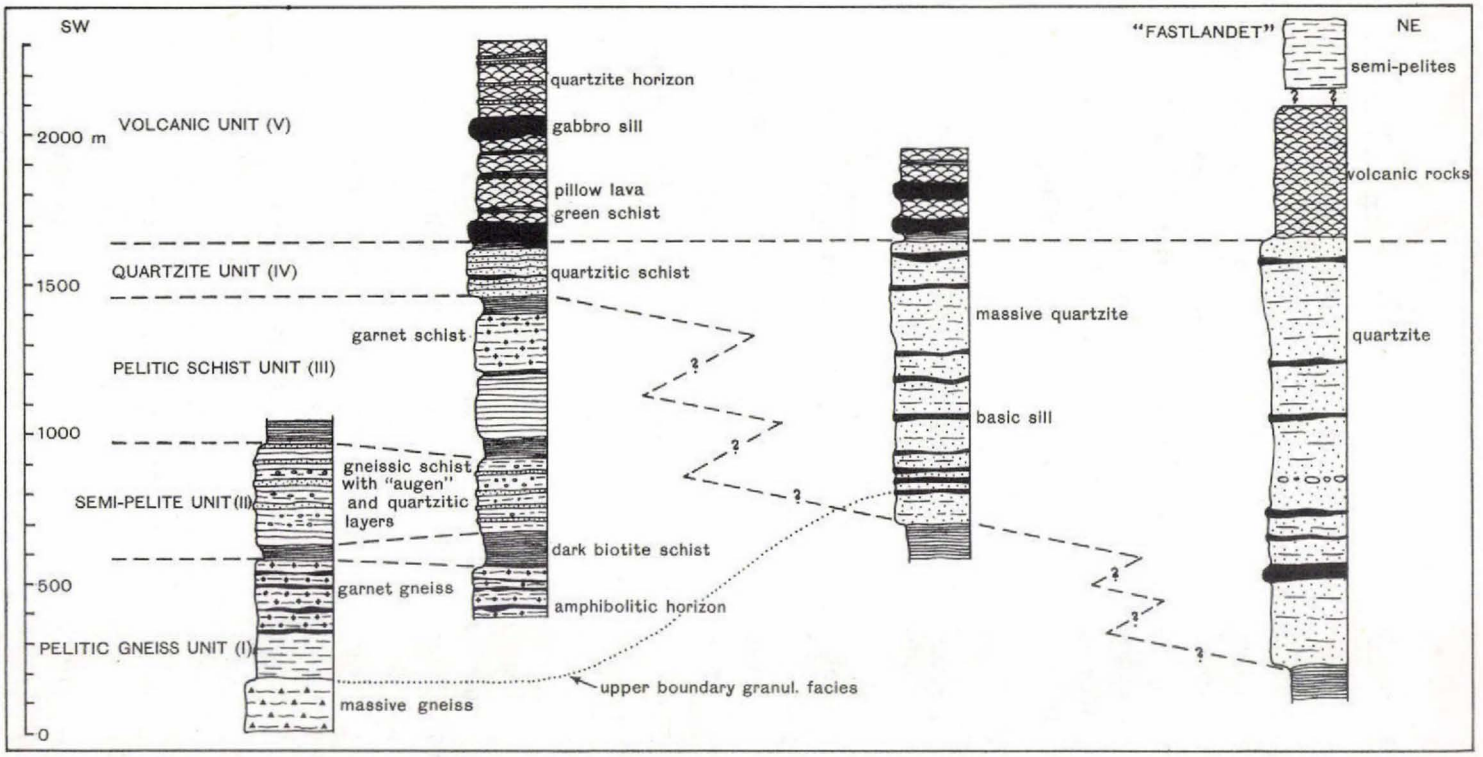
Gabbro sills are frequent throughout this unit. They probably belong to the same episode of igneous activity as the volcanic rocks.

IV. Quartzite. In the south-west it is relatively thin and consists of quartzitic schists. To the north-east the unit increases gradually in thickness (see fig. 1) and grades into massive quartzites containing numerous basic sills intercalated mainly at the top and base. In these rocks current bedding and graded bedding are still visible and even ripple marks occur. A few conglomeratic horizons have been found.

Still further towards the north-east this unit attains a thickness up to 1500 m and covers almost the whole of that part of the peninsula called Fastlandet between Tasermiut fjord and Syd Sermilik fjord. Basic sills are common and conglomeratic intercalations occur in many places. Some of the pebbles consist of granite and gneiss. Apparantly older basement has been exposed somewhere in South Greenland during the sedimentation of the quartzite unit.

III. Pelitic rocks with graphitic and sulphidic horizons which are probably the remains of organic material.

II. Semi-pelitic rocks consisting of original intercalated arenaceous and argillaceous rocks.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PELITIC SCHIST UNIT (III)
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PELITIC GNEISS UNIT (I)
quartzite horizon
gabbro sill
pillow lava
green schist
quartzitic schist
garnet schist
gneissic schist with "augen" and quartzitic layers
dark biotite schist
garnet gneiss
amphibolitic horizon
massive gneiss
upper boundary granul. facies
massive quartzite
basic sill
semi-pelites
volcanic rocks
quartzite

Fig. 1.

I. Pelitic gneiss with intercalated basic horizons.

There is not much sense in drawing far-reaching conclusions concerning the facies changes in the rock series in question. It seems however that the lower units were deposited in relatively deep water and that later the depth of the sea decreased and more detritus has been supplied. It is possible that the quartzite series of Fastlandet (see map) was a deltaic deposit and that it was at least partly synchronous with the lower units developed further to the south-west. If so, the boundary of the geosynclinal basin would not have been far away. More systematic observations concerning current directions in the quartzite unit are needed to obtain a clear idea of the source area of the sediments. Preliminary observations in Fastlandet suggest currents coming from the quadrant between north and west.

Structures

At least three phases of deformation producing major and minor folds can be distinguished (Escher, in prep.).

During the first phase small and large scale isoclines and often recumbent folds have been produced. It seems that their original axial directions trended NE to NNE; their amplitudes reach sizes up to one thousand metres but are in general about 50 m. Isoclinal small folds seem to be almost absent in the quartzites and volcanics, but are very widespread lower in the series. In several places however large-scale folds occur which also affect the quartzitic and volcanic rocks. In the lower part of the series granodiorite bodies are involved in the folding; these might be slices of older basement.

The second phase gave rise usually to open major and minor folds which deform and twist the previously formed isoclines. The axial trends average NW. It seems that the material behaved essentially plastically. This is confirmed by the observation that the migmatisation reached its optimum during this phase.

During the third phase very large-scale open structures were formed accompanied by faulting and on a small scale fracture cleavage and strain-slip cleavage developed. Apparently the material was more rigid than during the preceding phase.

Throughout the orogenic period there was a slight disharmony between the two upper and the three lower units mentioned above. This is

marked by the greater intensity of folding in the lower units especially during the first two folding phases. In several places a tectonisation of the boundary between the two groups has also taken place. The discordance between these groups appears only to exist on a small scale and is locally associated with the formation of "wild folding".

A few metamorphosed basic dykes which probably are second period DAs are folded by the last phase of NE-folding. These relations produce difficulties with the interpretation of the collected observations. Two possibilities have to be considered. One is that only the first two of the phases of folding described above are Ketilidian, while the third is Sanerutian. The alternative is that after the second phase of Ketilidian folding on NW axes there were two phases of folding on the same NE axial trend, one Ketilidian and the other Sanerutian: the latter is only distinguishable from the co-axial third Ketilidian phase where DAs are folded.

Metamorphism

In the area in question, which more or less forms an island between the gneisses and granites to the north-west and the granulite facies rocks towards the south-east, the degree of metamorphism in the rock series increases with depth. North-east of Nanortalik the lowest visible part of unit I appears in granulite facies characterised by hypersthene, sillimanite and cordierite; the rocks higher in the series are in amphibolite facies. A transition between the amphibolite facies and the albite-epidote amphibolite facies was found in the upper part of unit IV, while the upper part of the volcanic rocks seems to be in the greenschist facies although locally oligoclase is not uncommon there.

Near Nanortalik the upper boundary of the granulite facies occurs in the lower part of unit I while to the north-east the boundary can be found in the quartzites which belong to the much higher unit IV. It should be noted however that in the latter part of the area the unit IV is much thicker than in the south-west. As the degree of diachronism of the quartzites might be considerable the discordance between the metamorphic isograde and the lithostratigraphic units is not necessarily so pronounced as might seem at first sight.

The earliest visible signs of medium- to high-grade metamorphism could be correlated with the second phase of deformation. A second phase of metamorphism can be distinguished after the second phase of folding (NW) and the beginning of the NE-folding. After the break, represented by

the second period dykes, metamorphism was connected with metasomatism by alkalis and silica.

In the units I, II and III and locally also in the quartzites migmatisation did occur. It began during the first phase of deformation. A great number of pegmatites was produced mostly concordant, boudinées and folded. They are usually very poor in potash-rich feldspar. Late- to post-kinematic pegmatites occurring as flat sheets contain large amounts of microcline.

Age relations

There are two possibilities for the age of these rocks. Either the supracrustals and gneisses are Sanerutian in age or they are Ketilidian. Concerning the first possibility Watterson (in press) correctly remarks that until now it has not been possible to disprove conclusively the Sanerutian age of the rocks in question. This is mainly because of the lack of sufficiently detailed information. As the Sanerutian plutonic episode probably does not represent a real orogeny, as for instance the Ketilidian does, this possibility might be considered only as being of sophistic value.

The main reason why the second alternative is most probable is that in this area a main period of regional metamorphism and large-scale folding can be separated from an episode of reactivation and granite emplacement by a period of intrusion of doleritic dykes. This succession is identical to that in the Julianehåb area. From a chronological point of view a weak point remains however in that in this area it has not been possible to collect enough conclusive field evidence which necessarily should form the basis of the DA chronology. A second important argument might be that the structural development of the rock series shows much similarity to that of the Ketilidian rocks in the Ivigtut area. The new facts collected during the last few years seem, therefore, to confirm the interpretation earlier given by Wegmann (1938).

Another question is how far this series of probable Ketilidian rocks can be followed towards the area of Julianehåb granite. This will be treated in the next paragraphs.

Correlation towards the west (Unartok-Sardloq)

Wegmann (1938, p. 55) more or less suggested that north of Sermilik fjord and east of Sermersôq an older basement could occur when writing that the series of gneisses and supracrustals (Sermilik series) is "jammed against some blocks which must have been situated north of it". In another place (op. cit. p. 54) he writes that south of Unartok fjord fea-

tures occur suggesting that folded masses had been dammed up against a resisting massif. According to Wegmann a thorough survey of the whole area would be necessary "to dissect the structures more clearly".

This work has now been done and the area around Unartok fjord has been mapped by Wegmann's own pupils. It has not been possible to collect any evidence indicating that old basement is present in the area in question. On the contrary, it seems that the structures and the rock series continue to the west at least to a NE-trending line not far east of the Igaliko fjord. The following field evidence can be supplied. 1) Areas of large basic enclaves often embedded in basic granodiorite to quartz-diorite can be followed more or less continuously from Sermilik fjord towards the northwest up to Qagdlumiut and Nûgârssuk. Probably these rocks represent granitised material derived from the volcanic unit described under lithostratigraphy. 2) The geometric analysis in the peninsula north of Unartok fjord made it possible to reconstruct a lithological succession and a variation similar to those from the Tasermiut area. It has however to be noted that the rock series consists of 75 to 80 % granite. Thus this evidence cannot be used to show that there is no change in facies when compared with the area just mentioned. 3) The work done on structures in the area around Sardloq and the Unartok fjord suggests a marked similarity in structural development with the Tasermiut area.

At least three phases of deformation can be distinguished. The first one whose intensity probably does not vary very strongly from place to place, produced isoclinal to closed folds on a meso- and megascopic scale. Their style is plastic to semi-plastic. The second one twists and deforms the folds of the first phase and is rather variable in intensity and distribution. The trends of the fold axes usually make large angles with those of the first phase folds, averaging NW; they have been mapped on a mesoscopic and megascopic scale. The third folding has axes trending NE and has only been observed on a mesoscopic scale. Its distribution is irregular and so is the intensity of the deformation. Major structures have not been found, in contrast with the Tasermiut area. The relations to second period DAs give the same difficulties with the interpretation of the NE-trending structures as in the Tasermiut area. One alternative is that there are two Ketilidian phases followed by a Sanerutian one, and the other is that a third Ketilidian folding phase produced NE-trending structures while during the Sanerutian deformation adapted itself to the older directions and folded the second period DAs.

Migmatisation and metamorphism began during or immediately after the first phase of folding, thus slightly earlier than in the Tasermiut area.

A clear difference in intensity of folding is evident between the lower and higher parts of the succession in the peninsula north-west of Unartok fjord during the second phase of folding.

It is highly probable that these structures and the Ketilidian gneisses continue into the area of Julianehåb granite. As has already been remarked the possibility of the presence there of reconstituted pre-Ketilidian basement cannot be excluded.

V. THE SANERUTIAN GRANITE SERIES

Regional reactivation

Aspects. After the emplacement of the second period basic dykes in what is supposed to have been cold country rock the segment of the crust of which the map area forms part, once again came under plutonic conditions. The north-western boundary of the reactivation front does not lie far from Ivigtut and towards the south-east reactivation phenomena have still been observed beyond Frederiksdal. It seems that at the same time almost the whole map area underwent at least medium-grade metamorphism.

The reactivation is only recognisable from the mutual relations between second period basic dykes and country rock. In different parts of the map area these are identical to those between the Hangö granite and the metabasaltic dykes from South Finland. Of these Sederholm (1923) concluded that they showed features of being younger as well as older than the country rock granite which he called palingenetic. In this report the designation reactivated granites will be used for granites with similar relations in the map area.

In other parts of the map area the granite has not been aggressive towards the DAs which are therefore usually well preserved. In most of them shearing is internal suggesting that the dykes were less competent than the granite itself. Locally the dykes can be shear-folded. The dyke rocks are clearly metamorphosed so that the country rock granite can be called metamorphosed Ketilidian granite.

In the reactivated granites the most spectacular aspect is the aggressiveness of the country rock granite so that it veins the metamorphosed dykes. In many cases these veins seem to be controlled by pre-existing joints in the basic rocks. In other cases they are irregular. Replacement veins are not uncommon but very often the veins are clearly dilatational. This type of veining usually grades into actual fragmentation of the dykes. This fragmentation reveals one other very typical characteristic of the reactivated granites and that is that they have been less competent than the dyke bodies. One form of fragmentation is boudinage and this can be closely connected with the deformation in the granite, formation of foliation and stretching parallel to the direction of the dyke. In these cases the relative differences in competency do not seem to be very great. In other

cases the differences in competency are relatively large or the granite relatively more mobile so that the dykes seem to be brittle and to break into rectangular pieces. Locally these fragments are turned as a result of local mobilisation. On a rather larger scale (100 m) disorientation can also occur.

Deformation. Signs of Sanerutian deformation can be found throughout the whole map area. The deformation seems to have adapted itself to earlier structures.

Shear belts with local development of mylonites are not uncommon in metamorphosed Ketilidian granite, as for instance between Kobbermine-bugt and Qagssimiut. These can reach a width up to 1 km. Their distribution is irregular. The deformation results in destruction of the minerals with almost no recrystallisation. The hornblende and biotite remained stable suggesting that the rocks were rather hot. Locally there are indications that the deformation continued for a long time. The second period dykes from these belts can be folded.

In the reactivated granites the deformation has been more or less plastic and connected with recrystallisation producing a foliation which is often difficult to distinguish from the Ketilidian relic foliations. Formation of augen at the expense of pre-existing feldspar megacrysts can however still be observed in rocks with Sanerutian foliation. The deformation is usually developed locally and second period dykes can be folded. With the onset of the final rigidity deformation again produced local mylonites. Watterson (in press) has made a very detailed study of the different types of Sanerutian deformation in the Ilordleq area.

Distribution. On map 2 an attempt has been made to give an idea of the variation of the intensity of the Sanerutian reactivation in Ketilidian granites in the map area. The frequency and distribution of fragmentation of the second period dykes and veining by the country rock granite are used as means to express this variation. Four symbols are used to characterise different degrees. Each dot or circle represents a locality in which one or more second period DAs have been observed. The map does however not give information on the frequency of the second period DAs. It will be clear that most dykes have been studied in areas with small islands and well exposed coast sections. In the area where no dots occur their number might be relatively small although the mapping has not been detailed enough to find those DAs which are present.

A symbol is used to show the areas and belts where Sanerutian deformation has been demonstrated. It is probable that it is more common than it seems on the map.

Although the information given on the map is far from complete it will be clear that in the whole area between Kobberminebugt and Unartok fjord the frequency and distribution of the reactivation phenomena is very variable and patchy. This irregularity can be apparent on a scale of tens of metres but also of several kilometres. Even dykes of different directions can show clear differences in degree and frequency of veining but this might however be controlled by their position relative to the stress field present during the Sanerutian reactivation.

On the map a shading indicates the areas where the reactivation is most spectacular (filled dots). In three or maybe even four of these areas (Ilordleq, Bredefjord, Akia? and Unartok fjord) there has been considerable deformation although of irregular distribution. Along the outer parts of Bredefjord the intensity of the different aspects of the reactivation might very well be closely associated with each other. The second period dykes are highly veined and fragmented. There is also considerable deformation. At the same time the dyke rocks themselves show an exceptionally strong degree of recrystallisation. Original igneous textures are rare even in the dykes which are more than 10 m thick. The dykes are however hardly migmatised, not even the folded ones.

In areas with no or only slight deformation the veining and fragmentation are usually not so intense and they have a less regular distribution while relic igneous textures in the basic dykes are usually much better preserved.

In two of the shaded areas of map 2 (Ilordleq and Johan Dahl Land) the DAs are relatively strongly replaced and granitised and the pre-existing granitic country rock is considered to have been reconstituted more strongly than elsewhere. In Ilordleq this reconstitution was closely related with intense shearing (Watterson, in press). In Johan Dahl Land however the influence of Sanerutian deformation is slight.

It has to be admitted that the system used on map 2 might not be the best one. The map does not say anything directly about the degree of reconstitution of the reactivated granites. Nor is it possible to get some idea about the relative importance of the different aspects of the reactivation. This was also not the intension of the author. Systematic microscopic in-

vestigations of the autochthonous granites of the map area to be done in the future might give more information about some of these aspects. For the present purpose a system is used which is thought to be simplest. Moreover it is to a considerable extent based on direct field observations and to a relatively low degree on interpretation or imagination.

Summarising, it seems clear that the intensity of the reactivation is very variable from place to place. The observations have also shown that there is a certain pattern in the regional distribution of the reactivation phenomena. More field work is needed to get this regional pattern complete so that a better understanding can be obtained of the factors which caused these processes.

Julianehåb granite originally Ketilidian granite (?). There are strong indications that the area from Kobberminebugt to at least as far east as Igaliko fjord already consisted of granite before the intrusion of the second period dykes and sheets; in other words this area probably consisted for the greater part of Ketilidian granites. The following evidence can be supplied to support this. 1) In the area running north-east from Nunarssuit to the Inland Ice where the reactivation did not produce recrystallisation in the rocks, the granite occurring outside the Sanerutian shear belts is homogeneous coarse-grained and unfoliated. These characteristics were evidently acquired during the Ketilidian plutonic episode. In some other areas more to the east where the reactivation is relatively weak the country rock is also very homogeneous. 2) In areas with relatively intense reactivation the DAs are not as a rule granitised more strongly than in areas where these processes have been less strong. In the former they have of course been broken, deformed and boudinées as a result of deformation and mobilisation. 3) In the area along the outer part of Bredefjord, where the reactivation phenomena are most spectacular, the gneiss bands (pre-reactivation in age) do not show any trace of recrystallisation, reconstitution, partial migmatisation or increase in grain size. The DAs continue from gneiss bands through granite zones without any differences in degree of migmatisation, not even folded DAs whose axial planes are parallel to the foliation and banding in the surrounding rocks. Thus the distribution and frequency of gneiss and granite had already been imposed before the second period dykes were emplaced. 4) Physical evidence. Watterson (in press) listed a number of features of DAs which might be considered as evidence that they had been intruded into country rock which was a granite.

He distinguished two sorts of evidence i. e. physical evidence (conclusive evidence) and circumstantial evidence. A few features considered as being conclusive evidence have been observed very regularly in the area between Bredefjord and Igaliko fjord.

Autochthonous granites

The plutonism during the Sanerutian period resulted locally in the generation and the emplacement of a large range of different sorts of granite. The reactivated granites might well be considered as the autochthonous and perhaps for a small part parautochthonous members. The reactivation phenomena have already been described above while in the following paragraphs a few types of autochthonous members will be dealt with in which the reconstitution has been relatively strong.

On table V an attempt has been made to lay out the different members of the series and their mutual relations. The double arrows mean that age relations between the last stages of emplacement and another event have been established. The single arrows with the question marks indicate uncertain age relations.

Ilordleq. Watterson (in press) has described a granite (see map 1, indicated as Sanerutian granite) which he considers to have been reconstituted to a very great extent by intense deformation and recrystallisation at the expense of an original Ketilidian granite. In the hand specimen this granite is not different from Ketilidian or reactivated Ketilidian granite. The relations to the 2nd period dykes show however that the Sanerutian deformation and recrystallisation has been very intense while the degree of granitisation of the DAs by the granite is relatively high. It does not seem that alkali metasomatism has had any influence during the reactivation processes.

Johan Dahl Land. In this part of the map area (Walton, in prep.) an example occurs of a large body of fine- to medium-grained granite which is considered to have undergone a process of static recrystallisation which seems to have been more extreme than that in most of the reactivated granites described above. The original rock was probably also granitic. The relatively high degree of reconstitution of the rock is also revealed by extensive replacement of metamorphosed basic dykes present in it. In addition a large part of the dark minerals in the rock can also be considered as new. In the granite a few large basic to intermediate plutons occur which

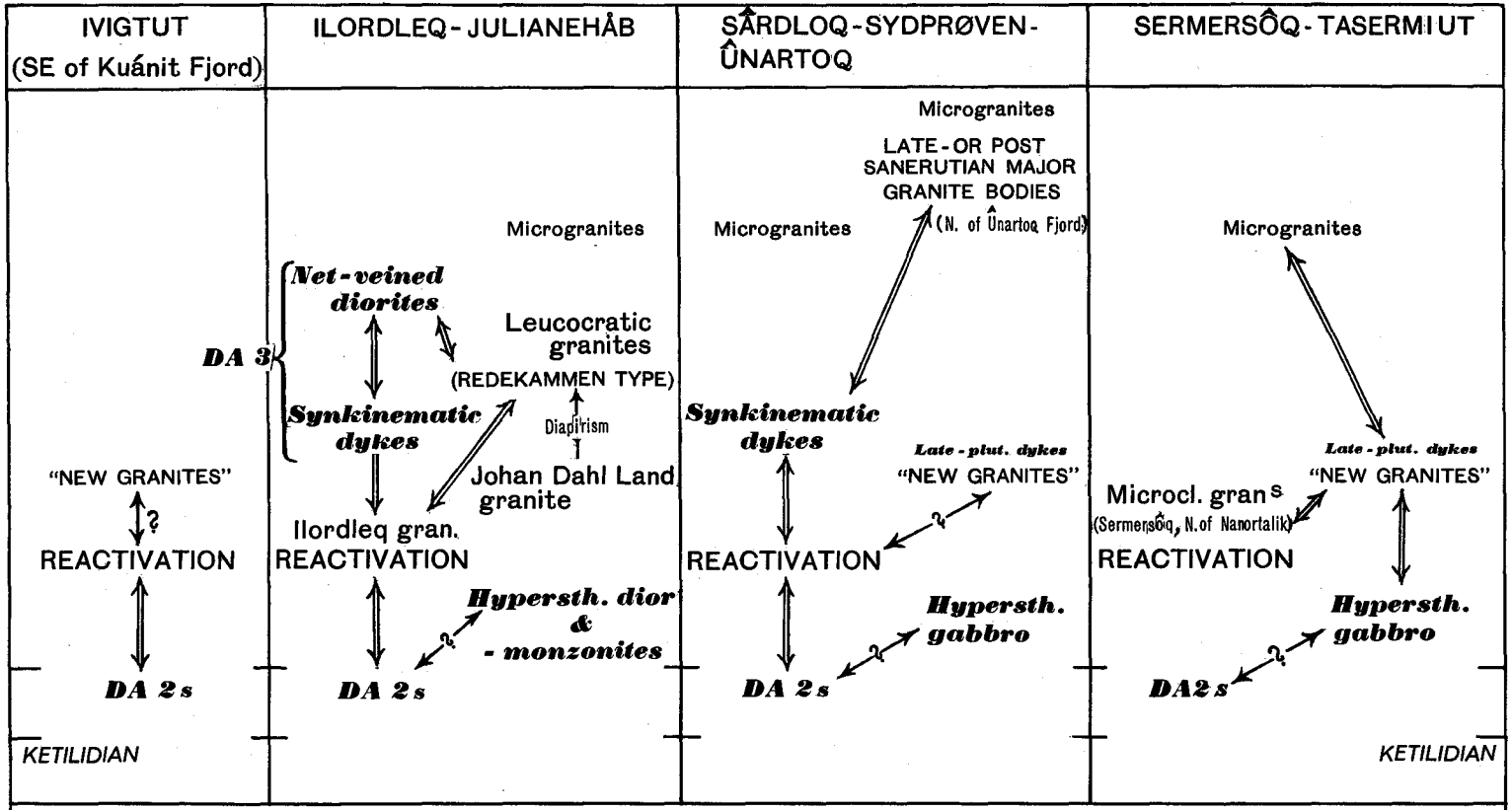

TABLE V. THE SÅNERUTIAN GRANITE SERIES

For explanation see text

are zoned. These consist of margins of partly hypersthene-bearing diorite with cores of monzonitic rock. The granite is clearly later than these bodies.

Microcline granites (Sermersôq - Tasermiut). On the island of Sermersôq and north-west of the Tasermiut fjord a few relatively large bodies occur of foliated granite in which microcline predominates over plagioclase. They clearly cut through the Ketilidian structures in the surrounding gneisses and suprastructural rocks and appear to be the result of replacement which has been accompained by potash metasomatism. The foliation in the rock is a relic foliation which follows a fold pattern running continuously from the surrounding rocks through the granite.

In the Tasermiut area the microcline granite has a rather high position in the supracrustal series, partly replacing the lower parts of the volcanic rocks (unit V, p. 15), the upper parts of the quartzite unit (IV) and the pelitic schists (unit III). On Sermersôq the position of these granites seems to be much lower in the rock series.

The relation of these granites to a few possible second period dykes suggests that they are Sanerutian in age. It is tempting to look for a close connection with the Sanerutian reactivation. The microcline granites are also older than the "New granites".

It has however to be admitted that there is still not enough field evidence to rule out the possibility that they are late-Ketilidian in age and that the DAs mentioned have been affected by local reactivation phenomena active during the Sanerutian.

The "New granites"

These granites have already been briefly described in a clear way by Bridgwater (1963). They were called "New granites" because at that time they were considered as one of the latest formations of granite emplaced before the beginning of the Gardar period. More recent work made it necessary to revise this suggestion to some extent. Bridgwater (in press) is however maintaining this name, mainly to hint at their similarity in setting to that of the "Newer granites" of Scotland (Read, 1961). The reader is referred to both the papers just mentioned, but in this report it is necessary to summarise the main characters and the relations of these rocks.

Three plutons of "New granite" occur in the gneisses of the Ivigtut area north of the area of Julianehåb granite. Further south where gneisses

are also predominant a large number of bodies of "New granite" has been reported, (see map 1 and also Bridgwater, 1963, fig. 2). Some of these have a sheet form. It is possible that the more or less symmetrical arragement of the "New granites" with respect to the central area of Julianehåb granite is only of a deceptive appearance.

The most typical feature of this rock is its coarse porphyritic texture (on map 1 the "New granites" are indicated as being "porphyroblastic"). The megacrysts of potash-rich feldspar vary in size between 0.5 and 20 cm, averaging 4 cm, and they occur in a medium-grained groundmass granodioritic in composition. Some of them are clearly porphyroblastic; these are seen to grow into amphibolitic dykes emplaced during the final stages of consolidation of the granite. In the pluton of Tigssaluk, north of Ivigtut, Emeleus (1963) described megacrysts of potash-rich feldspar which are of early origin and true phenocrysts. Apparently their formation was a continuous process overlapping successive stages of emplacement of the granites.

The "New granites" cross-cut the structures in the basement rocks and their contacts are as a rule sharp. Most of the bodies clearly show intrusive relationships, but in many places they are seen to replace the country rocks. As a whole these granites are however clearly allochthonous.

One of the most interesting aspects is the occurrence of a few small plutons of hypersthene gabbro which seem to be closely associated with the "New granites". The basic bodies are considered to be slightly earlier, but the emplacement processes of both rocks seem to overlap to some extent.

The Sydprøven granite and the other bodies of "New granite" around Tasermiut fjord are reported to post-date the second period dykes. Their minimum age is difficult to determine. The late-plutonic amphibolite dykes occurring within the "New granites" do not seem to have regional chronological significance but to represent only a late stage in the emplacement of the bodies themselves. On Unartok island however there is field evidence suggesting that the "New granite" exposed there is earlier than one of the generations of third period dykes which seem to be related to the later stages of the Sanerutian reactivation. A radiometric age date (Bridgwater, in press) gives the impression that their age is not very different from the reactivation in the Julianehåb area. It is therefore thought that they are connected with the reactivation and are an aspect or a consequence of it.

In other words the reactivation might represent an initial stage of the development of the allochthonous "New granites". It has to be admitted however that this relation is not straightforward. Although local mobilisation in the autochthonous granites has been observed the stage where larger masses of granite as a whole start to move upwards has not yet been recognised.

The leucocratic granites of Redekammen type.

Several bodies of leucocratic granite have been found (map 1). The largest one occurs on Igaliko peninsula and forms the peaks of a steep ridge with the expressive name Redekammen (hair comb). The rock of these bodies is as a rule leucocratic, fine- to medium-grained and usually has a porphyroblastic texture. The number of microcline porphyroblasts is however not great and their size does not exceed 2 cm. Quartz is present in considerable quantities. Biotite usually forms very small crystals of 1 mm or even less. Aggregates of biotite up to 1 cm in length occur but are not very common. Basic inclusions are rare and in many places completely absent. Occasionally the rock can be more mafic, hornblende-bearing and also richer in basic inclusions. In the leucocratic granite on Eqaluit gneiss inclusions are common. Elsewhere these bodies are very monotonous.

The general trends of the largest bodies are parallel with the regional trends in the Julianehåb granite and it seems that their emplacement was controlled by pre-existing structures in the rock series. The smaller bodies can be irregular. Usually the contacts are steep or vertical although locally they are shallow dipping. The field relations suggest that most of these bodies have a diapiric character. Along their contacts the granites are seen cutting and veining the country rocks and are clearly younger.

Two different bodies are seen to be later than second period dykes. In one locality there is conclusive evidence that veins going out from the granite have been emplaced after the regional reactivation. In addition east of Julianehåb circumstantial evidence can be supplied that the southern part of the body occurring on the Igaliko peninsula is later than the synkinematic dykes of the third period. Thus it seems that the last stages of emplacement of these granites took place rather late in the Sanerutian period. The same two bodies mentioned above are however cut by swarms of net-veined diorites which thus post-date these granites.

Although they are relatively late there are also indications that the

emplacement of at least one of the bodies of leucocratic granite can be traced far back in time and possibly even to before the intrusion of the second period dykes. The granite of Eqaluit for instance contains a considerable number of DAs which probably are second period dykes. These DAs are seen to cut through banding in this granite in a way suggesting that the country rock which they intruded was already of granitic material. It is also evident that after the emplacement of the DAs plastic movement and especially a high degree of stretching took place which seems to be connected with a process of diapirism during the Sanerutian. The position of the Eqaluit body seems to be controlled by NW-SE trending structures in the surrounding granites which are relatively very mafic. It therefore seems probable that it originated in the core of an anticline. There are no indications suggesting that the leucocratic granites are connected with some sort of alkali metasomatism. It is quite possible that they originated from original quartz-rich rocks. The differences in composition between the Eqaluit granite and the surrounding dark granites are so striking that differences in density between the two rocks might well be an important factor of the diapirism.

Microgranites, aplites and pegmatites.

Relatively small but still mappable bodies of microgranite and aplite occur in many places. Many of them have a sheet form while others seem to be plug-like. Their age is often difficult to ascertain. There are a few minor bodies older than the second period dykes and therefore late-Ketilidian in age. Others are late-Sanerutian and some of them are cutting through the leucocratic granites. One body has been mapped on Igaliko peninsula which seems to be more or less contemporaneous with the net-veined diorites. There are even bodies which are recorded to be still later.

Pegmatites have been formed throughout the Sanerutian period. In the Julianehåb district, and especially in the surroundings of Sardloq (Windley and Bridgwater, in prep.), a clear concentration of pegmatite emplacement appears to have occurred during the later stages of the plutonic activity. Most of these pegmatites are dilational dykes and sheets with well developed layering, carrying garnet and occasionally beryl and tourmaline.

Major bodies, late-Sanerutian in age.

In three places north of Unartok fjord sheet-like bodies of granitic

rock have been mapped, two smaller and one of very large extent (see map). The rocks of these bodies are medium- to coarse-grained often clearly foliated and varying in composition between true granite and quartz-diorite. In some places they can be very mafic in composition.

These bodies appear to be of replacement origin and to have been generated at a structural level between amphibolitic material and granitic gneisses derived from metasediments. Large parts of the granite seem to replace the overlying basic rocks. Their structural position can be compared with that of the microcline granites from the Tasermiut area. Their age seems however to be different as they are later than three generations of third period dykes.

Their significance is not yet fully understood. It might be possible that they represent a last gasp of plutonic activity in the cooling segment of crust during the later stages of the Sanerutian. It is also possible that they are local manifestations of plutonic activity later than the Sanerutian and independent of the igneous activity during the Gardar period.

VI. SUMMARY AND CONCLUSIONS

During the systematic mapping of the area Wegmann´s suggestion that pre-Ketilidian basement would be widespread has not been confirmed. Only in one place in the Ivigtut area can conclusive evidence be produced showing supracrustal rocks of Ketilidian age lying unconformably on high-grade gneisses. This unconformity is a major one separating units of very different ages.

In many other places the older basement is presumed but not demonstrated to be present. Much more detailed work is required before definite conclusions can be drawn. It is however almost certain that if pre-Ketilidian basement is present in the map area it has been considerably reconstituted.

Wegmann´s hypothesis that the supracrustals and associated rocks from the Syd Sermilik-Tasermiut area can be correlated with the supracrustals from the Kobberminebugt and the Ivigtut areas and that they belong to one and the same fold belt has remained the most probable. The structural evolution of this rock series indicates that it has been formed during the geosynclinal stage of the Ketilidian period. The other characterising events of this period are orogenic activity and plutonism.

A new aspect is the discovery of the Sanerutian plutonic episode already recognised in the south-eastern part of the Ivigtut area. In the Julianehåb district it has been shown that the Sanerutian plutonism has been active on a regional scale. Whether the Sanerutian period is comparable to the Ketilidian orogeny, the closing stage of the Ketilidian main episode of plutonism or even an independent non-orogenic (?) period of reactivation is difficult to decide.

Especially in correlation problems the basic dyke method has been shown to be very useful. It has also been possible to demonstrate that detailed mapping gives the opportunity to distinguish the different types of Discordant Amphibolites and intrusion episodes. That there are still difficulties and uncertainties is mainly due to lack of sufficiently detailed observations.

The nomenclature concerning the DAs (metamorphosed basic dykes) will certainly be confusing for outsiders. When the three periods of basic dyke intrusion were distinguished during the mapping and they received

their succession numbers it had not been possible to decide what kind of event was represented by each of these periods. Originally it was even suggested, although provisionally, that each of them could represent an episode of initial volcanism active during the geosynclinal stage of a major geological cycle. Very soon it became possible to supply convincing evidence that the first period of dyke intrusion really is comparable to such an episode of initial volcanism. For the third period it could however be shown that it had a completely different meaning, marking the last stages of a plutonic episode. Different types of third period dykes could be distinguished.

The second period of dyke intrusion has also to be considered as an important break in the plutonic history of the area. During this episode dolerite dykes, among others, had evidently been intruded into cold crust and under tensional conditions. Whether this break represents an episode of initial volcanism as has been supposed until now or an intra-orogenic period is difficult to decide with the evidence available and this will at the moment remain a matter of opinion. The following factors make a serious consideration of the second possibility necessary and in the author's opinion the most probable.

1) The second period dykes are as a rule very thin and apparently discontinuous.
2) Many of the second period intrusives have an original dioritic composition.
3) The discovery of a few rather large plutons of basic to intermediate rocks apparently not very different in age from the second period dykes and with a geological setting reminiscent to that of some of the members of the Appinitic Suite from Scotland.
4) It has been possible neither to correlate the second period dykes with a supracrustal series of volcanic rocks, nor to find sediments of the same age.
5) Deformation, although locally very intense, has in general been weak during the Sanerutian period. It seems therefore that the plutonism has been confined to reactivation and granite emplacement. Seen in a broad perspective the Sanerutian period does not seem complete unless it is considered as a logical continuation of the Ketilidian.

The future will learn which alternative is the best. It has to be noted however that if the second period DAs are intra-orogenic, then the three

pre-Gardar periods of basic dyke intrusion distinguished in the area will mark different stages of the same major geological cycle. We have thus returned to Wegmann's (1938, pp. 15, 55; 1948, p. 9) original interpretation that there were only two cycles before the Gardar period.

Finally tribute must be made to this great geologist who after only one summer of reconnaissance mapping in South Greenland gained a deep insight into the geology and all its problems.

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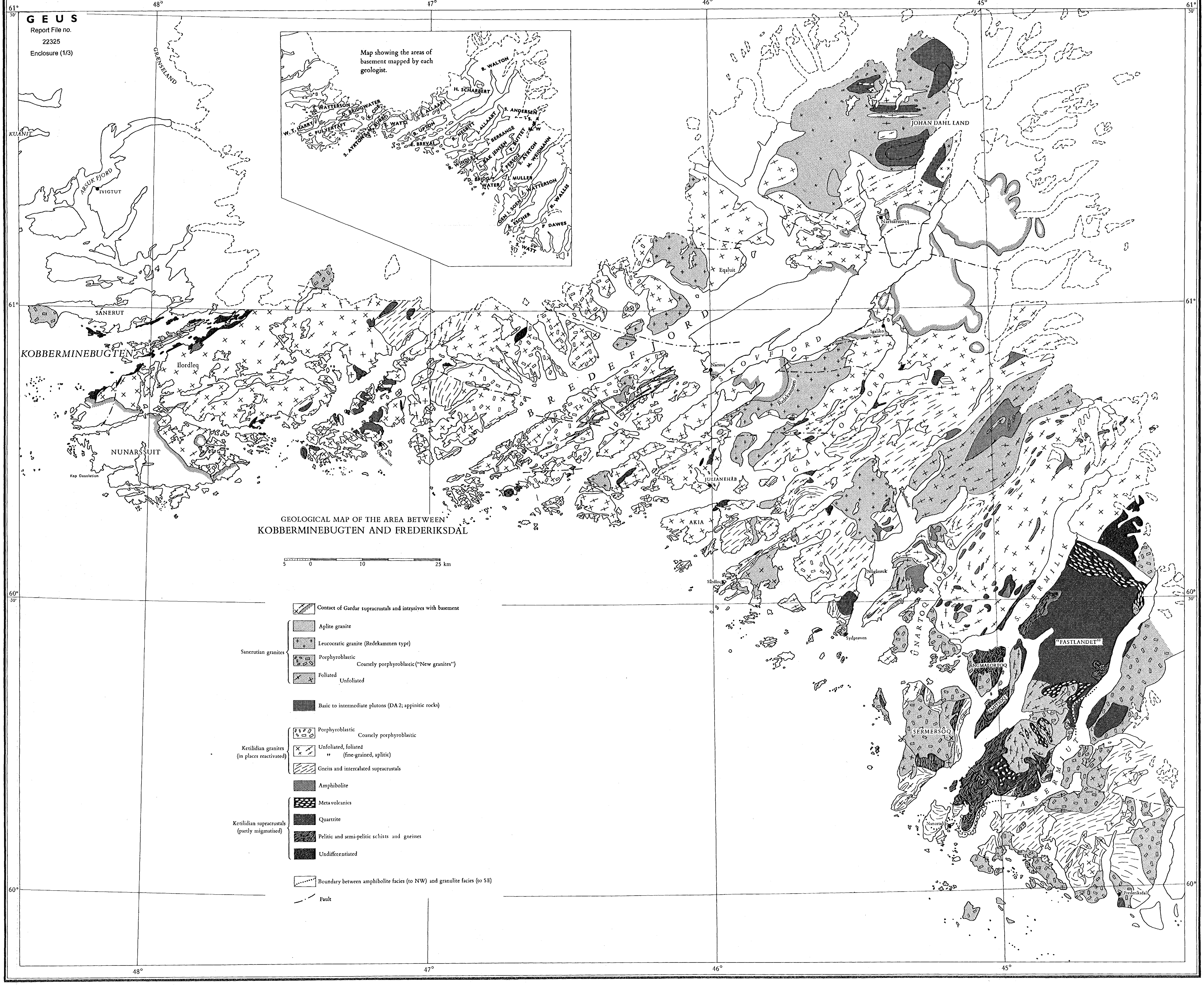
GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND



GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND

G. G. U. RAPPORT NR. 1 (J. H. ALLAART)

MAP 2.

THE VARIATION IN DEGREE OF REACTIVATION

IN THE AREA BETWEEN

KOBBERMINEBUGTEN AND FREDERIKSDAL

1: 500 000

0 10 20 30 40 50 Km

48° 47° 46° 45°

61°30' 61° 60°30' 60°

KOBBERMINEBUGTEN
Ilordleq
BREDEFJORD
JOHAN DAHL LAND
AKIA
UNARTOQ FJORD
Frederiksdal

BEHAVIOUR OF SECOND PERIOD BASIC DYKES

- Veining and fragmentation (replacement - Ilordleq, Johan Dahl Land) very regularly distributed
- Veining and fragmentation irregularly distributed
- Slight granite veining (local boudinage)
- Dykes only metamorphosed

Areas where reactivation phenomena are most apparent

Sanerutian deformation

T A B L E I

Ivigtut A	Nunarssuit-Julianehåb-Ûnartoq	S. Sermilik-Tasermiut A
GARDAR	GARDAR	GARDAR
PLUTONIC EPISODE: "New granites" Reactivation SE of Arsuk Fjord	SANERUTIAN PLUTONIC EPISODE: "Synkinematic" dykes (DA_3); Reactivation of Julianehåb granite	PLUTONIC EPISODE: "New granites" Microline granites (late-kinem.) migmatis.& obliter. of unconf.
	Dykes (DA_2)	*Supracrustal series with dykes and sills*
Some Kuanitic dykes?		
PLUTONIC EPISODE: Reactivation of some Ivigtut gneiss obliteration of unconformity in most places.	KETILIDIAN PLUTONIC EPISODE: Mise-en-place of most of the Julianehåb granite	Old basement
Supracrustal series *with dykes (Kuanitic)*	*Supracrustal series with dykes (DA_1)*	
PLUTONIC EPISODE: Formation of "Ivigtut gneisses"	Old basement	
[Supracrustal series (pre-DA_1)]		

T A B L E II

Ivigtut A	Nunarssuit-Julianehåb-Ûnartoq	S. Sermilik-Tasermiut B
GARDAR	GARDAR	GARDAR
PLUTONIC EPISODE: "New granites" Reactivation SE of Arsuk Fjord	SANERUTIAN PLUTONIC EPISODE: "Synkinematic" dykes (DA_3); Reactivation of Julianehåb granite	PLUTONIC EPISODE: "New granites" Microcl. granites Local reactivation?
	Dykes (DA_2)	*Dykes*
Some Kuanitic dykes?		
PLUTONIC EPISODE: Reactivation of some Ivigtut gneiss obliteration of unconformity in most places.	KETILIDIAN PLUTONIC EPISODE: Mise-en-place of most of the Julianehåb granite	PLUTONIC EPISODE: Migmatisation
Supracrustal series *with dykes (Kuanitic)*	*Supracrustal series with dykes (DA_1)*	*Supracrustal series with dykes and sills*
PLUTONIC EPISODE: Formation of "Ivigtut gneisses"	Old basement	Old basement
[Supracrustal series (pre-DA_1)]		

T A B L E III

Ivigtut B	Nunarssuit-Julianehåb-Ûnartoq	S. Sermilik-Tasermiut A
GARDAR	GARDAR	GARDAR
PLUTONIC EPISODE: "New granites" Reactivation SE of Arsuk Fjord	SANERUTIAN PLUTONIC EPISODE: "Synkinematic" dykes (DA_3); Reactivation of Julianehåb granite	PLUTONIC EPISODE: "New granites" Microline granites (late-kinem.) migmatis.& obliter. of unconf.
Dykes (Kuanitic)	*Dykes (DA_2)*	*Supracrustal series with dykes and sills*
PLUTONIC EPISODE: Formation of "Ivigtut gneisses" separation of gneisses from superstructure	KETILIDIAN PLUTONIC EPISODE: Mise-en-place of most of the Julianehåb granite	Old basement
Supracrustal series *Including volcanics*	*Supracrustal series with dykes (DA_1)*	
Formation of the nebulitic gneisses of Grænseland	Old basement	
[Supracrustal series (pre-DA_1)]		

T A B L E IV

Ivigtut B	Nunarssuit-Julianehåb-Ûnartoq	S. Sermilik-Tasermiut B
GARDAR	GARDAR	GARDAR
PLUTONIC EPISODE: "New granites" Reactivation SE of Arsuk Fjord	SANERUTIAN PLUTONIC EPISODE: "Synkinematic" dykes (DA_3); Reactivation of Julianehåb granite	PLUTONIC EPISODE: "New granites" Microcl. granites Local reactivation?
Dykes (Kuanitic)	*Dykes (DA_2)*	*Dykes*
PLUTONIC EPISODE: Formation of "Ivigtut gneisses" separation of gneisses from superstructure	KETILIDIAN PLUTONIC EPISODE: Mise-en-place of most of the Julianehåb granite	PLUTONIC EPISODE: Migmatisation
Supracrustal series *Including volcanics*	*Supracrustal series with dykes (DA_1)*	*Supracrustal series with dykes and sills*
Formation of the nebulitic gneisses of Grænseland	Old basement	Old basement
[Supracrustal series (pre-DA_1)]		