A Review of the Sydprøven granite and other "New granites" of South Greenland

by

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Abstract

A preliminary field study of the Sydprøven granite has shown that this is not an intrusion belonging to the Gardar alkali province, but is a genetically complex granite of late pre-Gardar age. A comparison of the features of this granite with the information available from other areas marked as "New granite" or "syenite" by earlier workers in South Greenland suggests that these are of the same type and probably of comparable age.

The "New granites" have the following features: 1) The sharp or agmatitic contacts are either vertical or dip inwards. 2) "Rapakivi" texture is locally developed. 3) They are earlier than a series of dolerite dykes of presumed Gardar age. 4) Inclusions in the granites are irregularly distributed with some areas very rich in them. 5) The association with semi-contemporaneous basic rocks (noritic gabbros). 6) They vary in composition between quartz-poor granodiorite and granite (*sensu stricto*).

Introduction

In the 1961 field season The GEOLOGICAL SURVEY OF GREENLAND (G.G.U.) geologists began mapping the third of the so-called "New granites" mentioned by WEGMANN in his 1938 memoir. As the first two complexes, Kûngnât and Nunarssuit, had proved to be largely syenitic intrusions of late Gardar age when mapped in detail, considerable interest was attached to the remapping of the Sydprøven granite. Not only was the intrusion of potential interest in its own right but it was expected that the results could be applied to the larger complexes of Frederiksdal, Lindenows Fjord, the Aluk islands and other young intrusions, recorded but unmapped, in South Greenland.

As the Sydprøven granite was found to extend over a greater area than had previously been suspected it was not practical for one geologist to map the entire intrusion. This preliminary description therefore contains observations made by OEN SOEN, J. WATTERSON and J. MULLER. The interpretation of these observations need not necessarily coincide with those of my colleagues.

History of Research

The first record of a younger series of granite goes back to GIESECKE's travel diaries (1806–1813). The following passage recorded on a journey from Nanortalik to

Lichtenau is of great interest. 10/8 1806. "..... reiste ich von Cap Farvel [now the southern point of Sermersôq] ab; auf der ganzen Strecke von hier bis Tuktuartok findet sich regenerirter Granit mit Milchquarz und eingewashsenen rundlichen Glimmerschiefergeschieben, auch Granit mit Hornblendschieferbroken." (GIESECKE 1878 p. 25.). GIESECKE's evidence for a "regenerative" origin for the Sydprøven granite seems based on the large number of inclusions which it contains.

GIESECKE's notes are also of interest since he is the only geologist, other than WEGMANN, who has published an original account of both the Nunarssuit intrusion and the younger granites south of Julianehåb. It is unfortunate that his nomenclature was not retained by later workers as he refers to the Nunarssuit intrusion as syenite and that of Sydprøven as granite.

GIESECKE was followed in 1881 by SYLOW (HOLM 1883) and the latter author introduced the term "syenite" into his descriptions of the "New granites". His specimens show that he used the term irrespective of the amount of quartz. SYLOW was the first person to describe the Frederiksdal and Aluk islands intrusions and from his specimens and descriptions it can be seen that they have the following features in common:

1) The intrusions are locally rich in inclusions.
2) "Greenstone" dykes cutting these masses are thin, irregular and uncommon. (SYLOW's specimens suggest that he used the term "greenstone" to include both dolerite and amphibolite).
3) On the skerries the intrusions show a characteristic rounded appearance due to the rapid weathering of the coarse, felspar-rich rock.

A Swedish expedition in 1883 collected numerous samples from an immense stretch of the coast of Greenland and TÖRNEBOHM has described two specimens of noritic gabbro from the Frederiksdal intrusion (TÖRNEBOHM 1886 p. 439). He noted both orthopyroxene and multiple lamella twinning in the clinopyroxene. These observations have been confirmed in specimens collected by BØGVAD and seem characteristic of the "New granites" and associated rocks in South Greenland.

H. KNUTSEN and P. EBERLIN (1889) revised some of SYLOW's work and extended the geological mapping along the east coast north of 63°N. Their work still stands as the only published account of original work northwards from Kap Farvel towards Umanak. They were the first to note the inward dipping contacts of the "New granites", from the Aluk islands and Lindenows Fjord. EBERLIN used the term "Paddehat" (mushroom) to describe the granite of Lindenows Fjord and suggested that the "stem" is still hidden from view. He explained his use of the term "syenite" as a general term, to include all the rock types in the "New granites" which, although they contain minerals similar to those in the basement granites and gneisses, are distinguished from the latter by the following features:

1) They have discordant contacts against the earlier rocks.
2) They contain inclusions of the earlier rocks.

EBERLIN noted that there are more mafic-rich rocks in the Frederiksdal and Aluk islands than in the Sydprøven granite.

As KNUTSEN and EBERLIN travelled north their notes and specimens became more scanty and although they marked a large "syenitic" mass on Kangerdluluk fjord there is only one specimen of this "intrusion" in their collection. This is a biotite-hornblende granite with oval megacrysts of felspar very similar to the "rapakivi" granites of Sydprøven and Frederiksdal.

The first author to use the term "New" or "Younger" granite was JESSEN (1896). He mapped the boundaries of the Frederiksdal and Sydprøven intrusions and his boundaries for the latter are almost in agreement with those mapped last summer by G.G.U. geologists. However, JESSEN misinterpreted the large ultrabasic body which occurs at Lichtenau, giving it the same symbol as the noritic gabbro found on Qeqertarssuatsiaq. This led both USSING and WEGMANN to reinterpret JESSEN's boundary. The former included Lichtenau within the Sydprøven granite while the latter, having seen the Lichtenau rocks, excluded both.

JESSEN makes the following points about the Sydprøven granite all of which except the first are substantiated by modern work.

1) Cross cutting dykes of either dolerite or pegmatite are not seen.
2) Large well formed felspars dominate the granite.
3) The ground mass contains milky quartz.
4) The weathering of the "New granite" is highly characteristic, forming low, rounded, gravel-covered islands near the coast or steep, inaccessible, naked walls with sheet jointing where it forms high mountains, such as on Sermersôq.

JESSEN also visited the Tasermiut fjord granite and noted the spectacular alpine scenery, with spires and towers of bare rock.

On his map JESSEN distinguished between granite and syenite in the Frederiksdal intrusion but in the text he observed that there is commonly a gradation between the two. From JESSEN's description of the syenite it appears that the presence or absence of hornblende was the most important criterion in his division of the two rock types, while that of quartz was less important. He also drew attention to the "rapakivi-like" texture shown by the felspars in the Frederiksdal intrusion. This texture is emphasised when the rocks are slightly sheared, the centres of the felspars then stand out red while the mantles are white.

In this century, although the "New granites" have been visited several times, original observations have been published only by WEGMANN. USSING in 1912 compiled the work of earlier geologists and used the same symbol for the "New granites" as for the Nunarssuit syenite of which he had personal experience. This practice has been continued to the present day.

One other geologist should be mentioned in connection with the "New granites" before discussing WEGMANN's work. R. BØGVAD, on the 7th Thule Expedition (1932–33), probably visited a larger stretch of the coast of Greenland in two summers than any other geologist before him and although much of his work was done at great speed it is possible to reconstruct some of the geology of the east coast from his unpublished diaries. A very good collection of specimens, slides, photographs and even rock analyses are deposited with the Mineralogical Museum in Copenhagen and these give a useful idea of the rock types to be met from Kap Farvel to north of Angmassalik.

From a brief glance at this material it appears that the major "intrusions" on the east coast are likely to be members of the "New granite" group of rocks. Minor intrusives strongly reminiscent of the Gardar province occur which include such distinctive rock types as dolerites with anorthosite inclusions and a few alkali dykes. These dykes are important because they may extend the Gardar chronology to the east coast. It is interesting to note that they are later than the major intrusions which have previously been regarded as probably belonging to the Gardar period.

Wegmann's Chronology of the "New granites".

Probably WEGMANN's greatest contribution to the chronology of South Greenland was his use of basic dykes to divide the basement (Ketilidian and pre-Ketilidian) from the younger supracrustal and intrusive rocks (the Gardar period) (WEGMANN 1938 p. 92, 1939 p. 204). He generally placed the basic dykes in the Gardar period, although in 1939 he restricted the term Gardar to the supracrustal rocks regarded by him as later than the dykes. The age of the "New granites" depends on their relationship to these dykes.

WEGMANN (1938 p. 121) after working north of Julianehåb suggested that the "New granites" were later than the dykes. They were thought to be semi-contemporaneous with the alkali rocks of Ilímaussaq. After two more field seasons, spent mainly south of Julianehåb, he revised this chronology and suggested that at least some of the "New granites" should be placed earlier than the basic dykes and were therefore pre-Gardar. In his 1948 paper WEGMANN stated explicitly that these rocks are the youngest phase in the "Ketilidian" (1948 p. 11). He also suggested that the "Ketilidian" could be sub-divided by an older group of basic dykes which were cut by these late granite intrusions. The name Sanerutian has been given to the younger of the subdivions (BERTHELSEN 1961b).

Unfortunately WEGMANN never indicated *which* of his "New granites" belonged in the Gardar and which were pre-Gardar. When G.G.U. geologists mapped Kûngnât (UPTON 1960) and Nunarssuit (HARRY and PULVERTAFT 1962) and found them to be late Gardar in age WEGMANN's latest chronology was disregarded in favour of that in his 1938 paper.

WEGMANN's (1938) description of the "New granites" was written before he discovered that they could be divided into two groups and not all his remarks are applicable to the pre-Gardar examples. A detailed discussion of WEGMANN's views on the formation of the "New granites" is unnecessary at this stage.

The first geologist to revisit the "New granites" after WEGMANN was G. H. FRANCIS of the British Museum (Natural History) in 1957. He carried out reconnaissance mapping in Tasermiut fjord and Sermersôq but his observations were unpublished at the time of his death.

R. WALLIS of Birmingham University continued FRANCIS's work on the Tasermiut granite in the 1960 and 1961 field seasons. Many of his results are similar to those of the G.G.U. team working on the Sydprøven granite to the west. I am indebted to WALLIS for the opportunity to examine his preliminary report on the Tasermiut granite in which the following points are of particular interest.

1) The Tasermiut granite is pre-Gardar, it is cut by a considerable number of dykes and faults.

2) WEGMANN's boundaries are revised considerably. The area marked as country rock between the two outcrops of "New granite" (WEGMANN 1939) has been reinterpreted as an inclusion-rich roof zone.

3) The granite contacts are sharp or agmatitic; the south-east contact dips steeply inwards.

4) In contrast to the Sydprøven granite there are no basic rocks associated with the Tasermiut granite.

5) Pegmatites are more numerous in the Tasermiut granite than in the Sydprøven granite.

6) The felspar megacrysts which in places show rapakivi texture may be late in origin.

7) Lithologically the Tasermiut granite closely resembles the Sydprøven granite.

The Sydprøven Granite

Distribution.

Fig. 1 shows that the Sydprøven granite is a highly irregular body with a total area of approximately four hundred square kilometres, over half of which is under the sea. Three main areas occur which are closely related although there is no direct evidence that they are either contemporaneous or consanguineous.

Form of the Instrusion.

The granite is a discordant intrusive body with sharp contacts which vary in attitude from vertical to 30° dipping inwards towards the centre of the intrusion. On Angmalortoq the granite forms a sheet approximately five hundred metres thick which dips gently south. This form may be repeated in other areas where the contacts are not now exposed.

The Contacts.

The contacts show sudden changes in direction and may even be zigzag in shape. This has suggested to OEN and myself that the form of the intrusion has been partly controlled by earlier joint systems. The granite is discordant on a regional scale, although there are many areas in which

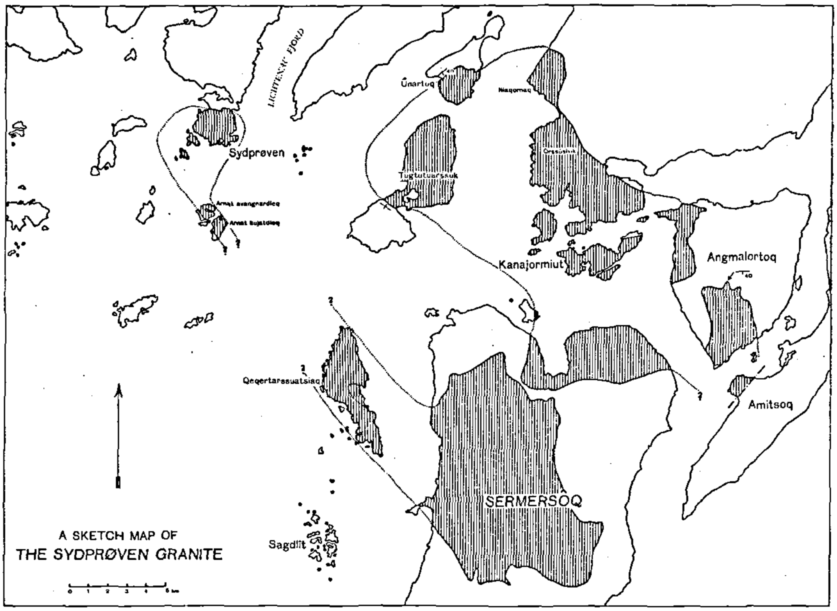

Fig. 1.

the granite contact is parallel to the foliation in the adjacent country rocks. In such cases the only discordant features are granite veins cutting the gneiss.

Contact Metamorphism.

Very little effect is seen near the contacts of the Sydprøven granite on the gneisses and metasediments which form the country rock. Occasionally the knife-sharp contact of the granite is masked by the development of felspar megacrysts in the country rocks up to ten metres away from the "New granite". This is probably due to late potash metasomatism rather than the original contact metamorphism. The adjacent gneisses may develop two mineralogical features seen in the Sydprøven granite. Poikilitic hornblende surrounds the biotites and the quartz crystals become blue and strained. In the biotite garnet gneisses, which form the majority of the metasediment inclusions, the only effects noticed are the growth of felspar megacrysts and a recrystallisation of the garnets within a felspar rim. In a few cases inclusions within the granite show replacement by potash felspar. Near the contact the local gneisses show signs of having become mobile and may even "intrude" late structures in the granites. A few contacts show the growth of a biotite layer between the normal "New granite" and the country rock.

Migmatite structures within the Sydprøven granite.

Wegmann suggested that the Sydprøven granite was emplaced by "imbibition" on the evidence of the migmatite structures developed in the vicinity of Sydprøven village. (See fig. 59, WEGMANN 1938).

In my view these particular migmatites are not formed by the transformation of earlier gneisses into the Sydprøven granite but are the result of recrystallisation of the Sydprøven granite after its emplacement. Evidence for this is seen where the migmatites approach the contacts or where they carry inclusions of recognisable gneiss. In both cases the contacts between the migmatites and the older rocks are sharp, there is no agreement between the migmatite structure and the attitude of the contact or the foliation in the country rocks.

The migmatites are made up of three components:

1) A basic rock approaching noritic gabbro in composition which is in various stages of granitisation or hybridisation by the granite.
2) A medium to fine grained structureless granodiorite.
3) A coarse megacryst-rich granite.

The latter is the rock most typical of the Sydprøven granite. This rock may have been emplaced in two different ways; by *in situ* replacement of a fine grained phase of the Sydprøven granite or by direct crystallisation. The end products are indistinguishable in the absence of migmatitic structures.

The migmatites show the development of the late coarse grained phase in the following ways.

1) Veins. Regular veins of megacryst-rich granite cut the earlier rock, commonly with a well-defined biotite-rich margin.
2) Nets. Megacryst-rich granite forms irregular anastomosing veins. This leaves isolated patches of the fine grained granodiorite with porphyroblasts of felspar growing in them.
3) Diffuse replacement. A gradational recrystallisation of the granodiorite takes place. The felspar megacrysts may be found up to ten metres in front of the completely recrystallised rock.

The Felspar Megacrysts.

One of the most noticeable features of the "New granites" is the common occurrence of felspar megacrysts. These crystals are irregularly distributed but in a "typical" specimen of Sydprøven granite they form approximately 30 % of the rock. The distribution of these megacrysts does not coincide exactly with the distribution of Sydprøven granite. In a few areas they grow in the country rock up to twenty metres away from the contacts. In others the marginal fifty metres of the granite may be free from them.

The felspars range from groundmass size (approximately 5 mm) up to 20 cm in length. When seen in a fine grained groundmass they appear to be more euhedral than those in a coarse granite. Many of the felspars have a coarse perthitic texture which gives schiller effects in hand specimen.

The following evidence suggests that the felspars continued to grow for a considerable time after the initial emplacement of the Sydprøven granite.

1) The felspars grow within the amphibolites intruded during the final stages of consolidation of the granite.

2) Felspars commonly contain inclusions of other minerals, which may retain their original orientation.

3) The felspars grow across contacts and original structures in the granite such as mineral banding and oriented inclusions.

4) The formation of the coarse granite from the fine grained granodiorite is largely accomplished by the growth of potash megacrysts.

The Rapakivi Texture of the Sydprøven Granite.

The term rapakivi has caused considerable confusion in South Greenland due to its use in describing two different phenomena. HARRY and PULVERTAFT (1962) have discussed this problem in their work on the Helene granite of the Nunarssuit intrusion. In Nunarssuit WEGMANN used the term in the Scandinavian sense, to mean a post-orogenic granite of a particular type. In some of the "New granites" further south the term can be used in the textural sense preferred by British petrologists. Large potash felspar ovoids mantled by granular plagioclase are seen in both the Tasermuit fjord and the Frederiksdal granites.

In the Sydprøven granite this texture is never dominant and the only mantled felspar megacrysts seen are those growing in basic rocks which occur either as inclusions or as an earlier phase in the formation of the granite. WEGMANN's remark that the rapakivi texture is restricted to "those parts of the massifs in which inclusions are present as also where they are about to disappear, or have just disappeared", may be true, but cannot be substantiated. (WEGMANN 1938 p. 117).

Inclusions in the Sydprøven Granite.

Inclusions in the Sydprøven granite are very irregularly distributed. They vary in size from fragments of graphite a few centimetres long to rafts of metasediment several hundred metres in length. Both OEN and WEGMANN have noted that on the island of Sermersôq inclusions of metasediment are present throughout a thousand metres vertical exposure of the granite. The local country rock is a gneiss, and it is reasonable to assume that these blocks were transported considerable distances into their present position. On Tugtutuarssuk there are local accumulations of unsorted inclusions of various metasediments. These inclusions may be packed together in an apparently completely random manner and it seems most improbable that a ghost stratigraphy exists. Veins from the granite cut the adjacent gneisses carrying with them fragments of the metasediments aligned parallel with the walls of the vein.

Orientation of the Inclusions.

The amount of preferred orientation of the inclusions is variable. On the west coast of the Arnat islands the inclusions are mainly pelitic gneisses with the foliation generally parallel to their length. These inclusions are in alignment with the local granite margin, the attitude of the country rock foliation, and with a felspar megacryst orientation in the granite. On the other hand measurement of the attitudes of several hundred inclusions on Ûnartoq island shows no preferred orientation. Most of the granite is between these two extremes. There is a slight preferred orientation controlled by the shape of the inclusions not by original foliation. This preferred orientation is commonly disturbed by late movement within the granite.

Areas in the granite which show a well developed parallelism of inclusions often posess other planar structures. A distinct alignment of the biotites in the granite may run parallel to the contact. This foliation is locally accentuated by the growth of late porphyroblasts. Biotite sheaths sometimes develop around inclusions in the granite. These may be single layers up to 10 cm thick or they may be multiple, forming a "rhythmic banding". The bands are irregular lenses which wedge out laterally. They are separated from each other by felspar bands which continued growing after the biotites and sometimes broke through the mafic layers.

Original igneous layering, of the type described by EMELEUS (HARRY and EMELEUS 1960) from the Tigssaluk granite, has not been seen on the low ground where most of the Sydprøven granite is exposed. However, OEN reports layering similar to that of the Tigssaluk granite on some of the higher parts of Sermersôq.

Locally there is evidence that the granite was highly mobile at some stage of its formation. On Tugtutuarssuk an elongate inclusion of recrystallised quartzite has acted as a screen separating an inclusion-rich area of the granite from an inclusion-poor area. This screen is cut through by small veins from the granite which carry flow oriented inclusions through into the inclusion-free area.

Jointing in the Sydprøven Granite.

J. MULLER has collected a considerable amount of data on the jointing seen on the Niaqornaq peninsula and many of his results may be applied throughout the Sydprøven granite.

Based largely on MULLER's work the joints can be classified into four groups.

1) Joints parallel to the contacts and internal foliation of the granite.
2) Joints at right angles to the contact and thus at right angles to the foliation in the granite.
3) Later joints both vertical and sub-horizontal due to shearing movements.
4) Sheet joints.

The first two categories possibly represent primary directions within the granite formed during its emplacement. The second type is often used by late quartz veins, pegmatites and amphibolites intruded while the granite was still mobile. It does not appear to be a simple dilational feature as several of the amphibolites are sheared parallel to their length.

The last category, sheet joints, is one which has caused the most controversy. Where best developed these joints give the granite the appearance of a giant onion. The sheets run sub-parallel with the topography and are often curved. Each sheet is lenticular in shape and the average thickness varies from place to place, probably controlled by such factors as rock grain size, original structure in the rock, and the local topographical slope. Where the sheeting is most spectacularly developed, as on Niaqornaq and Sermersôq, each sheet may reach 10-20 metres in thickness wedging out laterally. The sheets are best developed in the "New granites" but are not confined to them. Any moderately homogeneous rock from quartzite to ultrabasic mass may develop good sheeting.

Nearly all early workers on the "New granites" have noticed sheeting although none of them discussed its origin. JESSEN used the term "afskalning" which seems very close in meaning to "exfoliation".

After the classic work of CLOOS on primary jointing in granites more significance was attached to these structures. WEGMANN in 1938 (p. 98) discussed the significance of what he termed the "bedding" of the "New granites" and noted that the sheets cut across boundaries of the Sydprøven granite into the country rock. He concluded from this that the sheeting in the Sydprøven granite was not the same as the intrusion jointing of CLOOS. WEGMANN therefore suggested that other processes might give rise to this joint system, such as cooling of the crust after the emplacement of the granite.

Some of my colleagues have closely followed WEGMANN's ideas, but in the view of OEN, WATTERSON and myself there is no need to invoke a primary or even very ancient origin for these joints. Recent work by geologists employed by mining or quarrying companies has helped considerably towards the explanations of sheeting in rocks. There seems general agreement that jointing can develop at right angles to the release of pressure. The removal of overburden by weathering is a pressure release which can give rise to jointing parallel to the topography. The violent rock bursts encountered during deep quarrying operations are a more spectacular example of the same phenomenon.

Several workers, among them KIESLINGER at Vienna (1960), EMERY at Sheffield (1960) and PRICE at The Mining Research Establishment, Isleworth (personal communication), have performed experiments to show that rocks which have been under compression retain some of the energy stored in them. This energy may be released when the retaining pressure is removed. In nature the topography may develop faster than the jointing. This is especially marked in glaciated regions where the jointing may develop parallel to the pre-glacial surface (see JAHNS (1943) and CHAPMAN (1958)).

Ideal conditions for sheeting to develop occur when structurally homogeneous rocks are rapidly weathered. It has been suggested that rocks with two phases, i.e. a porphyritic or porphyroblastic texture, are more likely to store residual energy than equigranular rocks. The Sydprøven granite seems an ideal medium for sheet formation by exfoliation.

This explanation for the sheet joints in the Sydprøven granite does not imply that all joints running parallel to the topography in South Greenland are due to exfoliation. On the contrary, there are many examples where the land forms are controlled by earlier jointing and therefore each case must be taken on its merits.

Basic Intrusions within the Sydprøven granite.

The western limb of the Sydprøven granite contains several masses of basic material, the largest of which is two kilometres in diameter. The variation in these rocks is considerable, they range from a fresh noritic gabbro to a hypersthene augite granite. The variation may either be due to hybridisation between granite and gabbro, presuming the rocks to have been mobile at the same time, or it could be caused by granitisation of the gabbro. There is no conclusive evidence in the Sydprøven area as to the exact relative ages of the gabbro and granite. Certainly the granite was active for some time after the emplacement of the gabbro over a large enough area to suggest that rheomorphism is not the cause of hybridisation, but there is local evidence that the gabbro was intruded after the granite was in place.

The best developed basic mass is seen on Qeqertarssuatsiaq. The centre of the body is a fresh noritic gabbro while the margins vary between apparent hybrids and an agmatite of basic blocks set in the normal granite. The hybrid rocks frequently show a colloform margin against the granite. Lobes of a basic diorite push into the granite with apparent chills of the contacts of the basic rock. Granite pipes (described in the next section) are confined to those parts of the basic masses which show colloform margins against the granite and it seems possible that both phenomena developed under the same conditions. Biotite pyroxene diorite hybrids along the contact of the basic mass are veined by a network of granite from the surrounding rock. Megacrysts of potash felspar grow inside the basic centres to this network, the megacrysts frequently show a pale rim suggesting rapakivi structure. Banding within the granite may run parallel with the contact of the basic mass. Large cross cutting sheets of granite with a pegmatitic upper zone cut the basic masses.

It seems probable that WEGMANN's "syenitic nucleus" to the Sydprøven granite (WEGMANN 1938 pp 107-109) is a basic mass similar to the gabbro on Qeqertarssuatsiaq.

Granite pipes.

The basic rocks are cut by a series of small granitic and pegmatitic pipes of which approximately three hundred examples have been seen. The pipes either run from one granite sheet cutting the basic rock to another sheet, or they die out gradually. Very occasionally there may be a bulbous end to the pipes in the granite. The pipes are generally seen in cross section, where they are fairly regular ovals between twenty to fifty centimetres in diameter with a sheath of biotite up to two centimetres thick. It is possible to observe the development of these pipes in a series of cross sections in one locality. The first phase is the development of a group of potash megacrysts set close together in a fine grained groundmass. These megacrysts have almost invariably an oval shape with a white rim round a pink centre. The ground mass then recrystallises with an increase in quartz and a growth of the biotites, especially towards the outside of the pipe. The final rock type is a rather pegmatitic variety of the "New granite" with a higher proportion of sphene than normal. A curious feature of these pipes is that in some areas they are not vertical but all steeply inclined in the same direction (cf. ELWELL, SKELHORN and DRYSDAL 1960).

The basic rocks are distinct from any described from the Gardar as they contain hypersthene and quartz. Other intrusive rocks containing hypersthene are found in the late pre-Gardar among the youngest amphibolites cutting the Julianehåb granite north of Bredefjord. WALLIS also reports hypersthene-bearing dykes cutting the Tasermiut granite.

Amphibolite Dykes in the Granite.

A series of amphibolite dykes are possibly connected with the basic masses within the Sydprøven granite. These dykes were intruded into the granite before complete solidification. They are common on the Arnat islands and near Sydprøven. There is a wide variation in form and contact relationships due to the variable condition of the granite into which the dykes were intruded. The dykes intruded into the more mobile parts of the granite are generally thin, irregular in form and are heavily attacked by the adjacent granite. Those intruded during the final stages of consolidation show straight parallel margins, sometimes with chilling against the granite, and a flow structure developed in the marginal felspars. Occasionally the chilled margins lose their planar nature and become colloform, suggesting that there was little or no resistance to the movement of the dyke magma. Local mixing takes place with the formation of considerable amounts of sphene and the growth of felspar porphyroblasts in the dykes. There is a complete gradation between these extremes. Furthermore a dyke which cuts the granite for several hundred metres with chilled parallel margins may suddenly become sinuous and granitised.

Some of the amphibolites have a sheath of a more leucocratic granite which may vein the dyke itself. This appears to be formed by the last phase of the granite crystallisation which used the dyke margins as a convenient passage.

An important group of these amphibolites was intruded at right angles to the contacts and local foliation in the granite. Generally the dykes do not cut the contact but die out approximately fifty metres away. The few examples which cut the contact and continue into the gneisses are sheared and irregular in the contact zone, although they are more regular in the granite itself. In the gneisses these amphibolites are less regular than in the granites and they are cut by fine grained granite veins and pegmatites. The fine grained granite veins are often controlled by horizontal shear planes which cut the amphibolites. Occasionally the gneiss structure is distorted and the foliation is bent into one of the veins cutting the late amphibolite. These relationships suggest that the gneisses were mobilised during the emplacement of the Sydprøven granite and remained in a plastic state after the main body of granite had become rigid.

Pegmatites.

The large swarm of pegmatites near Sardlok, which WINDLEY has examined in detail, is late Sanerutian in age and thus approximately contemporaneous with the Sydprøven granite. The swarm dies out before reaching the Sydprøven granite so that no direct age relationships are seen. There is considerable mineralogical similarity between the pegmatites of this swarm and those which cut the Sydprøven granite. Both the pegmatite swarm and the Sydprøven granite are cut by a distinctive set of amphibolites with primary plagioclase phenocrysts.

Large swarms of pegmatites have been reported from other areas adjacent to the "New granites" in South Greenland, especially in Lindenows Fjord.

Pegmatites within the Sydprøven granite. A systematic study of the pegmatites within the granite has not yet been compiled, at present it is possible to recognise three main types of pegmatite cutting the granite.

1) Small irregular pegmatites seen near the margins and cutting inclusions within the granite. The mineralogy of these pegmatites varies considerably according to the rock type which they cut. When the dominant country rock is granite these pegmatites are mafic poor, but in the vicinity of pelitic inclusions there is commonly abundant tourmaline, andalusite, garnet and some beryl.

2) Aplite/pegmatites in shear zones. A set of 70° shear zones cuts the eastern part of the Sydprøven granite. A series of dioritic aplites developed along these shear zones contemporaneously with the movement. These aplites are partially replaced by pegmatites which generally formed later than the movements.

3) Zoned sheets. On the west coast of Qeqertarssuatsiaq the granite is cut by a group of sub-horizontal pegmatite lenses up to three metres thick and one hundred metres long. They have sharp cross cutting margins and have been emplaced along a series of tension cracks. Combining the features seen in all the sheets the following structure can be put forward for the pegmatites.

a) At the apex of the lenses the sheets are aplite locally replaced by a quartz-felspar intergrowth.

b) Away from the apex the aplite dies out and the sheet becomes intergrowth from wall to wall.

c) In the centre of the lens there is a quartz core with free floating felspar. The core is completely surrounded by the mantle of intergrowth.

Mineralogy of the sheets. The minerals in the sheets show a crude zoning. The central quartz core contains some blue amazone-stone and beryl with minor amounts of a green muscovite, mispickel and tourmaline. The intergrowth contains larger pockets of tourmaline which also collects along the upper margin of the sheet. The aplite-pegmatite mixture at the apex of the sheets contains some garnet and tourmaline-quartz intergrowths. Sheets of biotite or chlorite grow at right angles to the margins of the sheets along the contact between granite and pegmatite.

A Preliminary Account of the Petrology of the Sydprøven granite.

The granite contains the following rock forming minerals: Microcline, plagioclase, quartz, biotite, hornblende, orthopyroxene and clinopyroxene.

The composition of the granite is not constant, the main variable being the amount of potash felspar. Not all the megacrysts are potash felspar, a few are plagioclase crystals mantled by microcline. Hornblende and biotite may occur separately or together and they appear to be contemporaneous since poikilitic crystals of both minerals are frequently intergrown. The pyroxenes have an irregular distribution, they are common near the basic masses within the granite and in some of the granite veining the country rock, otherwise they are accessory. The clinopyroxene crystals show a remarkable lamella twinning which is also found in the pyroxene crystals in the basic masses. The quartz and groundmass felspar are commonly strained, the quartz may show a blue colouration in hand specimen.

The accessory minerals in the Sydprøven granite have not been fully studied. Sphene has been noted from several places especially in the migmatitic areas round Sydprøven village. Fluorite has not been observed.

The Age and Geological setting of the Sydprøven granite.

The chronology of South Greenland is still the subject of active discussion. The main terms are listed below:

"TD"	A series of olivine dolerite dykes unaffected by faulting or metamorphism.
Gardar	Supracrustal rocks accompanied by major and minor intrusions. Approximate age 1300–1000 million years.
Sanerutian	A period of reactivation of the earlier granites and gneisses.
Basic dykes	Possibly with contemporaneous extrusion and sedimentation.
Ketilidian	Folding, metamorphism and granitisation of a series of supracrustal rocks laid down on an older basement. Basic dykes contemporaneous with the supracrustal rocks probably cut the pre-Ketilidian basement.
Pre-Ketilidian	Gneisses, granites and amphibolites on which the Ketilidian supracrustal rocks lie. These rocks have been through so many later episodes that the boundary between Ketilidian and pre-Ketilidian is controversial.

The "New granites" occupy an intermediate position both in time and petrology between the plutonic rocks of the pre-Gardar and the hypabyssal rocks of the Gardar. No sharp distinction can be made between granites formed *in situ* by reactivation of earlier rocks and those which have become mobile. In the Sydprøven area there are several generations of Sanerutian granite which show an increase in intrusive features as they get younger. In any one granite there may be features suggesting formation *in situ* and others suggesting movement and intrusion. The "New granites" are the most mobile of the Sanerutian granite series and show many of the features found in the large Gardar intrusions.

The break between the Sanerutian and Gardar periods is less distinct in the Sydprøven area than further north. The granite is associated with fresh gabbroic rocks not previously found in the pre-Gardar. It is cut by a series of basic dykes which range from amphibolites to fresh dolerites. It is not known which of these is of the same absolute age as the earliest identified Gardar rocks futher north. It is quite possible that some of the "New granites" were still evolving while typical Gardar dykes were being emplaced fifty kilometres away. The basic rocks associated with the "New granites" contain hypersthene which distinguishes them from the Gardar gabbros. This need not, however, reflect a fundamental difference in magma type but could be caused by the different crystallisation history of the southern gabbros in their rather more mobile environment.

Provisionally I would suggest that the Sydprøven granite is of Sanerutian age as it has more affinity to the Sanerutian granites than it does to the major Gardar intrusives. However, I consider it dangerous to separate the two periods into watertight compartments: the "New granites" are reminders that the history of the crust is more likely to show a gradual evolution than a series of unconnected events. In the absence of absolute age determination of the oldest rocks accepted as Gardar no more positive conclusion can be reached. The suggestion (Berthelsen 1961a) that the southern tip of Greenland underwent post-Gardar regional metamorphism is not confirmed by observations on either the Sydprøven granite or the dykes which cut it.

A Summary of the "New granites"

Figure 2 shows the distribution of the "New granites" according to earlier workers. It is largely redrawn from WEGMANN (1939) modified after the 1961 field season, but without the addition of newly discovered granites of similar age. If the idea that these granites are Sanerutian is correct then it is far more difficult to limit them to the area shaded in figure 2. Other late pre-Gardar granites are widespread in South Greenland and only differ from the Sydprøven granite in their mineralogy and the fact that they have not been previously recognised as being of a similar age. This review is limited to areas which have been called "New granites" or "syenites" by previous authors. With the exception of the Sydprøven and Tasermiut granites very little detailed information is available from the individual intrusions but the following features are known.

1) The granites have sharp discordant contacts against the older granites, gneisses and metasediments. These contacts are generally vertical or dip inwards. (This feature is one of the few differences between the "New granites" described in this paper and the Tigssaluk granite described by EMELEUS (HARRY and EMELEUS 1960).)

2) The granites are cut by basic dykes of probable Gardar age. The Sydprøven and probably the Frédériksdal and Aluk island intrusions are cut by amphibolites emplaced while the granite was still mobile. The earliest set of recognisable dolerites cutting these granites is a pyroxene-rich rock

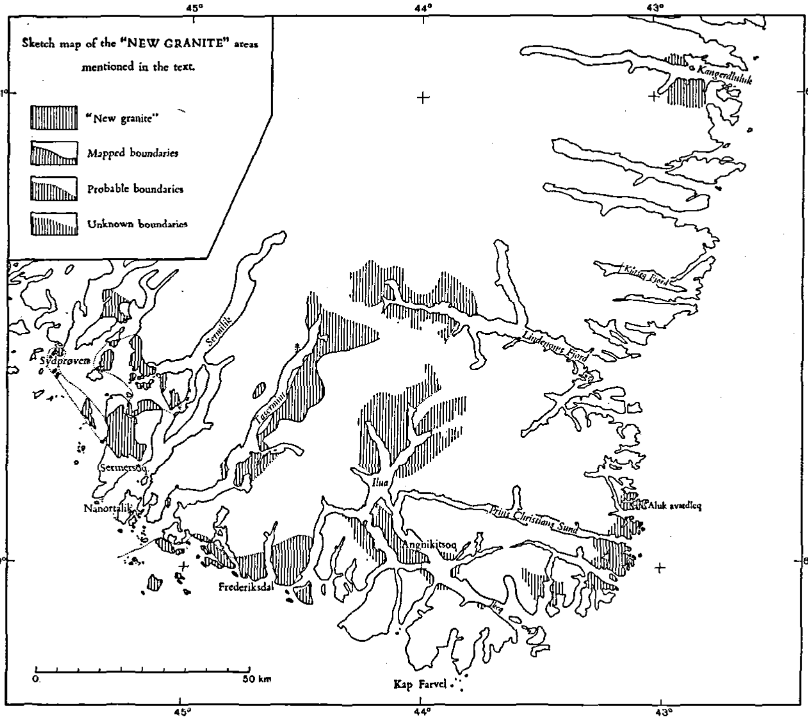

Fig. 2.

in which the felspars have been sericitised, which gives the dyke a distinct blue colouration in the field.

3) Inclusions are irregularly distributed in the granites; they may form fifty percent of the rock and reach more than 100 metres in length. Many of the inclusions show evidence of having been moved.

4) The petrology of the "New granites" varies considerably. Rapakivi texture is quite commonly developed. Areas in the Sydprøven, Frederiksdal, Aluk islands and probably several of the other granites show distinctly charnockitic features. Many of the rocks are quartz-poor. The only available analyses (from Lindenows Fjord) shows a quartz syenite composition.

5) Hypersthene gabbros are associated with the "New granites".

CONCLUSIONS AND ACKNOWLEDGMENTS

I would like to emphasise that only a preliminary survey of the "New granites" has been attempted. In a few years many of the suggestions put forward here may need to be revised.

I would like to acknowledge the help I have received from my colleagues both in the field and in helpful discussions in the laboratory.

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