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GRØNLANDS GEOLOGISKE UNDERSØGELSE

THE NUNARSSUIT INTRUSIVE COMPLEX SOUTH GREENLAND

Part I
GENERAL DESCRIPTION

BY

W. T. HARRY and T. C. R. PULVERTAFT

WITH 63 FIGURES IN THE TEXT
AND 3 MAPS

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

The Nunarssuit complex intrudes the pre-Cambrian basement of South Greenland. Measuring 45×25 km it appears to be the largest pluton in the Gardar Alkaline Province; abundance of augite syenite is an outstanding feature. Although the complex has not previously been the subject of a detailed study it has been taken in the past as providing evidence for 'transformist' views. In fact, however, it presents the features of an igneous intrusion and metasomatic replacement of older rocks was not important in its formation. The boundary between the complex and the basement is highly discordant and it abruptly truncates the numerous Gardar dykes in the basement. Stoping of large blocks seems to have been the main means of emplacement: ring fracture, if operative, was unimportant.

The chief members of the complex are as follows.

The Alángorssuaq Gabbro has a roughly arcuate outcrop mainly comprising unaltered olivine gabbro, uralitized gabbro, and various hybridized rocks formed under the influence of later granites.

The Helene Granite is clearly later than the gabbro and has much in common with the Scandinavian rapakivis: disintegration to 'moro'; occurrence of quartz in two generations; accessory fluorite; scarcity of pegmatites and of preferred mineral orientation. 'Rapakivi' mantled K felspar ovoids are, however, lacking. The granite is remarkably homogeneous considering its areal extent. For the most part it is a coarse-grained rock chiefly consisting of perthite mainly as subrectangular crystals 2–3 cm long, and quartz. Green hornblende and pale-green clinopyroxene are the common coloured minerals but fayalite and biotite can occur.

The Kitsigsut Syenite resembles the larvikites of the Oslo region though its felspars are not usually schillerized. It includes a dark variety essentially consisting of perthite with some pale-green or -brown augite and olivine, and a pale variety in which the felspars tend to be highly exsolved.

The Biotite-Granite, a stock-like body, contains both microcline perthite and oligoclase or albite. Biotite is the chief dark mineral. There is some evidence that the Biotite-Granite is slightly younger than the Helene Granite and it is undoubtedly ounger than the gabbro and Kitsigsut Syenite.

The Nunarssuit Syenite, a large monotonous mass of pyroxene-fayalite syenite, resembles the Kitsigsut Syenite although apatite is not a common accessory and quartz often occurs in small amounts. Towards much of its contact with the Helene Granite and to some extent against the basement it passes into a marginal finer-grained quartzose phase. Other varieties of minor extent occur within the intrusion. The Kitdlavât Granite laccolith and various small bodies of aenigmatite-bearing soda-granites were later intruded into the syenite. The Nunarssuit Syenite is younger than the Helene Granite; in parts of Nunarssuit, however, the Helene Granite veins the syenite and was probably not completely consolidated at the time of the syenite emplacement.

The Malenefjeld Granite, a large independent mass of soda-granite, is nowhere seen in contact with the main body of the complex but is plainly part of the latter.

Xenoliths are uncommon in the complex as a whole but are abundant at certain localities, the most significant being a zone that approximately coincides with the boundary between the Nunarssuit Syenite and Helene Granite in western Nunarssuit. The inclusions in this and two other eastward-dipping zones in S.W. Nunarssuit are largely metavolcanic rocks derived from the Kobberminebugt green schists and measure up to 100 m in thickness. Many are lenticular: these lie with their lengths in the plane of the zones. It seems likely that they are the remnants of roof-pendant wedges disrupted more or less in situ. Unlike the Julianehåb Granite and green schist country rocks of the complex the xenoliths have often suffered high-grade thermal metamorphism.

Mafic mineral layering is well-developed at certain places in the complex. In the gabbro it can be concordantly accompanied by felspar lamination and is inclined towards a focus in the interior of the complex. In the Helene Granite it is highly localized: remarkable sequences resembling the trough banding of Skærgaard occur and another type involves textural variants of the granite as well as mafic bands; there are also planar successions and isolated bands in which cumulus fayalitic olivine is common. More or less planar rhythmic sequences generally unaccompanied by mineral parallelism are extensive in the Kitsigsut Syenite; as in the Helene Granite layering, grading and cross-bedding can be present. Some banding also occurs in the Biotite-Granite and Kitdlavât Granite. In the Nunarssuit Syenite mafic layering is mainly confined to three zones in S.W. Nunarssuit. These and the remaining occurrences are inclined towards a focus in central Nunarssuit. Numerous spectacular structures faithfully mimic primary sedimentary features such as cross-bedding, wash-outs, slumping and graded bedding.

The mafic layers are concentrations of cumulus minerals formed under the influence of gravity in a cooling magma-chamber. Magmatic currents were also effective in most intrusions, particularly the Nunarssuit Syenite. Their activity indicates a high degree of mobility in the magmas concerned and this may be connected with the fluorine content of the complex.

I. INTRODUCTION

(a) Scope of work.

The Nunarssuit pluton is a mildly alkaline intrusive complex on the western seaboard of South Greenland, forming most of the large island of Nunarssuit (Greenlandic—"the big land"), much of Alángorssuaq (Greenlandic—"the big dark side") and all the Indre and Ydre Kitsigsut skerries on the edge of the open sea separating Greenland from Labrador. Although its full extent under the ocean is not known, the complex appears to be the largest 'younger' pluton in South Greenland, its visible area 45 km long by 25 km wide far exceeding that of the famous Ilímaussaq complex near Julianehåb about 120 km to the east. Size, however, is by no means its main claim to interest. Wegmann (1938) has given it a niche in the literature of 'transformist' petrology along with similar massifs in the region by asserting that the granitic members of these plutons are transformation products *in situ* surrounding syenitic nuclei and passing into the metamorphic country rock through a marginal zone of rapakivi. These statements have been quoted with approval in several important publications by leading authorities. Read (1957 p. 35) for example, in a valuable analysis of the granite problem, mentions "the beautiful replacement phenomena seen in the Southern Greenland rapakiwi granite described by Wegmann" and later remarks (op. cit. p. 144) that "Wegmann (1938 pp. 98–121) found that many granitic massifs in S. Greenland are surrounded by a zone of rapakivi granite which is transitional into the metamorphic country rock". Termier and Termier (1956) also write "Wegmann a interprété les rapakivis de la formation de Gardar comme un cas de migmatisation" and quite recently Wegmann (1959 pp. 50–51) has referred without reservation to his (1938 pp. 98–121) account of the South Greenland granite plutons including the Helene Granite.

Such views need reconsideration in the light of fresh data given below. As will be seen, Wegmann's transformist ideas appear inapplicable to the Nunarssuit complex which seems best interpreted solely in magmatist terms: each of the present writers, it is emphasized, came to this conclusion independently whilst working in separate areas. The present account is thus a contribution to the granite controversy as well as to the study of alkaline rocks.

But not only for purely petrological reasons has the Nunarssuit complex attracted recent attention. Since the Ilímaussaq batholith was found to contain appreciable quantities of uranium and thorium all alkaline 'younger' plutons in South Greenland acquired possible economic significance. Thus for several reasons the Nunarssuit complex was selected as the first object of study when the Geological Survey of Greenland (Grønlands Geologiske Undersøgelse, G.G.U.) contemplated the geological survey of the Nunarssuit map sheet extending from 47°00′ to 48°30′ west and 60°30′ to 61°00′ north. The writers began this work in 1957 during a summer field season of three months duration and continued it for a similar period from June to September in 1958, mapping on the scale of 1:20,000 and collecting a total of about 1000 rock specimens. Excellent base maps on this scale, contoured at 25 or 50 m intervals, and aerial photographs were supplied by the Geodætisk Institut, Copenhagen.

Working independently the first author (W.T.H.) investigated the northern portion of the complex in Alángorssuaq and the Indre Kitsigsut whilst the second author (T.C.R.P.) examined the rest of the complex in Nunarssuit and the Ydre Kitsigsut. The survey was extended to cover the whole of the Nunarssuit map sheet which was completed in 1960; the results, it is intended, will appear in a map of 1:100,000 scale accompanied by an explanatory memoir. Meanwhile, units of particular interest are to be described in detailed special reports, the first major contribution being the present paper. This is divided into three parts. Part I, for which both authors share equal responsibility, provides a general description and discussion of the Nunarssuit complex. Parts II and III will be separate petrological accounts of the northern and southern portions of the complex in which each author will bear sole responsibility for his own particular area.

(b) Previous work.

No systematic detailed description of the geology of the Nunarssuit district has appeared hitherto. Few geologists have visited the area and fewer still have left a permanent record of their findings. Only the following need be mentioned here. The earliest investigator appears to have been Giesecke (1806, 1809) who recognized syenite in the Indre Kitsigsut and discovered the zircon so abundant at certain localities in those skerries The same islands were also visited by Garde (1896) and, in the summer of 1908 the great pioneer N.V. Ussing sailed extensively in the Alángorssuaq-Nunarssuit area, accurately recording many geological observations that owing to his untimely death in 1911 have unfortunately remained unpublished. His diaries, deposited with the Geological Museum, Copenhagen, have been made available to us, however, through the kindness of lektor H. SØRENSEN. They contain sketch maps showing the general distribution of syenite, younger granite and gabbro in Alángorssuaq and the Indre Kitsigsut and record that the coarse syenite forming the islands around Tulugartalik is cut by thin veins comprising hornblende, zircon and magnetite. USSING also remarked in his diaries that the younger (micaceous) granite in the islands around Ũmánánguaq contains fragments of syenite and gabbro, that in Alángorssuaq the younger granite developes a contact facies which veins the gabbro, and that arfvedsonite pegmatites cut the younger granite near the syenite contact south of Helene Havn. In a sketch of the view south from Mercurius Havn he indicated inclusions of thermally metamorphosed sediments and diabase porphyries and the approximate position of the contact between the younger granite and syenite. Furthermore, he noted that the younger granite continues south to Kap Desolation and forms the islands around Naujatalik where a little 'rapakivi' (ring) structure occurs.

USSING appreciated the wide extent of the Nunarssuit Syenite and observed that its pegmatites consist of felspar, quartz and arfvedsonite with occasional zircon, galena, molybdenite and a mineral like euxenite. At two places in south-west Nunarssuit he noted "stratification" due to parallel bands rich in magnetite.

In all these hitherto unpublished observations USSING was remarkably accurate and by drawing attention to them the present writers hope to pay some small tribute to their distinguished predecessor. Not unnaturally, though, he was sometimes mistaken; for instance, in describing the pinkish rocks around Itivdliatsiaq as rapakivi and the granite on the shore where he landed south of Malenefjeld as Older (i. e. Julianehåb) Granite.

The admirable regional study of South Greenland by WEGMANN (1938) has already been mentioned. This work, which has provided a basis and constant source of reference for all subsequent studies in the region, briefly summarizes early investigations and comments upon the Nunarssuit massif. It will frequently be mentioned and discussed in the following pages. Whilst the writers cannot agree with WEGMANN's interpretation of the Nunarssuit complex they would like to record their whole-hearted admiration for his achievements in unravelling the regional chronology of South Greenland.

(c) Topography.

The area covered by the Nunarssuit map-sheet (60°30′ to 61°00′ north, 47°00′ to 48°30′ west) differs in some topographical respects

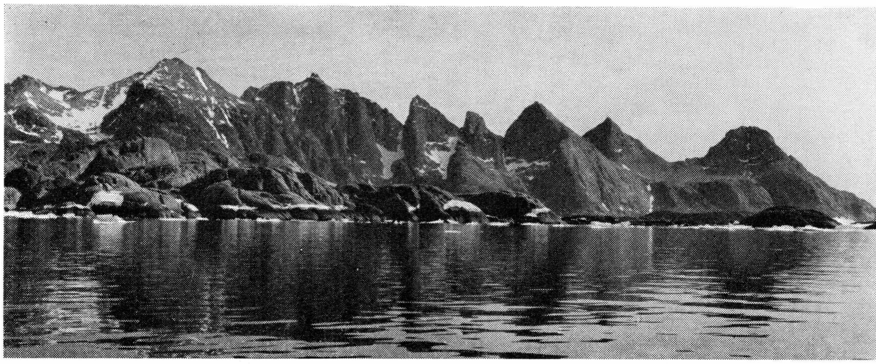

Fig. 1. View of the Kitdlavât mountains, looking south-east from outside the entrance to Torssukåtak. The highest summit (left centre) is formed of Kitdlavât Granite: otherwise the mountains consist entirely of Helene Granite. Kap Desolation on the extreme right. (Photo G.G.U., T.C.R.P.).

from the rest of South Greenland. The strip of land separating the inland ice sheet from the sea is only 30 to 40 km wide—narrower than anywhere else south of Disko Bugt—and furthermore of relatively low altitude. Extensive tracts around Qagssimiut and the inner part of Kobberminebugten do not exceed an elevation of 100 metres above sea level and have been included with the strandflat of South Greenland by Wegmann (1938). Much cf the higher ground elsewhere attains a summit level of only 270–350 metres in contrast with the extensive 700–800 metre level characterizing the area covered by the Ivigtut map-sheet 40 km to the north. This 270–350 metre level rises gradually E.S.E. to over 500 metres when traced to the north-west side of Bredefjord; but when followed northwards towards the Ivigtut plateau no such gradual rise takes place. Instead there is a step between eastern Sánerut and Kînâlik separating the 270–350 metre level af the Nunarssuit district from the 700–800 metre high plateau of the Ivigtut region. These two surfaces are therefore separate and distinct erosion levels.

Only near their western seaboards do Nunarssuit and Alángorssuaq surpass heights of more than 600 metres. Although never more than 800 metres high this ground presents mountain scenery as imposing as any in South Greenland, rising steeply from the sea in an array of pinnacles which are generally unclimable because of the weathered nature of the granite that forms them (see fig. 1).

(d) Access.

The inaccessibility which previously hindered investigation of the region has become less pronounced today with the establishment of the airstrip at Narssarssuaq about 200 km away. A regularly-used shipping route also connects Ivigtut with Copenhagen. It was indeed possible to plan an excursion to the region as part of the XXI International Geological Congress in 1960, though this project unfortunately failed to mature.

Ivigtut provided the main supply base for G.G.U. operations in the region from 1955 until 1959 when it was supplemented by Dyrnæs near Narssaq. From these bases camps were set out and supplied by motor cutters using the coastal waters and fjords that ramify through the region. Torssukátak, the channel between the island of Nunarssuit and Alángorssuaq, is an important sea-route for all vessels, especially those small enough to employ Nyboes Kanal, the narrow waterway which separates Alángorssuaq from the mainland at high tide. Motor cutters of this type, the 16 tonners "Graah" and "Koch", were essential for visiting the skerries and exposed western coasts of Nunarssuit and Alángorssuaq, but within protected inland waters a 22 ft. cabin cruiser "Uralit" proved more suitable and served each author in turn.

Access to the area by sea early in the summer field-season may be hampered by ice. The West Greenland polar current which flows north-west from the southern tip of Greenland, Kap Farvel, along the south-west coast of Greenland is particularly fast off Nunarssuit where it is confined to a stretch of sea no more then 18 km from the land. Consequently in the spring ice floes transported to the region from north-east Greenland by the current are often densely packed near the coast and an on-shore wind may push them far into the fjords. Few are left by about mid-July, however, and they do not usually trouble shipping in the summer months.

(e) Exposure and general conditions.

As can be seen from the map, Plate 3, the complex is partly concealed by either lakes or sea. Apart from this, however, it is exceptionally well exposed (see fig. 2) and its western and southern parts would be a continuous expanse of bed-rock but for occasional scree and gravel patches. Even the Kitsigsut Syenite mass, which is visible only in numerous small islands is, within the area of the skerries, probably as well exposed as many parts of the Scottish Highlands since each island in the skerries is entirely naked rock. All these exposures have, moreover, been scoured clean. Moving away from the coastal belt, however, vegetation, particularly *Empetrum* and *Vaccinium uliginosum* heath, covers an increasing area of ground and although rock outcrops are still abundant they are often covered with lichen and in consequence are not so readily examined as the clean coastal rocks.

Fig. 2. View roughly south from the oval lake at the north-west corner of the Nunarssuit Syenite in Alángorssuaq. Helene Granite in the foreground, Nunarssuit Syenite in the middle distance. Torssukátak just visible in the centre of the picture, Nunarssuit in the background. (Photo G.G.U., W.T.H.).

Since the Nunarssuit area projects out to sea its climate is distinctly maritime. The south-east wind which frequently blows in summer months brings much rain to the area and banks of sea mist often drift in from the Davis Strait with an onshore wind. Snow, common in winter, disappears from all but north-facing slopes by June.

The maritime nature of the Nunarssuit region is reflected in its wild life. Seabirds are numerous, black guillemots and eider duck being commonest. On many lakes divers and mergansers can be found especially where there are runs of arctic char, *Salvelinus alpinus* (the Greenland 'laks'). Among land birds, ptarmigan, snow buntings and wheatears—the last a summer and autumn migrant—are most abundant. The only land mammals, excluding rare polar bear visitants travelling from east Greenland on ice floes, are the arctic fox and snow hare. Insects are a major inconvenience for about seven weeks during the summer when dense swarms of various gnats and mosquitoes hatch from the many lakes in the region.

Alángorssuaq and Nunarssuit are uninhabited. The nearest settlement is Qagssimiut, a Greenlandic hunting community about 30 km east of Nunarssuit. A smaller Greenland village, Arsuk, lies about 40 km to the north of Nunarssuit.

(f) Acknowledgements.

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II. THE REGIONAL SETTING OF THE COMPLEX

(a) General.

The Nunarssuit complex is situated in an extensive region of pre-Cambrian rocks which WEGMANN (1938) has divided into two separate and distinct cycles. These he termed Ketelidian and Gardar. Although the pre-Gardar age nomenclature of the region is now under review, so that the use of the term "Ketelidian" may need to be modified, WEGMANN's work draws special attention to what is undoubtedly an outstanding feature of greatest significance in South Greenland, the contrast between the early tectogenesis and metamorphism of the region on the one hand and its subsequent history on the other.

In pre-Gardar times the Julianehåb Granite and an older geosynclinal series of metasediments and metavolcanics were welded together by tectogenesis and regional metamorphism to form a resistant block which has reacted to later earth-movements only by fracture and warping. After a long period of erosion following this ancient plutonism the Gardar cycle was initiated in the Igaliko area by deposition of continental sandstones intercalated with lava flows. These strata, despite their age still more or less horizontal, rest with marked angular unconformity on folded migmatites in the down-faulted zone between Bredefjord and Tunugdliarfik, the only place where they are preserved. Cutting them are dykes and plutons, the intrusive aspect of the Gardar cycle. Similar dykes and plutons elsewhere in South Greenland outside the area covered by Gardar supracrustal rocks are also assigned to the Gardar cycle for field and petrographic reasons. Thus numerous dyke swarms ranging from at least latitude 60 to 62 north on the west coast of Greenland are confidently assigned to the Gardar cycle and a number of plutons which puncture the basement between Ivigtut and Frederiksdal south of Julianehåb can also be classed as Gardar because of their relationships to the regional dyke swarms. A map of the general geology of the region is provided in Plate I.

(b) The pre-Gardar basement.

The oldest rocks shown on Plate I are those of low or medium metamorphic grade occupying two areas, the Arsuk basin and a long tract of country stretching from Kobberminebugten through Kînâlik to Sermiligârssuk fjord. They include a lowermost predominantly metasedimentary series overlain by a metavolcanic (Arsuk) series. The metasediments display a wide range of rock types, pelitic and semipelitic schists, quartzite, conglomerate, dolomite and various amphibolitic rocks. The metavolcanics chiefly comprise a considerable thickness of basic lavas, sometimes with pillow structures, and occasional tuffs, agglomerates and metagabbro sills. The Arsuk group is succeeded by the Qipisarqo group, comprising a series of metasediments containing much pelitic schist and some conglomerate. The low-grade metamorphics in the southern arm of Kobberminebugten overlie the Qipisarqo group and are of mixed sedimentary and volcanic origin. Their stratigraphy has been outlined by WATTERSON (in press). On the northern shores of Alángorssuaq they form an impersistent narrow outcrop running north-eastwards along the coast, composed of various rocks arranged in parallel layers striking north-east and either vertical or dipping steeply south-east. Schistosity due to preferred orientation of biotite and green amphibole is often developed and lies roughly parallel to the major lithological layering. The following distinctive rock-types occur. Plagioclase porphyrites contain abundant gray rectangular felspars up to a few cm long in a fine-grained epidotic matrix. The phenocrysts tend to parallelism and are sometimes highly deformed without rupture. They mainly consist of andesine often recrystallized to a clear granular aggregate containing stumpy epidote prisms apparently in equilibrium with the felspar. Some microcline is present; brown biotite and green amphibole in the groundmass of the rock generally show a pronounced preferred orientation. Uralite porphyrites are dark green schists consisting chiefly of green amphibole which forms both the groundmass of the rock and sporadic larger crystals or crystal aggregates a few mm long. Elongate vesicles up to 5 cm long lined with epidote and containing magnetite or haematite occasionally occur. Pillow lavas are seen at several localities. The pillows are gray elongate oval bodies up to 30 cm long in a dark schistose matrix which may consist entirely of green amphibole. Banded schists appear in the field as gray or green medium- or fine-grained schists with a banding, visible on the scale of a hand-specimen, which is parallel to the major lithological layering of the schist-belt. Some are obviously mylonites due to shearing on steep planes striking N.E. In thin-section the banded schists comprise quartz, microcline, plagioclase, brown biotite, green amphibole and pistacite in various proportions together with accessory sphene, apatite and ore. Epidote-rock: a fine-grained granular pistacite-rock forms folia and numerous ovoids up to about a metre long in the rocks described above.

The Green Schist outcrop of Alángorssuaq has therefore obviously been folded and regionally metamorphosed under amphibolite facies conditions.

An area of gneisses in the Ivigtut district well to the north of Alángorssuaq is believed to be the result of migmatization during the folding of the lower groups of metamorphic rocks although there is a possibility that these gneisses may possess a core representing a still more ancient basement.

Contrasting with the syn-kinematic development of the Ivigtut gneisses is the late-kinematic migmatization to which the Julianehåb Granite owes its origin in the first place. The term Julianehåb Granite was introduced by Ussing (1912) to designate the basement granite which extends for over 100 km from Kobberminebugten to the Julianehåb area. The very varied character and history of this mass has only recently become apparent. In Alángorssuaq and Nunarssuit it includes many different rocks which, although separable in the field, are not distinguished on the map, Plate 3, for reasons of scale. They range from migmatitic hornblende-granodiorite to leucocratic quartz-rich granite with occasional enclaves. Large bodies of metamorphosed basic to ultrabasic rocks of massive appearance whose precise chronological status is uncertain are enclosed and marginally migmatized by the granite which also contains numerous areas of migmatized schists belonging to the Kobberminebugt Group.

After this orogenesis and migmatization a great number of basic dykes (the Kuánitic swarm), were emplaced throughout the region. In the north-west they remain relatively unaltered and retain their fine-grained margins but south-east of a line running roughly north-east from Kûngnât near Ivigtut they are metamorphosed to amphibolites. This later regional metamorphism increases in grade to the south-east and east so that on some islands within Kobberminebugten and at places in eastern Alángorssuaq and Nunarssuit the Julianehåb Granite has been locally reactivated and has attacked the amphibolite dykes which cut it. Further east, around Qagssimiut, a large area of Julianehåb Granite also shows evidence of reactivation during the same period of regional metamorphism as does the granite in most of the Julianehåb peninsula and the ground between Tunugdliarfik and Igaliko Fjord. Possibly contemporaneous with this reactivation are the granite intrusions on and north of Sánerut which post-date the Kuánitic dykes. Following the reactivation more thin metamorphosed basic dykes were emplaced in the Julianehåb Granite.

(c) The Gardar Period.

(i) Dykes.

Outside the Tunugdliarfik area of Gardar lavas and continental sandstones the Gardar period is chiefly represented by dykes of which dolerites are by far the largest and most numerous. Three generations of these can be discerned between Sermiligârssuk and Arsuk Fjord, the first running E.N.E. or E.-W., the second E.N.E. and the third N.E. In the country between Nunarssuit and the Inland Ice five generations have been separated but in the region to the east of this area there seem to be only three swarms. In addition to these dolerites dense swarms of thin E.N.E.- or N.E.-trending trachytes occur around Narssaq and Arsuk Fjord and many camptonites trending roughly at 70° are found in the vicinity of Arsuk Fjord.

Considering the Alángorssuaq—Nunarssuit area in particular, the abundance of basic dykes is most striking (Plate 3), especially north-east of Bangs Havn. The oldest Gardar dolerites run E.–W. or E.S.E. They are not very numerous but are rather more abundant than the N.–S. or N.N.E. dolerites which cut them and in their turn are cut by the main N.E. swarm. Some members of the last attain a thickness of 300 m and, as shown on the map, many present a complex outcrop suggestive of lateral crustal displacement as well as tension normal to the dyke walls during intrusion. The N.E. swarm is cut by a few E.–W. dolerites, the latest basic Gardar dykes in the area.

Although the vast majority of dykes in the main N.E. swarm present no outstanding features certain of them require special attention. For example, at Bangs Havn a number coalesce in a small igneous complex about 1 km wide and 6 km long trending north-east and comprising dolerite, anorthosite, pyroxene-syenite and pyroxene-granite units grading into each other through narrow transitional zones. The anorthosite, a coarse-grained rock mainly composed of plagioclase crystals up to 15 cm long, forms xenoliths up to 50 m broad in the dolerite. Related to this is the occurrence of numerous anorthosite blocks and large crystals of intermediate plagioclase up to about a metre long in certain Gardar dolerites of the region. South-east of Bangs Havn, for instance, a dolerite dyke 4–8 m wide contains numerous anorthosite blocks and large plagioclase individuals up to 60 cm long. Another Gardar dyke about 10–15 m wide that runs W.S.W. across northern Alángorssuaq is choked with anorthosite blocks and giant intermediate plagioclase crystals up to roughly a metre long.

A few members of the main north-easterly dyke swarm are composite, comprising acid centres and dolerite margins. In central Nunarssuit one of these 50 m thick has a centre of rather fine-grained porphyritic granite 10 m wide. Another, seen in the chain of small islands running north-eastwards from Qeqertarssuánguaq near the south-east coast of Alángorssuaq, also possesses a rather fine-grained porphyritic granite centre. On Qeqertarssuánguaq itself an E.–W. dolerite bears a central portion of quartz-porphyry.

Dykes of intermediate or acid composition are rare in the Alángorssuaq-Nunarssuit area. A few thin trachytes occur; one which trends W.S.W. cuts a N.E. dolerite and is cut by a post-Gardar dolerite. Occasional quartz-porphyries up to 12 m thick running roughly north-east transect the Gardar dolerites. Two thin ones cut and chill against the Nunarssuit syenite east of Itivdliatsiaq. A thin felsite cutting the Julianehåb Granite of south-east Alángorssuaq can be followed for several hundred metres. Acid dykes of E.S.E. trend found in S.E. Nunarssuit are of uncertain age: one is cut by a N.E. dolerite, another cuts a similar dolerite dyke.

(ii) Intrusive complexes.

The Gardar plutons of the region, with which the Nunarssuit complex is to be reckoned for reasons given in a succeeding sub-section, can be very briefly summarized as follows. In the Narssaq area lie the well-known Ilímaussaq batholith, the Igaliko batholith and the central complex of Tugtutôq. Ussing (1912) has described the first in some detail and given a brief account of the second. Upton (1963) has investigated the third.

In the Nunarssuit area there is, besides the complex described in the present paper, the small Puklen intrusion of syenite and soda-granite dealt with by Pulvertaft (1961).

North of Nunarssuit there are the two complexes of Grønnedal and Kûngnât. The former is a body of nepheline-syenite accompanied by carbonatite. The Kûngnât complex, consisting of pyroxene-fayalite syenites and a gabbro ring-dyke, has been the subject of a detailed study by Upton (1960).

In a later section of the present paper attention will be drawn to certain similarities and dissimilarities between these plutonic intrusions.

(iii) Faulting.

The rigid brittle character of the South Greenland block after pre-Gardar tectogenesis and metamorphism has already been alluded to, and is evident in the numerous dyke swarms briefly described above. A further testimony is the intense faulting the region has suffered, much of which is Gardar in age. There are two major sets of faults, roughly north-south dextral transcurrent faults, which considerably displace many of the older Gardar dolerite dykes but have little effect upon the youngest Gardar dolerites, and east-west faults with sinistral displacements of up to 6 km. One of the latter has been shown by Henriksen (1960) to have been initiated long before Gardar times.

Faulting in the Nunarssuit area is much less pronounced than in the other two main centres of Gardar igneous activity, the Narssaq region and the Ivigtut-Grønnedal peninsula. Two north-south dextral tear faults displace the Nunarssuit complex near Josvaminen as does another in central Nunarssuit, and the complex is affected by east-west faulting south of Mercurius Havn and between Bangs Havn and Emma Havn (see Plate 2). The existence of a major fault along Ikerasagssuaq is inferred from the intensely crushed nature of the granite on the islands in the sound just south-east of Aurora Havn and along parts of the shore east of this locality: this fault has no late Gardar displacement—the N.E. dykes are undisturbed—but pre-Gardar boundaries have been moved up to 2 km in a sinistral sense.

(d) Post-Gardar rocks.

Throughout the coastal districts of South Greenland as far north as Frederikshåb a swarm of regularly jointed dolerite dykes weathering to a reddish-brown runs N.N.W. parallel to the coast. The swarm is not dense but some of its members are highly persistent and have been traced for more than a hundred kilometres. Since the dykes cut all Gardar intrusions including the Nunarssuit complex and are never displaced by faulting they are regarded as being post-Gardar and possibly Tertiary in age (Berthelsen 1961).

In Nunarssuit and Alángorssuaq they contain intermediate plagioclase and a pink titaniferous augite with or without some olivine or quartz and attain a thickness of 50 m, though many are much thinner than that; the majority are inclined to the south-west and the dip of some is as low as 50 degrees. They are cut by a later set of E.–W. dolerites which differ from them chiefly in containing small zeolitic vesicles. At two localities in Alángorssuaq, Stærkodder Havn and about $^1/_2$ km south-east of Rødtop, the contacts of the later dykes are seen to be chilled against the N.N.W. dolerites.

(e) The Age of the Nunarssuit complex.

Various members of the Nunarssuit complex transect and hornfels Gardar dolerite dykes of all three main generations in the area. Although the quartz-porphyry dykes of Gardar age have not been seen in actual contact with the complex they, like the Gardar dolerites, are absent from the complex, as shown by the map (Plate 3), with the exception of two thin examples mentioned above. On the other hand, as already remarked, Gardar faults and post-Gardar dolerite dykes cut the complex. Thus the Nunarssuit complex is of late Gardar age. Its relations towards Gardar dyke intrusion and faulting resemble those of the Ilímaussaq, Kûngnât and Puklen complexes but differ from those of the

Grønnedal complex which is intruded by Gardar dolerites and intensely faulted (personal communication, C. H. EMELEUS).

MOORBATH, WEBSTER and MORGAN (1960) have recently given absolute ages for the Ilímaussaq and Kûngnât intrusions. Using polylithionite from Ilímaussaq they obtained a result of 1086 m. y. by the rubidium-strontium method and 1180 m.y. by the potassium-argon method. Biotite from Kûngnât gave an age of 1240 m.y. by the K/A method. It seems likely therefore that the Nunarssuit complex is roughly between 1100 m.y. and 1250 m.y. old[1].

[1]) Since this paper went to press, Dr. S. MOORBATH carried out a Rb/Sr age-determination on biotite from the Biotite-Granite in Alángorssuaq, and obtained a result of 1150 $\pm$ 30 m.y. (taking 4.7×10^{10} years as the half-life of Rb^{87}). The authors are grateful to Dr. MOORBATH for allowing them to publish this figure.

III. THE COMPONENT UNITS OF THE COMPLEX.

(a) The Alángorssuaq Gabbro.

A roughly arcuate outcrop of gabbro 5 km long forms low ground occupied by numerous lakes in central Alángorssuaq at the northern margin of the Nunarssuit complex. The intrusion can for general purposes conveniently be described under three headings, unaltered olivine gabbros, uralitized gabbros and hybridized gabbros, but it should be noted that the extreme western outcrops of the gabbro include a variety of basic rocks not described in this section of the present paper.

Unaltered olivine gabbros.

Olivine gabbros in which all the constituent minerals are fresh compose the central sector of the gabbro arc. A conspicuous variety, extending for about one kilometre along the northern extremity of the gabbro outcrop and for up to several hundred metres southward from its contact with the Julianehåb Granite, is a medium-grained regularly-joined olivine gabbro, without lamination or banding, containing small pegmatitic segregations at a few localities. In hand-specimen it resembles certain diorites because of the abundance of white felspar. Thin-sections of it vary slightly in grain-size and modal composition and closely resemble many slices from the large W.S.W. Gardar dolerite dyke running across east Alángorssuaq up to Naujat qáqât. Clear, well-twinned, generally non-zoned plagioclase of intermediate composition, about An 50 in several specimens, forms roughly 60–70 $^0/_0$ of the rock. Some crystals show slight continuous normal zoning; mild deformation of the albite twin lamellae has been noted. Fresh olivine with a high negative optic axial angle occurs in amounts up to about 16 $^0/_0$ of the rock.

Titanaugite is much less common than, and often encloses, olivine. It makes up less than 1 $^0/_0$ of the total volume of some specimens. Apatite and titaniferous iron ore are abundant accessories and lepidomelane is common as beards round the ore grains. A little interstitial alkaline residuum is present.

A chemical analysis of a representative sample is given in Table I.

Table 1.

Chemical analyses of some members of the Nunarssuit complex.

	1.	2.	3.	4.
SiO_2	45.70	59.35	57.41	74.72
TiO_2	3.02	1.15	1.60	0.28
Al_2O_3	18.85	18.10	17.22	12.55
Fe_2O_3	1.47	0.28	1.69	0.33
FeO	11.44	4.85	6.25	1.61
MnO	0.17	0.11	0.15	0.04
MgO	6.15	0.70	1.03	0.22
CaO	7.73	2.85	4.13	0.87
Na_2O	3.74	5.67	5.20	3.59
K_2O	0.99	5.00	4.36	5.00
H_2O^-	0.01	0.04	0.12	0.01
H_2O^+	0.48	1.08	0.41	0.48
CO_2	0.06	0.55	0.14	0.19
P_2O_5	0.40	0.35	0.49	0.09
F	n.d.	n.d.	n.d.	0.21
	100.21	100.08	100.20	100.19
			$\div O_2$	0.09
			for F	100.10

Analyst: B. Bruun. Numbers in brackets refer to G.G.U. collections.

1. Olivine Gabbro, Alángorssuaq (30106) about 120 m from margin of the intrusion and 800 m S.E. of the northern extremity of the outcrop of the intrusion.
2. Kitsigsut syenite (39415) pale variety. N.W. side of island 600 m long immediately N.W. of Tulugartalik.
3. Kitsigsut syenite (39458) dark variety. Island 200 m long (8051–06 on Geod. Inst. 1:20,000 map) about 1,800 m N.W. of anchorage at Tulugartalik.
4. Biotite-Granite (30173). Excavation near west side of large lake about 850 m east of termination of Angnikitsorssûp atâ, the inlet on S.W. side of Angnikitsorssuaq.

This variety, though not ubiquitous at the outer contact of the gabbro as will be seen, appears to be a marginal phase of the gabbro intrusion and in parts of its outcrop may correspond very closely in chemical composition to the original melt. Followed southwards from its contact with the Julianehåb Granite country rock of the complex it becomes coarser-grained and passes within a few hundred metres into laminated and banded gabbros which will be referred to later in Section VII.

Uralitized gabbros.

The eastern outcrops of the Alángorssuaq Gabbro are largely uralitized up to their contact with the Julianehåb Granite. Only at one locality have unaltered rocks been found at the contact of the intrusion with the basement granite in this sector of the gabbro arc and they are intrusion breccias with a granophyric groundmass bearing hypersthene.

Most if not all of the olivine and pyroxene in the altered rocks has been replaced by biotite and amphibole; the felspar, about andesine in composition, is saussuritized to varying degrees and sometimes shows true clouding; apatite and some ore are common accessories.

The biotite is a dark brown variety distinct from the lepidomelane of the unaltered gabbros. It tends to occur in aggregates of haphazardly orientated crystals up to about a millimetre long sometimes with relict cores of titanaugite. The amphibole ($Z \wedge c$ 23° in one slice) is a pale green colour, sometimes with blueish tint, and often forms feathery aggregates which can in certain instances be made out to be pseudomorphs after olivine.

The uralitized gabbros vary in grain-size. Many of them may be derived from the unaltered medium-grained olivine gabbro just described. At one place a metre from the Julianehåb Granite such a medium-grained uralitized gabbro contains rounded xenoliths of coarse uralitized gabbro with cloudy andesine.

A few small fine-grained veins or lenses rich in epidote or sodic plagioclase traverse the eastern outcrops of the grabbo intrusion. Some of them may mark small shears, for shearing is not uncommon in this part of the gabbro outcrop.

Hybridized gabbros.

In the extreme south-west of its outcrop the Alángorssuaq Gabbro has been intensely attacked by the Helene Granite over an area of several hundred square metres with the resultant formation of a wide variety of modified gabbros. This type of alteration is quite distinct from that just described. The highly hybridized gabbros are quartz-free rocks of intermediate composition, containing abundant microperthite which has extensively replaced original plagioclase. Boundaries between the two felspars are highly sutured and the plagioclase forms relict areas in the perthite. The dark minerals in these rocks include pale-green clinopyroxene (partly replaced by green hornblende mantles) and brown biotite. Sphene, apatite and ore are common accessories.

A poikiloblastic brown hornblende is sometimes developed especially at the margins of quartzo-felspathic veinlets cutting the gabbro where it weathers to small protuberances up to 1 cm in diameter giving the gabbro a pimply appearance in the field.

(b) The Helene Granite.

(i) Distribution and field appearance of the normal granite.

The Helene Granite, named by Wegmann (1938) after Helene Havn, a convenient anchorage for small ships passing through Torssukátak, has an outcrop which extends from Kap Desolation northwards for 12 km to Alángorssuaq where it turns eastwards for 15 km across the southern half of that island before returning to Nunarssuit in the vicinity of Helene Havn. Wegmann (1938 p. 101) remarks that it "extends through the whole massif from Kobbermine Bay to the isthmus of Malene Mountain" but in fact its outcrop terminates just east of the 251 m summit south of Bangs Havn.

Although the steep fantastic pinnacles that it forms between Mercurius Havn and Kap Desolation indicate that it was resistant to glacial erosion the Helene Granite is most susceptible to present-day weathering and much of its outcrop has disintegrated to yellowish gravel ("moro"). Because of this and the smooth rounded surfaces that the solid granite presents fresh samples of it—which are gray in colour—are difficult to obtain.

In the field the Helene Granite shows little variation. For the most part it is a coarse-grained rock, weathering to a yellowish brown colour, with widely-spaced mural jointing and chiefly consisting of alkali felspar, mainly as subrectangular crystals 2–3 cm long. In most outcrops these felspars are randomly arranged but they show slight preferred orientation at a few localities, for example, the eastern shore of Helene Havn where they are arranged roughly in planes striking N.E. and at the south-west end of the lake south-east of Angnikitsorssuaq, near the Biotite-Granite contact, where the planes dip east at 10°. Megascopically many large felspars display pink cores surrounded by gray or white rims, or *vice versa*, and occasional repeated colour zoning of this sort is seen though no corresponding zoning is revealed in thin-section under the microscope. Quartz is usually plentiful as clear or slightly milky aggregates up to 1 cm wide but is sparse at a few localities. Smaller quartz and felspar crystals are interstitial between the bigger units and when this groundmass becomes appreciable in quantity the rock assumes a porphyritic aspect. Some dark minerals are almost invariably present.

Aplite is rare but forms occasional thin sheets in the vicinity of Helene Havn, western Nunarssuit and Alángorssuaq. Pegmatites are even less common; those originating from the granite are small bodies consisting of quartz and felspar. The hornblende-bearing pegmatites which cut the Helene Granite near its contact with the Nunarssuit Syenite are derived from the latter, with which they will be described. A few druses occur; in the extreme west of Nunarssuit they measure up to a metre wide and contain large crystals of quartz, cream-coloured felspar, and biotite; one crystal of the last 15 cm broad and 5 cm thick was observed. In the same neighbourhood there are occasional lenses of white quartz up to half a metre wide but quartz veins and lenses are not common in the granite as a whole.

(ii) Distribution and field aspect of variants.

A slight textural variant which differs from the normal Helene Granite only in the smaller dimensions of its felspars and hence comparatively even-grained appearance forms quite large areas passing into the normal Helene Granite especially in the mountains south-west of Mercurius Havn.

Another more significant variety forms a few relatively fine-grained irregular bodies either passing into or bearing sharp irregular contact against the normal granite which occurs as occasional vague inclusions in the variant. The most interesting of these finer-grained bodies lies on one side in contact with the Nunarssuit Syenite at about 350 metres altitude in the valley south of Mercurius Havn. It is a pale-pink to gray rock, rather more radioactive than the other fine-grained granites.

In the same valley another variant is developed at two localities. This lies in sharp contact with the normal granite from which it differs in being even-grained and slightly finer-grained. It contains clear quartz and prismatic green aegirine crystals sometimes arranged in sheaves.

A relatively even-grained phase on the north-west side of the small island at Stærkodder Havn has a moderate content of fresh olivine and bears occasional rectangular alkali felspar phenocrysts 1–2 cm long. It contains small areas of normal Helene Granite and can be seen in contact with the normal Helene Granite forming the south-eastern side of the island. The contact has a steep or moderate south-easterly dip and can be sharp or vague. Near the north-eastern end of the island one of the large felspars of the normal granite at the (sharp) contact is almost completely enclosed by the even-grained phase. The normal granite on the island encloses and passes into a similar even-grained granite from place to place.

The thin lenticular outcrop of granite separating the Nunarssuit Syenite and normal Helene Granite in Alángorssuaq (see Pl. 3) is fairly even-grained and contains feathery aggregates of a sodic amphibole. Near the syenite it is rather coarse but it becomes fine-grained towards the normal granite. Its contacts with both the syenite and normal granite are sharp.

A marginal facies is often though by no means invariably developed in the Helene Granite close to its contact with older rocks, and is well displayed just east of Emma Havn where it sends intrusive apophyses into the country rock. It can also be seen against the Julianehåb Granite of south-east Alángorssuaq in the vicinity of Naujat atât. In hand-specimen it is pale pink with well-shaped felspar phenocrysts up to 3 cm long and round quartz areas about 0.5 cm broad set in a fine-grained quartzo-felspathic matrix. White plagioclase may form rims to some pink felspar phenocrysts but since the rims replace the potash felspar such phenocrysts do not constitute "rapakivi" felspars.

Rocks like the marginal phase near Emma Havn form areas in the normal granite in Nunarssuit up to 3 m wide with slight marginal concentration of dark minerals. Similar though gray coloured rocks form scattered oval xenoliths in the normal Helene Granite of West Alángorssuaq and Quiartorfik.

Close to its northern margin in west Alángorssuaq the Helene Granite becomes medium-grained and may contain biotite in conspicuous amounts.

(iii) Microscopic Petrography.

Felspar is almost wholly perthite; discrete crystals of plagioclase are scarce or absent. Sodic plagioclase, often with albite twinning, usually constitutes roughly one third, occasionally about half (mesoperthite) the volume of the perthite intergrowth; the potash felspar component of the perthite not infrequently shows microcline twinning. Purely as a means of describing their appearance in thin-section and without precise genetic implications, the perthites can be said to be mainly vein perthites with all gradations to string perthites on the one hand and patch perthites on the other. The perthitic intergrowths can be coarse enough to be megascopically visible or so fine-grained that they are resolved only with difficulty under the microscope.

Many of the large subidiomorphic perthite units are composite, consisting of several—often five or six—perthite crystals differing in crystallographic orientation and the appearance of their perthitic structure. These sub-units have irregular boundaries against each other and may be separated by very thin rims of sodic plagioclase. The last chiefly consists of numerous minute crystals arranged in double rows but some rims are optically homogeneous. Less commonly the boundary between two sub-units is marked by two thin albitic films each optically continuous with (and sometimes also connected to) the plagioclase component in the *opposite*, not the immediately adjacent, sub-unit.

Large individual perthite crystals that lie in contact with each other display thin albite rims with a highly denticulate outer margin resembling the textures shown by similar rims round perthite crystals in certain Nigerian granites (Jacobson *et al.* 1958).

Quartz is rather variable in texture. In some specimens it solely forms rounded areas up to 1 cm broad, consisting of several crystals with very irregular or even sutured margins; undulose extinction is almost ubiquitous, deformation (Boehm) lamellae are common and trains of minute inclusions or cavities are occasionally present. In much of the Helene Granite, however, especially its marginal facies, some of the quartz forms equidimensional, rounded, subhedral or euhedral areas 5–7 mm broad usually with strain extinction and sometimes composite, whilst the remainder of the quartz forms: (1) small subhedral or rounded crystals less than 1 mm wide within the anhedral perthite in the matrix of the rock, (2) irregular areas in the matrix of the rock moulded onto felspar, (3) inclusions in large perthite units. The last mode of occurrence deserves further comment. Many large composite perthites contain small rounded quartz inclusions usually in their outer portions. These inclusion zones are often well-defined, enclosing homogeneous cores with a subrectangular outline congruent with that of the whole composite unit. Very rarely two concentric zones of quartz inclusions are present. Occasionally quartz inclusions in the margin of a composite unit are vermiform and this can result in a delicate granophyric intergrowth which becomes coarser towards the margin of the composite perthite unit.

Hornblende. Almost ubiquitous, hornblende is anhedral and may enclose quartz, felspar, pyroxene, olivine, ore, zircon, or fluorite. It is pleochroic X: light-brown, Y: brownish-green, Z: green; a faint blue tint is also shown by the marginal zones of some crystals.

Sodic amphibole. This occurs only in accessory amounts, occasionally as thin borders to hornblende, more commonly as small acicular crystals sprouting from hornblende crystals. It can also be based on, or intergrown with biotite, and may be enclosed by quartz and felspar.

Clinopyroxene. Only about a third of the specimens examined from Nunarssuit contain clinopyroxene but the mineral seems more common in the Alángorssuaq outcrops of the Helene Granite. Usually it forms subhedral pale green crystals which may be feebly pleochroic gray-green to grass-green. Crystals from near Helene Havn gave 2V (+) 59° in their centre, 2V (+) 63° at their margins. A sample from the vicinity of Kap Desolation gave 2V (+) 70°. A more brightly coloured, presumably sodic, green clinopyroxene is not uncommon and acicular aegirine is present in the local variety of granite seen in two places south of Mercurius Havn.

Olivine. Sporadically distributed and seldom in conspicuous quantities, olivine occurs at Stærkodder Havn in the relatively even-grained granite forming the north-west side of a small island. It is also seen in west Alángorssuaq and at places in Nunarssuit where one specimen gave 2V (—) 47–48° indicating pure fayalite. Occurring as rounded grains up to a few mm long, it is frequently altered to ore, colourless amphibole, and a yellowish, probably serpentinitic, mineral.

Biotite. Frequently associated with sodic amphibole, biotite is a common accessory and occasionally, as near the basement about $1^1/_2$ km north of Graahs Havn in Alángorssuaq, an essential constituent of the granite. It usually forms ragged plates, pleochroic light yellowish brown to dark brown, though greenish biotite has been observed. Sometimes tiny biotite flakes are enclosed by felspar or compose small aggregates in the body of the rock.

Other constituents. Fluorite, usually interstitial, is the next most abundant and widespread accessory after biotite. Zircon as euhedral grains often enclosed by mica is common, and is quite plentiful in the radioactive fine-grained granite mentioned from Nunarssuit. Orthite forms scattered grains. Iron ores are common accessories throughout the intrusion and accessory apatite is common in the Alángorssuaq outcrops of the granite.

(c) The Kitsigsut Syenite.

(i) The Indre Kitsigsut.

The north-western part of the Nunarssuit complex is occupied by a syenite body forming the skerries around Tulugartalik. Much of the intrusion lies under the sea and its full extent is unknown but it must run for at least 14 km in an east to west direction. The syenite which forms it is a massive coarse-grained rock, cut by regular widely-spaced joints in sets roughly at right angles, weathering to rounded outcrops coloured dark-brown in the vicinity of Tulugartalik, light-brown in the northern part of the skerries. Because of their rather pale colour on weathering the northern outcrops of the intrusion might indeed be mistaken for granite when seen from a distance.

Preferred orientation of minerals is seldom seen although banding due to concentrations of dark minerals is common (see Section VII). Xenoliths are generally scarce but at some localities small rounded inclusions of more basic cognate material are abundant. Aplites and pegmatites are scanty; some of the latter on and in the vicinity of Tulugartalik are of particular interest in containing notable quantities of zircon in tetragonal prisms several millimetres long. In the same locality zircon prisms of similar size are abundant in widely-spaced parallel steep planes marked by concentration of pyroxene in zones a few cm wide and cutting the banding of the syenite.

Two main varieties of the syenite are apparent in the field. One, a dark-gray rock weathering light-brown as in the northern islands or dark-brown as in Tulugartalik, somewhat resembles in hand-specimen the darker varieties of larvikite in the Oslo region though its felspars often show no play of colours at all and those that do are only faintly labradorized. The other is a pale gray or almost white rock sometimes veined and enclosed by the darker variety into which it can often be seen to pass.

The dark variety essentially consists of abundant perthite, some pale green or brown augite and olivine. The felspar is often almost cryptoperthitic and commonly the crystal boundaries are fretted as in the Nunarssuit Syenite. Green or colourless amphibole may occur and frequent accessories are biotite, apatite, and ore. In the pale variety, on the other hand, the felspars tend to be highly exsolved. Coarse patchy perthites in which the potash felspar may show typical microcline twinning are common, and discrete crystals of sodic plagioclase are frequently present. Intricate reaction textures involving albite and microcline are characteristic and myrmekite-perthite, an intergrowth of potash felspar and albite also found in the Ydre Kitsigsut and Nunarssuit syenites, is common. Clinopyroxenes resemble those in the dark syenite but are often partly replaced by amphiboles and biotite. Olivine seems absent. Accessory apatite, ore and zircon are common.

A chemical analysis of each variety of the Kitsigsut Syenite is given in Table I.

Compared with the Nunarssuit Syenite the Kitsigsut Syenite as a whole differs in the following respects. Quartz is rarely present and apatite is a relatively abundant accessory. The intrusion also differs from the Nunarssuit Syenite in containing a number of mappable basic or ultra-basic bodies of cognate origin. One, a xenolithic block about 100 m long, seen on the island nearly $^1/_2$ km north of the anchorage at Tulugartalik, displays a pronounced planar mineral layering dipping gently north; some of the bands are essentially composed of titanaugite; others consist largely of basic andesine and an augite pleochroic in green and greenish-brown tints. Elsewhere in the skerries there are several dyke-like bodies a few metres wide in the syenite, chiefly containing microperthite, olivine and augite along with some biotite.

(ii) The Ydre Kitsigsut.

The Ydre Kitsigsut are separated from the Indre Kitsigsut by some 8 km of open sea, and thus there can be no certainty that the syenites of these two groups of islands belong to the same intrusion. However, in view of the similarity between the material collected from the Ydre Kitsigsut and the dark variety of the syenite around Tulugartalik, it is quite probable that the two do belong to the same unit: accordingly the Ydre Kitsigsut syenite is dealt with here.

Owing to heavy seas, it was only possible to land on the two largest islands of the Ydre Kitsigsut group, Thorstein Islænder and its neighbour immediately to the west. As the surrounding islands have the same appearance it is most likely that they are formed of the same syenite as these two. This syenite is a massive coarse-grained rock, dark greenish-gray when fresh, weathering to rounded brown outcrops similar to those of the Nunarssuit Syenite and the skerries around Tulugartalik. It is made up predominantly of alkali felspar, together with clinopyroxene and olivine; hornblende, ore and apatite are also present but in smaller quantities. Quartz, biotite and zircon have been observed but are rare.

The felspars are usually complex on account of zoning. Clear lamellar-twinned cores of plagioclase with marked zoning pass outwards into cryptoperthite, chequered antiperthite or vein perthite. The potash felspar component of the perthite is microcline frequently showing grid-twinning. A striking feature of the felspar is the development of areas of myrmekite-perthite, an intergrowth of potash felspar and albite which simulates myrmekite and has apparently formed at the expense of cryptoperthite. It has been described by Sederholm (1916 p. 133) who also notes Geijer's account of it. Oftedahl (1948 p. 30) has illustrated its occurrence in nordmarkite in the Oslo region.

The pyroxene is a pale brown variety, 2V (+) 56°–59°, forming subidiomorphic crystals up to 5 mm. Sometimes dark inclusions give rise to schiller structure.

Olivine (fayalite) forms equant grains which reach 5 mm across in the coarsest syenite. When fresh these are yellowish in colour, but a greater or lesser degree of alteration has affected the mineral in most slices with the formation of ore, iddingsite and amphibole. Minute dendritic ore inclusions have been noted in a few crystals.

Hornblende, a greenish-brown variety, is not very plentiful; it often has replaced or been moulded onto pyroxene.

In the otherwise normal syenite on the west side of Thorstein Islænder a little steep banding is developed, and there are in addition scattered lenses and wisps enriched in mafic minerals on both the islands visited. Occasional small dark clots up to 20 cm across were seen on Thorstein Islænder, composed of brown biotite, pale green amphibole, apatite and ore. In one of these a little molybdenite was found, a mineral also occasionally present in the Indre Kitsigsut on Tulugartalik.

On Thorstein Islænder there are two areas of light-coloured mottled syenite, about 35 and 80 m across respectively, with fairly well-defined borders against the typical syenite. These bodies are composed of perthitic alkali felspar with highly irregular mutual borders, and pale brown clinopyroxene which is bordered or replaced by amphibole. Ore, apatite and biotite are scanty accessories. Olivine was not observed in thin section. Thus this rock type resembles the pale gray syenite of the Indre Kitsigsut.

On the island west of Thorstein Islænder the coarse syenite is transected by rarer dyke-like bodies of medium-grained syenite consisting of perthite, augite (2V ca. 57°) and fayalite (2V 48°) with accessory ore, apatite and quartz.

Late-stage leucocratic veins are very rare. One such vein, 50 cm thick, is fine-grained and gray in colour. The component minerals are quartz in two generations, sodic plagioclase, microcline and a little colourless pyroxene. Another of similar thickness but with less well defined margins is of variable grain-size. Its dominant constituent is sodic plagioclase, in addition to which there is sodic pyroxene and accessory ore, soda-amphibole and biotite, all associated with the pyroxene.

(d) The Biotite-Granite.

A fairly coarse-grained pink granite forms north-west Alángorssuaq including the mountain Angnikitsorssuaq (fig. 3). The total extent of the intrusion is unknown, its outcrop being interrupted by the sea, but its known breadth is of the order of 5 km. In the field it plainly differs from the Helene Granite in being conspicuously biotitic and in bearing numerous milky white quartz veins and lenses up to a metre or so wide distributed throughout its outcrop. It displays little variation, and no preferred orientation of minerals is visible in the field. The dark minerals it contains often tend to be concentrated in areas up to 1 cm broad but these are roughly equant and evenly distributed. Only at one locality have mafic mineral layers been observed (see Section VII).

The appearance of the granite in thin-section is as follows.

Quartz is common in polycrystalline areas up to about 1 cm across, often showing Boehm (deformation) lamellae.

Felspar. Microcline perthite, frequently with a coarse patchy structure, is common as is also twinned oligoclase or albite in crystals

Fig. 3. View of Angnikitsorssuaq (Biotite-Granite) from Quiartorfik. The smaller hill to the left of and behind Angnikitsorssuaq is Rødtop. Sánerut lies in the far distance. The Helene Granite seen on the right-hand side of the photograph is separated by the inlet in the centre foreground from the Biotite-Granite forming the peninsula in front of Angnikitsorssuaq. (Photo G.G.U., W.T.H.).

up to one or occasionally two centimetres long. The discrete plagioclase in many slices tends to idiomorphism.

Biotite in brown plates up to a few mm in length is a ubiquitous and moderately plentiful constituent, occasionally intergrown with green hornblende.

Hornblende is green in colour and may or may not occur. When present it is generally subordinate to biotite.

Accessories. Iron ore is a common accessory. Fluorite, zircon, sphene and apatite are also frequently present, the first often as interstitial areas with a purple tint in hand-specimen. Orthite is scanty.

Near its boundary with the Helene Granite south of Angnikitsorssuaq the Biotite-Granite grades into a minor marginal variant in which biotite is less conspicuous and quartz forms smaller areas than in the main mass of the intrusion.

Another marginal variety is seen in west Alángorssuaq on the north shores of the inlet east of the northern tip of Quiartorfik. This contains scattered oval or rectangular felspar phenocrysts in a comparatively fine-grained base comprising quartz, felspar, and fine-grained aggregates

In a few thin-sections which tend to lack quartz the felspar is almost wholly cryptoperthite containing a few antiperthitic patches and sometimes showing cores with faint plagioclase twinning. Examples from the Amitsuarssuk neighbourhood are characterized by areas of myrmekite-perthite identical with that described from the syenite of the Ydre Kitsigsut.

Most of the normal syenite contains crystals of albite-oligoclase practically always subordinate in quantity to perthitic felspar. Under crossed nicols, due to polysynthetic twinning in two directions, they present a "blocky" chequered appearance enhanced by antiperthitic patches of potash felspar.

The potassic and sodic components of some alkali felspars have been considerably exsolved to form vein perthite crystals which when simply twinned show a striking herring-bone pattern in slices cut roughly normal to the twin plane. Many felspars have been marginally replaced by irregular areas of late, deuteric, clear twinned albite which sometimes also fills the interstices between crystals.

Clinopyroxene together with the other dark minerals is often gathered into glomeroporphyritic clusters up to 1 cm broad. It appears to have been one of the first minerals to crystallize in the syenite and accordingly can be more or less idiomorphic, though xenomorphic grains filling interstices between felspars also occur. Individual crystals attain 4 mm in diameter in the normal syenite. In mafic concentrates (bands, lenses, streaks) they tend to be smaller than elsewhere and idiomorphic. In one mafic lens from south-west Nunarssuit they form highly elongated prisms but this habit is unusual.

In most of the Nunarssuit Syenite the pyroxene is a slightly zoned ferroaugite generally with schiller inclusions arranged in two sets of planes. Under low magnification the inclusions form either distinct parallelograms or impart a clouding which can be resolved under high magnification into innumerable opaque rods.

Often the pyroxene crystals are a pale mushroom colour in their centre and a paler brown or faint green at their margin; some are feebly pleochroic; 2V (+) varies from 58° to 64°, the higher values obtaining in the green margins of the grains. Similar high values occur in the centres of those clinopyroxenes which are uniformly gray-green in colour. The highest optic axial angles, 70°–72°, are shown by the brightly-coloured grass-green, presumably sodic, rims around certain augites. It is interesting to note that these crystals generally have a very irregular outline, the green borders projecting into the interstices between felspar crystals.

Augites from the vicinity of Amitsuarssuk are mainly a pale brown tinged with purple and only show grayish-green colours in thin marginal zones. Schiller inclusions display particularly delicate patterns and optic axial angles are lower than usual, being about 54–55°.

In the Itivdliatsiaq area the pyroxenes are even more unusual. Besides subhedral grains between the felspars they form small amoeboid inclusions in perthite. They are pale brown with rare and incomplete green rims. Schiller inclusions are totally absent from them and their optic axial angle is 51°.

The pyroxene in the quartz-rich syenite immediately east of the metavolcanic inclusions zone south of Kitdlavât is pleochroic in pale brownish-green to bright grass-green colours. It is absent from one hand-specimen of this rock where the only dark mineral is an amphibole.

Amphibole. The amphiboles are obviously late minerals that can be built onto other mafic constituents of earlier origin or form independent anhedral more or less interstitial crystals up to 4 mm long. Most, though not all, slices contain them. Their occasional absence or scarcity in the Nunarssuit Syenite is not considered greatly significant for they show no particular areal distribution pattern. In mafic bands and lenses they are scarce.

The most widespread and abundant variety is a green hornblende pleochroic X: light brown, Y: brown or greenish-brown, Z: olive- or muddy-green. Slight zoning to margins with Z: blueish-green is quite common. This amphibole typically forms an overgrowth on or a partial replacement of pyroxene but often forms independent crystals. Less commonly it constitutes thin incomplete rims round olivine and ore minerals, sometimes separating olivine from pyroxene or opaque minerals.

The other amphibole, less widespread but nevertheless of fairly frequent occurrence, is also green but displays a slight blueish tint; its pleochroism is X: pale brown, Y: pale green with faint blue tint, Z: pale green with definite blue tint, though the colours are sometimes rather more intense. It usually occurs in aggregates, often including an unusual biotite, which may fill the interstices between other minerals or, together with ore, constitute areas which judging from their outline represent pseudomorphs of olivine, a conclusion strengthened by the observation that this amphibole sometimes forms thin rims round olivine or definite olivine pseudomorphs.

Both the amphiboles just described can develop thin bleached zones against fresh or altered olivine and can either coexist as individuals in the same thin-section or be combined in a single crystal as continuous or discontinuous zones.

An apparently more sodic hornblende in the relatively quartz-rich syenite south of Kitdlavât is pleochroic in pale slate-gray to green colours. It is accompanied by a pleochroic green, presumably sodic, pyroxene.

Olivine. Small amounts of olivine occur throughout the Nunarssuit Syenite except near the metavolcanic inclusion zone east of Kap Desolation and in a biotite-syenite collected by Ussing at the northern end of Eqatdliartarfik. In this connection it is significant that, as already noted, the syenite south of Kitdlavât and east of Kap Desolation is relatively quartzose and can lack pyroxene, amphibole being then the sole dark mineral phase.

The olivine crystals when fresh are pale brown in hand-specimen and frequently show cleavage. They measure up to 3 mm long and are usually xenomorphic. Even in mafic concentrates they are less well-formed than the associated pyroxene. Under high magnifications they are occasionally seen to contain minute inclusions of dendritic ore which have regular, parallelogram or lenticular form. Determinations from eight slices gave 2V 48–51° indicating Fa_{95-100}.

Most olivines, whether in the normal syenite or mafic concentrates, are partly or wholly altered to other minerals. Perhaps the commonest pseudomorphs consist of iddingsite, ore and colourless amphibole. Some comprise ore and blue riebeckitic amphibole. Others consist of ore and yellowish-green serpentine.

Mica. Biotite (lepidomelane) pleochroic X: pale brown or straw, Y = Z: reddish-brown or dark brown, and with occasional marginal zones showing slight greenish tints, is a common constituent, though rarely exceeding 1 per cent of the syenite. It is virtually absent from the syenite south of Kitdlavât and the mafic bands and lenses. Generally it forms reaction rims round ilmeno-magnetite surrounded by felspar. Some of these rims are single crystals. When, as occasionally happens, an ore unit lies partly within felspar and partly within pyroxene it developes a biotite rim against felspar but a thin hornblende rim against the pyroxene. Thus it seems that ilmeno-magnetite will only develop lepidomelane rims against felspar. This might explain the lack of biotite in mafic streaks and bands though it must be pointed out that in such concentrates hornblende rims between pyroxene and ore are also absent.

Biotite occurs as a essential mineral independent of ore in two samples of Nunarssuit Syenite and in mafic clots within the syenite in Alángorssuaq. One of the syenite samples, from west of Helene Havn, contains biotite crystals up to 3 mm across. In the other, called "light syenite" by Ussing who collected it from the northern end of Eqatdliartarfik, olivine is absent whilst pyroxene is subordinate to hornblende and biotite, the last mineral forming large flakes with X: light brown, Y = Z: reddish-brown or umber.

Another dark mica is scantily present in many syenite specimens containing the pale blueish-green hornblende described above. Its pleochroism is X: reddish-brown, Y = Z: olive-green or brownish-green. Absorption is roughly equal in all three optical vectors. This is the same variety as that described from the Western Layered Syenite of the Kûngnât Complex by Upton (1960 p. 72) who suggests it to be the lithium mica cryophyllite.

Ores. Ilmeno-magnetite occurs in small quantities in all slices examined, forming grains—mostly up to 0.8 mm but occasionally attaining 1.5 mm in size—which can be interstitial or idiomorphic and thus apparently of two generations. In pyroxene-rich bands and lenses it tends to be interstitial. In the normal syenite it is usually associated closely with other coloured minerals and sometimes forms lozenges in parallelism within hornblende. A symplectic intergrowth of ore and hornblende occurs in one thin-section.

Quartz occurs in about two-thirds of the slices examined as interstitial anhedral areas up to 3 mm long of obviously late origin. Generally it does not exceed 5 per cent by volume of the rock but slightly greater quantities occur in specimens from just east of the metavolcanic inclusion zone south of Kitdlavât. It appears to be totally absent from the syenite around the inner part of Amitsuarssuk and from mafic concentrates but its absence in some slices from other parts of the intrusion may be purely fortuitous owing to the coarse grain-size of the rock and the small area of the slice.

Accessories. Apatite is ubiquitous as euhedral elongated prisms up to 0.7 mm long usually embedded in coloured minerals, including ore.

Zircon, present in about a quarter of the rocks that have been sliced, forms euhedral crystals which are usually small though some 2–3 mm long have been found. One zoned crystal has been seen.

Fluorite occurs in two samples. Carbonate (?siderite) and aenigmatite have been found only once.

(iii) Minor variants.

The minor variants of the Nunarssuit Syenite take up a disproportionately large section of this paper considering their small areal extent.

The marginal facies of the Nunarssuit Syenite.

Towards much of its contact with the Helene Granite, and to a lesser extent near the Julianehåb Granite basement, the normal Nunarssuit Syenite passes gradually into a marginal phase up to 100 m wide with textural peculiarities slightly reminiscent of those shown by typical hornfelses and perhaps induced by heat from the interior of the intrua few mm wide of biotite and hornblende. It encloses a few oval or rectangular xenoliths up to several metres long of a biotite-granite slightly less coarse-grained than the Biotite-Granite on Angnikitsorssuaq, and passes gradually into coarse-grained Biotite-Granite well exposed on the headland at the entrance to the inlet. The granite at that headland contains numerous felspars 1–2 cm long, quartz in areas 0.5 cm broad and biotite in aggregates 0.5 cm in width; it encloses and veins some xenoliths, which are variable in texture, resemble the nearby marginal phase of the granite, have vague outlines and are aligned in trains parallel to the general trend of the Biotite-Granite boundary in the vicinity. Both they and their host are cut by aplite veins.

Aplite and pegmatite veins are not uncommon in the Biotite-Granite of west Alángorssuaq but their greatest development is outside and near the north-eastern margin of the intrusion in the higher parts of the hills several hundred metres south-east of Rødtop. Here, for a few hundred metres from the contact of the Biotite-Granite, pegmatite and aplite veins up to several metres thick presumably derived from the Biotite-Granite penetrate the Julianehåb Granite and green-schist country rocks of the intrusion. The veins dip gently, thin out with increasing distance from the Biotite-Granite and often show a banding parallel to their lengths due to the alternation of thin pegmatitic and aplitic layers grading into each other. This is emphasized in places by slight concentration of dark minerals in thin impersistent concordant folia.

The veins contain moderate amounts of quartz and abundant well-twinned microcline. In hand-specimen the latter is often an amazonite or rose-coloured; both varieties are frequently associated intimately and grade into each other. Green mica occurs and fluorite is common in small quantities. Zircon and occasional beryl crystals a few mm long have been found.

(e) The Nunarssuit Syenite.

(i) Field Appearance.

The Nunarssuit Syenite is a remarkably uniform intrusion at least 24 km long and 13 km wide, the monotony of which is relieved mainly by concentrations of dark minerals in either bands, streaks or clots. Repeated banding is so strikingly developed in the south-west and west of Nunarssuit that it will be described separately in a later section of this paper. Throughout the rest of the outcrop of the intrusion there are isolated streaks or bands up to 6 cm thick which vary considerably in strike and dip and are often steeply inclined. Mafic clots have been seen only along the Alángorssuaq shores of Torssukátak and at two localities in Nunarssuit—the shore of Tasiussaq and the Iserfiluk pen-

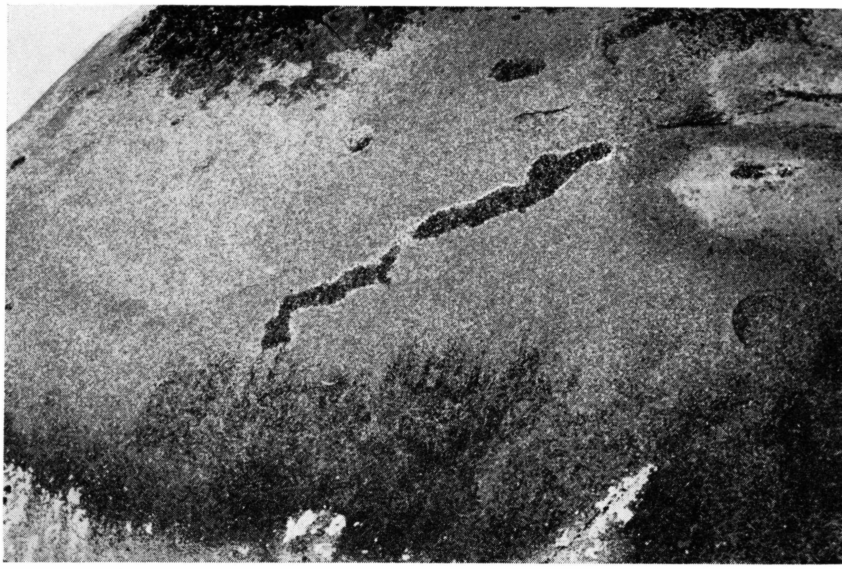

Fig. 4. Mafic clots with leucocratic rims. Nunarssuit Syenite, northern shore of Torssukåtak, about 1 km west of Graahs Havn. (Photo G.G.U., W.T.H.).

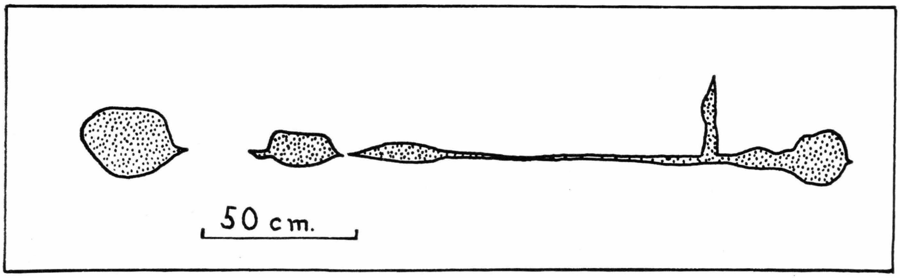

Fig. 5. Mafic "veins" in the Nunarssuit Syenite swelling into bulbous areas. East of the entrance to Eqatdliartarfik. Drawn from a field sketch. (T.C.R.P.).

insula. They mainly consist of stumpy pyroxene crystals up to 1 cm long, green amphibole and brown biotite in various proportions, and vary between a few cm and about a metre in length. Their outline which is rounded, oval or irregularly lobate may be vague or distinct. Some possess a thin felspathic outer shell (fig. 4) and one near Stærkodder Havn shows repeated mafic and felspathic concentric shells. Mafic concentrates of a different type occur east of the entrance to Eqatdliartarfik where the syenite contains coarse-grained mafic "veins". These occasionally swell into bulbous areas (see fig. 5) though for the most part they are planar. Their origin thus seems late and controlled by planes of structural weakness.

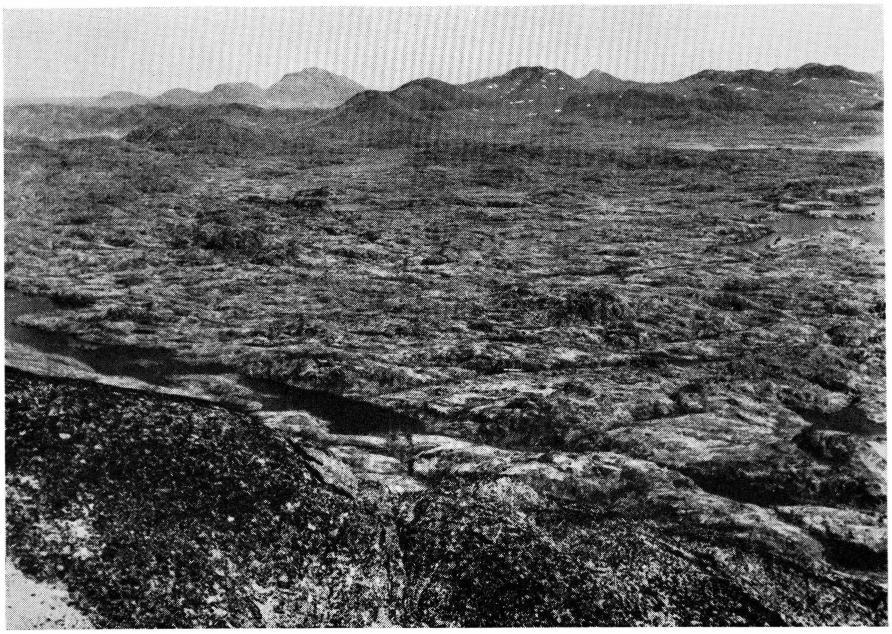

Fig. 6. View south-east across Nunarssuit from 340 m summit south of Peru Havn. Malenefjeld in the distant left. But for the top left-hand corner of the picture the area is entirely Nunarssuit Syenite. (Photo G.G.U., T.C.R.P.).

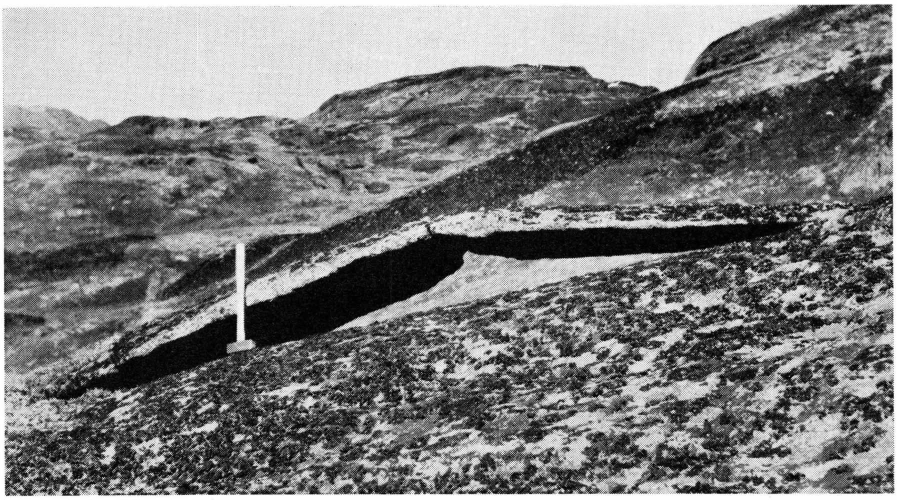

Fig. 7. Exfoliation weathering. Due to expansion on weathering a large slab of syenite has split away and arched upwards from the bedrock. (Photo G.G.U., T.C.R.P.).

For the most part the normal syenite is a coarse-grained massive rectangularly-joined rock, devoid of any internal contacts, though locally it grades—without compositional change—into medium-grained syenite.

Its uniformity is matched by that of the terrain it gives rise to within the interior of Nunarssuit, low ground covered by grasses, moss and *Empetrum* and slightly diversified by numerous syenite outcrops rising gently above the concealed areas (fig. 6). Many of these exposures have disintegrated to brown gravel *in situ* and much of the rock that still remains coherent shatters readily into its constituent mineral particles when struck with a hammer.

Large exfoliation domes due to expansion by weathering of uniform massive syenite with widely spaced joints (see fig. 7) characterize inland exposures but are absent from the areas nearest to the sea and from exposures with closely-spaced jointing.

The intrusion is extensively weathered, usually to a brown colour though reddish tints prevail on the coast of south-eastern Nunarssuit near Itivdliatsiaq. Fresh rock is dark gray-green in colour and can only be collected from water-worn exposures. A faint play of colours like that typifying larvikite has been seen in the felspars of the syenite around Amitsuarssuk.

(ii) Microscopic Petrography of the normal syenite.

Felspar. Because of its coarse grain-size modes of the syenite are difficult to obtain but it can be fairly confidently said to consist of about 85 per cent by volume of felspar, mostly as xenomorphic or roughly rectangular crystals 0.4 to 0.7 cm long though some crystals measure up to 3 or 4 cm in length; these phenocrysts tend to occur near the Helene Granite where they may be xenocrysts derived from the granite.

Almost invariably the syenite is massive and its felspars are arranged haphazardly but sometimes they occur in parallelism when they are more or less tabular and on the whole smaller than in the rest of the intrusion.

All the felspar crystals whether megascopically idiomorphic or not exhibit under the microscope irregular boundaries of variable complexity.

Most of the felspar is perthitic. Perhaps the commonest crystals are those with a homogeneous or cryptoperthitic core of alkali felspar (sometimes containing small blebs of grid-twinned microcline) passing with concomitant slight zoning into a vein perthite margin. The potash felspar in the marginal perthite can show microcline twinning and is generally slightly turbid with alteration. The exsolved albite associated with it may exhibit very thin polysynthetic twin lamellae and is clear and unaltered. Where two alkali felspar crystals lie in contact each may possess a thin albite rim continuous with the plagioclase in its marginal perthite, the boundary between the two albite rims being highly denticulate. Similar relationships have been described above from the Helene Granite.

Pyroxene is a bright green monoclinic variety, pleochroic from yellowish-green to bright grass-green, sometimes surrounded by amphibole.

Accessories. Zircon is ubiquitous; when enclosed by pyroxene it can be anhedral. Small amounts of ore, astrophyllite, aenigmatite, carbonate, biotite, and apatite in minute grains may occur. Quartz in one slice contains microscopic radiating aggregates of a pale brown moderately birefringent mineral identical in thin-section with elpidite in the Ilímaussaq granite according to Dr. E. Hamilton who kindly examined the material.

(f) Late-stage Acid Rocks within the Nunarssuit Syenite.

The late-stage acid rocks associated with the Nunarssuit Syenite fall conveniently into three groups: (i) alkali granites, (ii) spotted soda granite 'dykes', (iii) pegmatites. The first two are similar in mineralogical composition but differ considerably in their mode of occurrence. Although the spotted dykes and pegmatites are often also very similar mineralogically the pegmatites are usually simpler than the granite dykes, and their texture is altogether different from that of the dykes.

(i) Alkali Granites.

The Kitdlavât Granite and the soda-granites north-east of Itivdliatsiaq are comparatively large bodies of alkali granite. A few smaller lenses 6–8 m thick, which are not shown in plate 3, also occur in the syenite, e. g. 1 km south of Helene Havn, 3 km S.S.E. of Kangerdluluk and on the north shore of Ilua.

The Kitdlavât Granite.

This forms the summits of the highest mountains in Nunarssuit, Kitdlavât and the 728 metre high mountain to the north. It is laccolithic in form, having a planar lower contact dipping gently east at 12–26° and an upper contact which is much less regular, being steeper and sometimes vertical, except in the northern extention of the granite where it narrows to form a thin sheet south of Mercurius Havn.

The granite is medium- to moderately coarse-grained light greenish-gray when quite unaltered but normally gray. Weak layering, due to the concentration of mafic minerals in layers 2–3 cm thick and 10–30 cm apart, and slight felspar lamination are locally developed parallel and near to the base of the laccolith east and north-east of the summit of Kitdlavât. On the east ridge of the mountain the granite contains clots up to 40 cm across which are usually elongate and consist entirely of stumpy amphibole crystals averaging 2 cm in size.

The contact between the Kitdlavât Granite and the Nunarssuit Syenite is always sharp and distinct. The granite sends only a few thin veins into the syenite and does not develop a marginal phase against the latter. A few isolated lenticular inclusions of hornfelsed metavolcanics occur near the base of the granite.

Two granitic sheets belonging to the spotted dyke group cut the Kitdlavât Granite. Both trend N.N.E. and dip steeply west. The larger, in which the spotted texture is only weakly displayed, is 4–6 m thick and can be traced for 2 km.

Only one small area of pegmatite was seen in the granite. This contains large crystals of intergrown aegirine and amphibole, and small clusters of zircon.

The Kitdlavât Granite is the least sodic of the alkali granites. Its normal constituents are alkali felspar, quartz, amphibole and pyroxene: aenigmatite is quite plentiful in one specimen. Ore, zircon, fluorite and very small radiating aggregates of elpidite have been observed as accessories, but none of these is widespread. Small serpentinous aggregates in one slice are highly reminiscent of olivine pseudomorphs.

Felspar, cryptoperthite or microcline vein-perthite, forms xenomorphic or subidiomorphic crystals with roughly rectangular outlines and occasional denticulate boundaries between adjacent grains. A little deuteric albite sometimes occurs.

Quartz occurs both interstitially and as small round inclusions in perthite and—less frequently—amphibole. Intersecting trains of minute pores often traverse the grains.

Amphibole was late in crystallizing. It forms anhedral grains up to 5 mm across which are pleochroic X: light brown, Y: brown, Z: olive or brownish-green and sometimes surrounded by a deep blue rim. In addition interstitial aggregates of duck-egg blue amphibole occur in some slices and in others microlites of sodic amphibole are enclosed by felspar.

Pyroxene is found in specimens from the basal part of the Kitdlavât Granite, especially in the mafic layers. It is normally a primary precipitate, occurring in subidiomorphic crystals surrounded or even replaced by hornblende, and has been extensively altered along cracks to red-brown material. It is strongly coloured, pleochroic from yellowish-green to strong grass-green, and generally zoned. The pale brown centres of some grains have 2V (+) 59° but the green crystals have 2V (+) 70–78°. Occasionally a little late sodic pyroxene is present in slices lacking pyroxene as a primary precipitate. One such slice contains about 4 % aenigmatite in deep red pleochroic crystals up to 4 mm across.

Soda-granites of south-east Nunarssuit and elsewhere.

Two types of soda-granite in south-east Nunarssuit can be distinguished by their appearance in both hand-specimen and under the microscope. One type, a medium- or medium-coarse-grained gray aenigmatite granite, forms a steep-sided oval body about 1 km × 450 m in the syenite north-east of Itivdliatsiaq, another smaller mass seen on the shore nearby, and many thin veins around these localities. The small lenses elsewhere in the syenite are of a similar but finer-grained granite.

The other type is a rather fine-grained granite studded with small equant amphibole grains measuring 2–3 mm across: It contains a few syenite inclusions and also one aenigmatite-granite xenolith showing that the aenigmatite-granite is the older. All these soda-granites have sharp contacts against the surrounding Nunarssuit Syenite.

Under the microscope the aenigmatite-granite is rather similar to the Kitdlavât Granite, but is seemingly more sodic. Aenigmatite, often the main dark mineral in the rock, is always present in subhedral grains up to 3 mm long which have crystallized later than the felspar but earlier than the other coloured minerals. The pyroxene, when present, is aegirine of late development, and is frequently intergrown with soda amphibole or associated with aenigmatite. No primary precipitate hedenbergitic pyroxene is seen. The amphibole is a sodic variety, pleochroic from light lilac-gray to deep blueish-green. The accessories are astrophyllite, zircon, fluorite, biotite, ore and apatite, the first two being the most widespread. The astrophyllite is usually associated with the aenigmatite.

In the fine-grained granite of the younger sheet numerous sodic plagioclase laths form a felt around larger perthite grains. Quartz occurs as xenomorphic crystals up to 3 mm across and also as much smaller equant grains in the matrix. The sodic amphibole crystals are roughly square or subrectangular in outline, but their margins are indented and they enclose many small inclusions of quartz and felspar. There are also abundant small microlites of blue amphibole in the felspars. The margins of the amphibole crystals are intergrown with a little aegirine. In contrast with the aenigmatite granite, this granite contains no accessories.

(ii) Spotted Granite 'Dykes'.

These granitic dykes are particularly prominent in south-west and south Nunarssuit, where they sometimes attain a thickness of 10 m and can be traced for as much as 2 km. Elsewhere they are sparsely distributed.

The spotted granite dykes are generally steep. They have distinct sharp contacts against the syenite except where pegmatite has developed along the margin of the dyke.

The granite forming the dykes is a rather fine-grained gray rock characterized by round black poikilitic amphibole crystals up to 1.5 cm across giving a spotted appearance to the rock. Its microscopic petrography is as follows.

Felspar. Microcline vein perthite forms rather well-shaped rectangular crystals up to 4 mm long, which sometimes show 'herring-bone' twins. There is some deuteric albite as replacement patches around the margins of perthites and as small lath-shaped crystals.

Quartz. Although anhedral crystals reach 3 mm across, most of the quartz is in equant grains up to a mm in size. Rarely a coarse intergrowth with felspar is developed. Undulatory extinction is sometimes shown.

Amphibole is sodic, being pleochroic from light greenish-brown to deep indigo or nearly opaque in the maximum absorption position, and is poikilitic, enclosing both felspar and quartz. In one slice the enclosed perthite, although superficially idiomorphic, proves to have an uneven boundary against the amphibole which extends into the felspar as small peg-like protuberances. The felspar in this specimen contains microlites of blue amphibole.

Aegirine is generally associated and intergrown with amphibole or aenigmatite. When independent of these minerals it is interstitial.

Aenigmatite, although not always present in slices, may be quite plentiful. It forms subhedral or anhedral crystals up to 2 mm long, and is sometimes enclosed in amphibole.

Accessories. Of these only zircon is ubiquitous. Astrophyllite is quite common and occurs in close association with aenigmatite when the latter is present. Fluorite, ore and biotite have also been found.

(iii) Pegmatites.

Pegmatite veins occur throughout the area of the Nunarssuit Syenite although they are scarce in the south-east part of the massif. Similar veins are found cutting the Helene Granite and also cut the Julianehåb Granite south of Kangerdluluk as far as 2 km from the margin of the syenite. The pegmatite veins trend in all directions and vary from vertical to horizontal in attitude. They reach a thickness of 4 m but there are in addition large bodies of pegmatite, one east of Eqatdliartarfik and the other in the country rocks 3.5 km south-east of Kangerdluluk, which reach 400 m × 150 m in size.

The pegmatites are characteristically very coarse-grained assemblages of felspar (sodic plagioclase and microcline perthite), quartz and

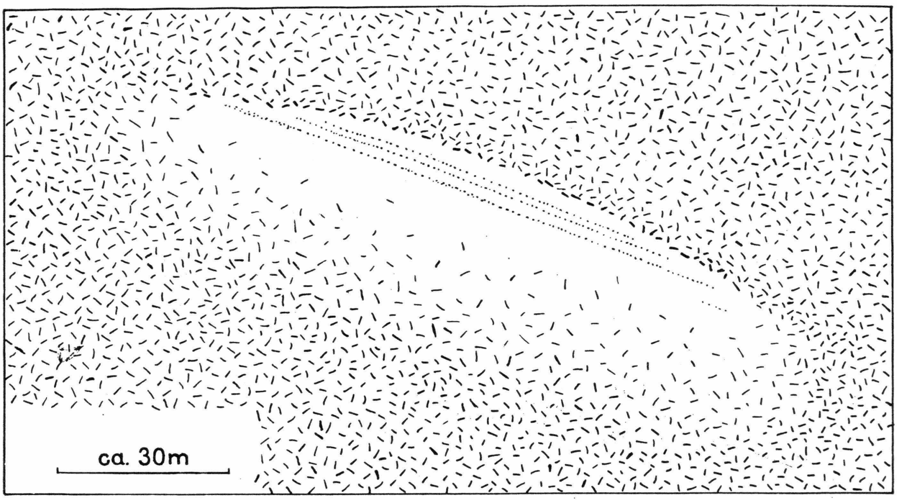

Fig. 8. Diagrammatic cross-section of one of the pockets of leucocratic syenite, illustrating its form and relations with the normal Nunarssuit Syenite. (T.C.R.P.).

sion. It contains phenocrysts (with vein perthite margins and cores of cryptoperthite or, sometimes, faintly twinned plagioclase) that in the field appear idiomorphic. But microscopic study reveals that what appears to be their outline in hand-specimen is in fact only the boundary between a kernel virtually free of inclusions and an irregular rim containing numerous pyroxene blebs. The medium- or rather fine-grained matrix of the rock is largely anhedral microcline-perthite; some antiperthitic plagioclase occurs together with pyroxene and a little anhedral or even interstitial olivine. Biotite is very scanty. Quartz, commonly present and often distinguishable in hand-specimen, can slightly exceed 5 per cent by volume of the rock. Ore, apatite and zircon are accessory.

Leucocratic syenites.

At two inland localities, north-east of Agdlerûssat avangnardlît and 2 km south of Peru Havn, there are small pockets of leucocratic syenite between 60 and 150 m wide which are particularly interesting on account of their form (see fig. 8). Their upper surfaces are arched but generally dip eastwards and bear sharp contacts against the normal syenite. Downwards they grade into the normal syenite. Within a metre from their tops they show a faint but nevertheless definite banding due to concentrations of dark minerals in thin bands 25–40 cm apart dipping eastwards roughly parallel to upper boundaries of the pockets.

In thin-section the rock composing these bodies is seen to be mainly chequered antiperthitic albite. There is some microcline perthite and the coloured minerals, which compose about 5 % by volume of the rock,

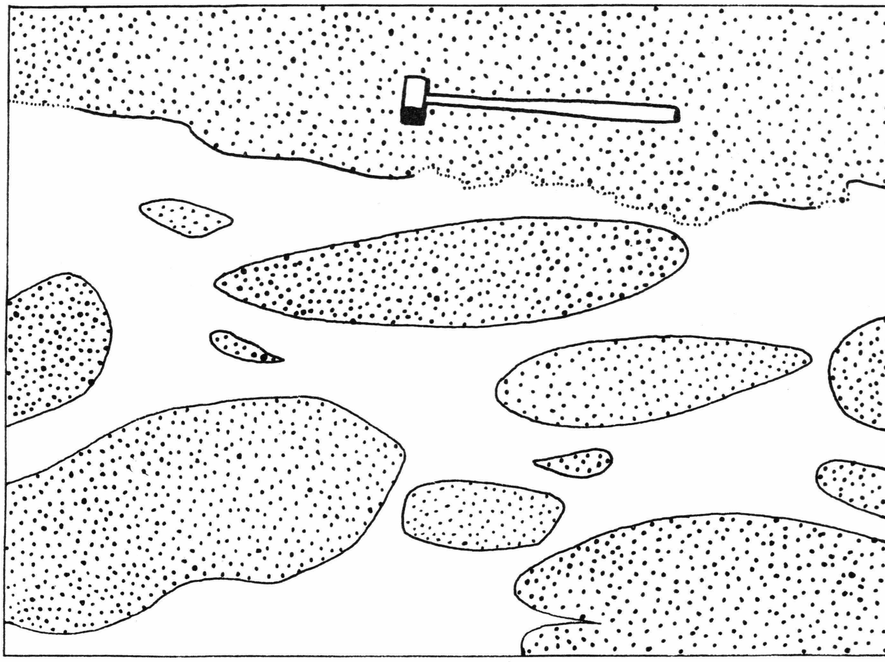

Fig. 9. Rounded-oval inclusions of porphyritic Nunarssuit Syenite in the upper part of the leucocratic sheet north of the entrance to Tasiussaq. Drawn from a photograph. (T.C.R.P.).

comprise colourless pyroxene, a little green hornblende, biotite, ore and aggregates of secondary brown mica and blueish-green amphibole

Another sort of leucocratic syenite occurs in the normal syenite. On the west coast of Nunarssuit, between Amitsuarssuk and Tasiussaq, a relatively fine-grained pale gray weakly laminated syenite mass 10–20 m thick with a sharp uneven upper contact dipping eastwards cuts and sends veins into the surrounding normal syenite which here is porphyritic. Inclusions of the latter within the leucosyenite (fig. 9) seem from their form to have been plastic when enveloped.

East of Mercurius Havn a rock indistinguishable from that in the upper part of the mass just mentioned forms a sheet 10–15 m thick with sharp lower contact dipping east at about 25°. This sheet is traceable inland from Torssukátak for nearly a kilometre and bears lenticular inclusions of hornfelsed metavolcanics up to 5 m thick (fig. 10) in its lower parts; towards its top it contains faint mafic bands 2–10 cm thick concordant with the general form of the body. Like the mass described in the previous paragraph it lies structurally below the main level of layering in the Nunarssuit Syenite. Both leucosyenite bodies are also very similar in thin-section under the microscope, containing perthite

Fig. 10. Eastward-dipping sheet of leucocratic syenite containing metavolcanic inclusions. In the Nunarssuit Syenite on the southern shore of Torssukåtak 500 m east of Mercurius Havn. (Photo G.G.U., T.C.R.P.).

85 %, quartz 6–8 %, coloured minerals 7–9 % and accessory zircon and pale blue-green amphibole. The felspar is exsolved vein perthite in crudely rectangular crystals up to 3 mm long with highly denticulate mutual contacts and often simply twinned to show a "herring-bone" perthite pattern. From textural relations and its weak lamination felspar seems to have been the first mineral to crystallize. Quartz forms small equant grains either in the interstices of the rock or set along the boundaries between felspar crystals. The pyroxene is a pale brown frequently zoned monoclinic variety with 2V (+) 56–66° in anhedral crystals up to 1 mm wide displaying pale green margins. Fayalite forms subhedral equant grains up to 0.7 mm across, partly or wholly pseudomorphed by serpentine and ore. Primary ore is ilmeno-magnetite.

Medium- or rather coarse-grained leucocratic syenite occurs within the metavolcanic inclusion zone of south-west Nunarssuit and around metavolcanic inclusions between Helene Havn and Eqatdliartarfik. It may either partly or wholly enclose the metavolcanic inclusions, sometimes forming a fairly thin sheath around them, or occur as sheets usually no more than a metre thick cutting the normal syenite near the inclusions. Such sheets in south-west Nunarssuit dip east or north-east at 20–30 degrees.

Petrographically this pale syenite, which always bears sharp contacts against the normal syenite, varies a little between a cream- or white-coloured virtually pure felspar-rock and a pale gray syenite containing up to 7 % of coloured minerals and from 0 to 12 % of quartz. In one of the almost pure felspar-rocks the felspar is patch or vein perthite together with some antiperthitic chequered albite individuals. In another it is non-perthitic. In the quartz-bearing specimens it is vein perthite with some marginal deuteric twinned albite. All samples contain pale green clinopyroxene, the only coloured mineral of consequence. Zircon is a constant accessory and a little ore is often present. Small aggregates of biotite and blue amphibole occur in one slice and in another felspar encloses tiny biotite shreds.

Quartz-syenites of south-east Nunarssuit.

Because they are probably the youngest variant of the Nunarssuit Syenite intrusion the quartz-syenites of south-east Nunarssuit are the last to be mentioned. Yet they are the most widespread of variants, forming quite considerable areas south of Itivdliatsiaq and in the extreme south-eastern outcrops of the syenite west of Malenefjeld. They appear to have intruded the normal syenite in which they form very irregular often small bodies with sharp or gradational contacts and without marginal modifications except those involved in passages to normal syenite.

In hand-specimen they are light purplish-brown-coloured fine- or medium-grained rocks evidently with more quartz and a higher content of amphibole relative to pyroxene than the normal syenite. Their appearance in thin-section under the microscope is as follows.

Felspar. Patch or vein perthite is common and albite occurs as either subidiomorphic crystals (smaller than the perthites and sometimes forming interstitial aggregates) or a later deuteric product.

Amphibole predominates over pyroxene in most slices. There are two varieties, one a normal hornblende pleochroic in shades of khaki and olive- or blueish-green, the other, a relatively sodic variety, showing pleochroism pale slate gray—pale green—deep blue with green tint. The first variety forms anhedral crystals. The second occurs either rimming or intergrown with the first or as shreds and sheaves of acicular crystals enclosed in felspar or quartz.

Quartz occurs as anhedral interstitial areas or more angular crystals distributed along the boundaries between felspars. It forms up to 12 per cent by volume of the rock and often contains minute cavities or inclusions arranged in trains or concentrated in patches.

amphibole. The last, a sodic variety pleochroic from light brownish-green to deep greenish-blue, forms prismatic crystals with indented margins up to 30 cm long and 8 cm thick: these are normally arranged roughly at right angles to the borders of the vein. In addition some aegirine (intergrown with or replacing soda amphibole), fluorite, zircon and, in one vein, galena may be present. Sometimes the veins are slightly zoned by the development of finer-grained and even aplitic centres which may show subparallel mafic bands. Coarse-grained graphic intergrowths of quartz and felspar can be observed in the large pegmatite bodies. Occasional veins consist only of felspar and amphibole.

The pegmatite veins are usually much more radioactive than the surrounding rocks.

One pegmatite vein deserving special mention was found on the shore of Eqatdliartarfik. In this aegirine forms fresh prisms and radiating sheaves, and there is no trace of amphibole. The felspar is albite. The minor constituents are monazite and fluorite, the first as abundant yellow crystals up to a mm across yielding a pink metamict product. A semi-quantitative spectrographic analysis of a chip from this vein (kindly carried out by cand. polyt. IB SØRENSEN) showed a considerable quantity of lanthanum as well as cerium, indicating that La has substituted for Ce to a considerable degree in the monazite.

Very rarely fine-grained green veins, which do not fit into any of the three categories above, are found cutting the Nunarssuit Syenite. These do not exceed a metre in thickness and are highly siliceous, being composed of quartz (about 50 %), felspar, aegirine, a little biotite, ore and a mineral that may be elpidite.

(g) The Malenefjeld Granite.

(i) Field appearance.

Malenefjeld is a conspicuous and isolated mountain 493 m high situated on a peninsula at the eastern end of Nunarssuit. Much of this peninsula and the southern part of the island to the east are formed of a soda-granite referred to as the Malenefjeld Granite. The exposed area of this granite is greater than that of any other soda-granite in south Greenland, and the form of its outcrop suggests that an even larger amount is submerged under the sea. Unfortunately it was never possible to land on the islands south-east of Malenefjeld to verify this.

The Malenefjeld Granite is a rather homogeneous unit: only slight textural variations are met with in traversing the massif. It is sufficiently well-exposed to allow one to scan the inaccessible areas with binoculars and assert with confidence that neither significant variations nor structures due to the concentration of mafic minerals are developed.

The rock is a medium-coarse even-grained light gray granite stained slightly by iron oxides on weathered surfaces. For about 1.5 km along its contact north-west of Malenefjeld this granite passes into a narrow border-zone of quartz-syenite weathering to a darker brown than any of the granite outcrops and with porphyritic felspars up to a centimetre long. At Qagssîssaq, near the border of the granite, a small area of syenite is enclosed by rather inhomogeneous alkali granite.

The Malenefjeld Granite is nowhere seen in contact with the other members of the Nunarssuit complex; it is separated from the Nunarssuit Syenite by a narrow strip of basement granite. The reasons for regarding it as a (late) member of this complex are discussed in a later section.

(ii) Microscopic petrography.

Felspar in the Malenefjeld Granite is an alkali felspar which shows a certain degree of variation over the exposed extent of the intrusion and is xenomorphic, except when in contact with sodic amphibole and pyroxene of late development: the grains seldom exceed 5 mm in size.

In many slices the felspar is predominantly microcline vein perthite with a subordinate amount of sodic plagioclase. The microcline component of the perthite usually shows normal grid twinning: denticulate interfaces between perthite grains are common. Deuteric action has resulted in marginal replacement of perthite by albite; similar albite may extend into the interstices between the larger felspar grains.

Other specimens contain patchy microcline perthite and abundant albite which sometimes borders the perthite and enters into a coarse chequered or vermiform intergrowth with quartz. Towards the eastern part of the intrusion exsolution textures may be lacking in the felspars. Microcline showing an unusual irregular twin structure is extensively eaten into by or intergrown with replacive albite. Granular patches of albite and highly sutured crystal boundaries suggest a measure of reworking and recrystallization in some rocks from this part of the massif.

One specimen from the western part of the intrusion is unique in carrying fairly large (6 mm) crystals of zoned sodic plagioclase. The inner zones have idiomorphic outlines and are usually not twinned. A cryptoperthite border which can form graphic intergrowths with quartz commonly surrounds these grains.

Quartz is prominent in the Malenefjeld Granite. Although always anhedral it can form equant grains up to 5 mm across as well as small interstitial areas. Undulose extinction is common and deformation (Boehm) lamellae have been observed. Many of the larger individuals contain minute cavities and/or inclusions. Intergrowths of quartz with albite and perthite have already been mentioned above.

Mafic constituents. Sodic forms of amphibole and pyroxene are usually present in the granite. These are anhedral and were the last minerals to crystallize in the rock. Frequently the two are closely associated or intergrown, the pyroxene generally being peripheral to the amphibole, a relationship common in other soda-granite bodies, e. g. the Quincy granite described by WARREN (1913). Although they may be ambiguous, the intergrowths suggest that pyroxene has replaced amphibole.

The sodic amphibole is pleochroic from light lilac-gray shades to deep blueish-green—though the colours vary somewhat from specimen to specimen and even within a single slice. Very small ore granules form inclusions in some amphiboles.

The soda-pyroxene in many slices may reasonably be called aegirine on account of its strong birefringence and pleochroism from pale yellowish-green to light emerald green. Sometimes the pleochroism is not marked and the mineral is rather murky. Minute ore inclusions may contribute to this.

Very small microlites of blue amphibole and, to a lesser extent, aegirine are enclosed by the felspar in many slices.

In the west of the Malenefjeld intrusion and towards the syenite fringe on the north-west border the granite contains a rather different mafic mineral assemblage, more like that found in the Nunarssuit Syenite. The pyroxene, a primary precipitate, is a zoned hedenbergitic variety surrounded by hornblende showing X: light brown, Y: khaki, Z: olive green, which is generally rimmed by a bluer amphibole. In addition light blueish-green hastingsitic amphibole forms aggregates together with small amounts of mica resembling cryophyllite. Occasional aggregates of ore, iddingsite and blue amphibole are taken to be pseudomorphs after olivine.

In one rock the contrast between the sodic and syenitic assemblages of mafics is striking. The "syenite mafics", together with ore, a little associated biotite, and apatite, form glomeroporphyritic aggregates seemingly quite foreign to the enclosing granite which contains xenomorphic aegirine, blue amphibole and a little astrophyllite. The status of aenigmatite in this rock is not clear as it is associated with both "syenitic" and sodic mafics.

Accessories. Zircon is the most widespread accessory. Apatite is only found in rocks which have the "syenitic" mafic assemblage. A little ore is present in most slices, and scanty biotite may occur. Of greater interest is aenigmatite which, though far from ubiquitous, is fairly common in some specimens, and is often enclosed by or intergrown with aegirine, as it is also in the Quincy soda-granite (WARREN, 1913, p. 222).

Fig. 11. Zoned pegmatite cutting the Julianehåb Granite near the Malenefjeld Granite. The dark bands are rich in fine aegirine. (Photo G.G.U., T.C.R.P.).

Astrophyllite is rare, but has been identified with certainty. Some very small fibres are thought to be elpidite.

(iii) Pegmatites.

Pegmatites are absent from the western part of the Malenefjeld intrusion. Although some conspicuous zoned pegmatites run nearly horizontally along the lower part of the southern cliffs of Malenefjeld, pegmatite veins are most abundant along the northern margin of the intrusion and in the country rocks up to 400 m from the contact. They are particularly numerous on Qipingajâp nûa, where because of them it is difficult to locate the granite contact accurately: even to follow dolerite dykes up to this contact is not easy, so intensely are they ramified by pegmatites.

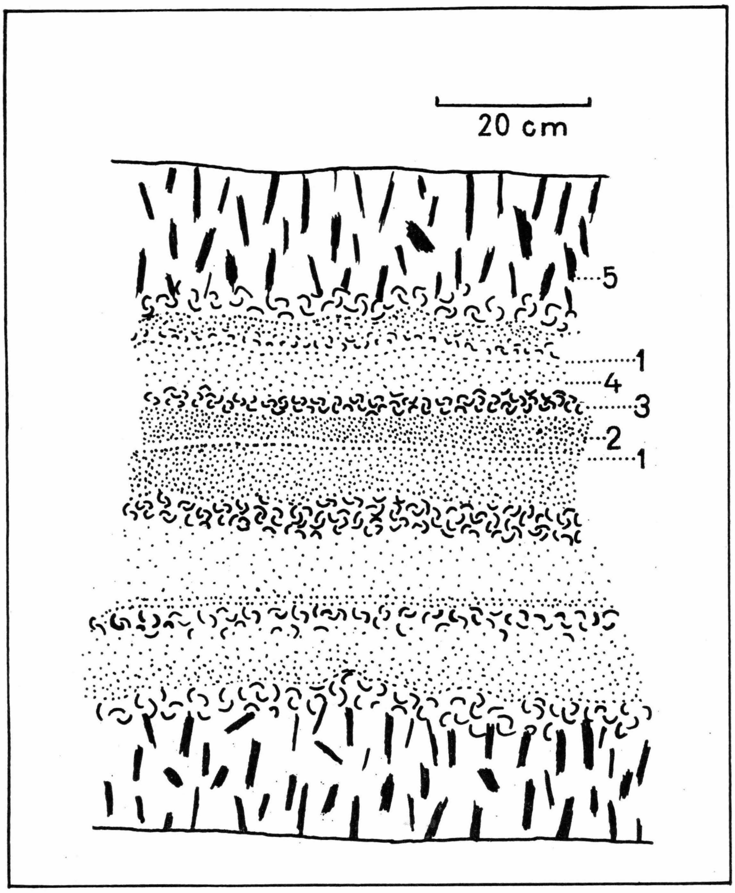

Fig. 12. Symmetrically zoned pegmatite in the Malenefjeld Granite. 1: rather fine-grained bands pink in colour due to the large amount of fine zircon and bastnaesite. 2: fine-grained green band rich in aegirine. 3: fairly coarse band consisting mostly of quartz, with some felspar and a little zircon and bastnaesite. 4: light green fine band with plentiful aegirine, felspar and quartz. 5: pegmatite band with large soda-amphibole-aegirine intergrowths, shown in black. Drawn from a field sketch. (T.C.R.P.).

The peripheral pegmatites and also those in the granite south of Malenefjeld reach 4–5 m in thickness and are characteristically zoned (fig. 11). The zones may or may not be symmetrically arranged: an example of a symmetrically zoned pegmatite is sketched in fig. 12. The zones consist of:

1) Pegmatite, composed of felspar, quartz and amphibole (black) intergrown with aegirine (green). Crystals of the last may be as much as 30 cm long by 4 cm thick, and are usually set roughly at right angles to the margin of the pegmatite. Although they are on the whole long

blades, their margins are very irregular and almost poikilitic. The aegirine generally rims and seems to have replaced amphibole (fig. 13). Skeletal tabulae of ilmenite up to 3 cm are occasionally developed and also tend to be set normal to the borders of the vein.

2) Thinner bands (or sometimes only lenses) with much quartz and often concentrations of fine-grained pinkish material. Where the latter is most abundant the radioactivity of the rock is unusually high. Specimens suitable for sectioning could not be obtained from the highly radioactive spots, but semi-quantitative analyses on a few chips showeld more than 1 $^0/_0$ Zr and 1 $^0/_0$ Y to be present. The most likely minerals

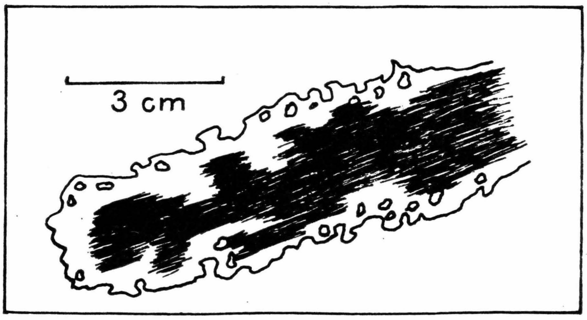

Fig. 13. Sketch of one of the large crystals of soda-amphibole (black) intergrown and replaced by aegirine (unshaded) in a pegmatite in the Malenefjeld Granite. (T.C.R.P.).

to carry these elements are zircon and xenotime. Some small grains were separated and X-rayed, and proved to be zircon and bastnaesite.

3) Quartzo-felspathic bands lacking in coloured minerals. These are cream-coloured and of variable grain-size.

4) Rather fine-grained green bands rich in aegirine. Under the microscope the quartz commonly shows undulose extinction and many minute cavities. The felspars are microcline and albite. The microcline sometimes exhibits typical grid-twinning, but more often displays the irregular "chess-board" twinning seen in microcline from the lujavrite of the Ilímaussaq intrusion (Ussing 1912, p. 159). Albite, often forming small laths with uneven outlines, is occasionally the only felspar present. Aegirine crystals are acicular and penetrate all the other minerals when small, but the larger grains have indented outlines and contain quartz and felspar inclusions. Rarely a little sodic amphibole is intergrown with the aegirine. The other minerals which are optically identifiable are zircon and fluorite.

At Qipingajâp nûa veins of spotted aplogranite occur in addition to the pegmatites. These are formed of microline, albite, quartz, sodic amphibole and aegirine, with accessory astrophyllite, zircon and fluorite. The 'spotting' is due to poikilitic grains of sodic amphibole intergrown with aegirine.

An isolated 3 m thick vein occurring about 1.5 km north of the contact of the Malenefjeld Granite is most likely a derivative of that granite. It contains quartz, microcline and albite, all with the same appearance as they have in the zoned pegmatites of the Malenefjeld Granite, and is conspicuous on account of its rusty colour which is due to the weathering of the abundant pyrite and ilmenite in it. A little pyrrhotite is also present, and brookite and sphene occur as alteration products of ilmenite. Zircon is plentiful as clusters of small grains.

IV. THE EXTERNAL CONTACTS OF THE COMPLEX.

Only the northern and eastern boundaries of the Nunarssuit complex are visible. From north-west to south-east the Biotite-Granite, Alángorssuaq Gabbro, Helene Granite, Nunarssuit Syenite and Malenefjeld Granite in turn lie in contact with the pre-Gardar basement.

(a) External contact of the Biotite-Granite.

In the hill-slopes east and south-east of Rødtop the contact of the Biotite-Granite with the basement is more or less vertical and transgressive. By means of frequent exposures it can be followed fairly closely from sea-level to a height of 300 metres. Owing to petrographic convergence the contact is difficult to make out in detail when the adjacent country-rocks are Julianehåb Granite but basic dykes of Gardar or earlier age in the latter do not continue into the Biotite-Granite. Against the hornblende schists south-east of Rødtop the Biotite-Granite passes into a fine-grained contaminated granitic rock forming a narrow marginal zone in which there are numerous dark angular blocks of fairly fine-grained schist apparently derived from the adjacent pre-Gardar green-schist belt. Veinlets of the fine-grained granitic rock cross these blocks in various directions and seem to be dilational for their opposite walls match each other and if the granitic material were to be removed from this xenolithic marginal zone the schist inclusions could often easily be fitted together to form large units. The inclusions themselves are homogenous and show no megascopically visible evidence of permeation by granitic fluids. They contain green hornblende, brown biotite, and alkali felspar, together with accessory ore grains surrounded by sphene reaction rims. Their metamorphic grade does not differ markedly from that of similar schists elsewhere in northern Alángorssuaq remote from the Biotite-Granite and other members of the Nunarssuit complex.

As already remarked in Section III the Biotite-Granite appears to be the parent of numerous gently inclined aplite and pegmatite veins cutting the pre-Gardar basement for several hundred metres from its contact with the complex south-east of Rødtop.

At the east end of the island 900 m north-west of the summit of Rødtop a small outcrop of green-schists, which seems to be an integral part of the Kobberminebugt schist belt and not a xenolithic mass, is intensely veined by granitic material derived from the Biotite-Granite constituting the rest of the island. On the island immediately to the north of this locality the Biotite-Granite again passes into a contact zone against green schists which it veins and permeates extensively, both the schists and the granite becoming highly modified.

(b) External contact of the Alángorssuaq Gabbro.

Near its western termination the contact between the Alángorssuaq Gabbro and Julianehåb Granite can be fairly accurately mapped in the hill-slopes rising several hundred metres above the lake east of Angnikitsorssuaq where it is demonstrably more or less vertical.

In the low ground of central Alángorssuaq its attitude is uncertain but probably steep.

For the most part the actual contact is concealed but it is visible at a small exposure about 1550 m south-west of the summit of Naujat qáqât. At this locality the Julianehåb Granite close to the contact is deficient in quartz, rather fine-grained, and highly recrystallized. It appears to have been locally remobilized by heat from the gabbro which it attacks and permeates for a few centimetres from the contact. Thin irregular veinlets of the granite ramify through and isolate wisps of the gabbro. At the contact the latter is fine-grained and highly altered. When followed for a few metres away from the contact it gradually becomes medium-grained.

(c) External contact of the Helene Granite.

(i) Alángorssuaq.

In Alángorssuaq the contact between the Helene Granite and its country rocks—the Julianehåb Granite—varies rapidly in strike; its dip, though also variable, is generally steep. It can be conveniently examined on the western shores of Naujat atât near a small headland where clean rock-surfaces clearly demonstrate a knife-sharp boundary between the Helene and Julianehåb granites, running irregularly for several metres. Medium- or fine-grained lenses of a basic hornblendic rock in the Julianehåb Granite—probably relics of pre-Gardar dykes—end abruptly at the contact and although the marginal Helene Granite generally bears rectangular or rounded alkali felspar phenocrysts about 2 cm and occasionally up to 4 cm in length it is locally aphyric and medium-grained for a few centimetres from its contact. Roughly 350 m west of here a knife-sharp contact between the Helene Granite and the Julianehåb Granite is extensively exposed. The contact can be mapped inland and is visible again 900 m west of the shore exposure as a clean-cutting boundary. From here it can be traced (though concealed) to the col on the south side of which it can be seen to be sharp and vertical. At this locality the Helene Granite at the contact is either of normal coarse texture or, in some places, a more even-grained variety with smaller felspars. A phase of the granite forms a horizontal vein intruding the Julianehåb Granite.

One or two hundred metres to the north-west, on the north side of a small valley, the contact is seen dipping west at 45° and a vein a metre thick derived from the Helene Granite intrudes the basement granite. The contact can be mapped from here to the top of a hill whence its trace descends steeply downhill to a large lake 2 km west of Naujat atât.

(ii) Nunarssuit.

The external contact of the Helene Granite is particularly well exposed and most accessible in the area between Helene Havn and Bangs Havn in Nunarssuit. For this reason and also because Wegmann (1938 pp. 98–105) to a large extent based his transformist interpretation of the Nunarssuit massif on his observations in this area the second author selected it for more detailed mapping on a scale of 1:10,000. It may also be mentioned incidentally that this ground illustrates a wide variety of Nunarssuit rock-types and can be recommended to anyone wishing to see the maximum amount of Nunarssuit geology in the minimum amount of time.

From the map of the Helene Havn area given in Plate 2 the transgressive nature of the Helene Granite contact is plainly evident. Moreover, in the field the contact between the Helene Granite and its country rocks is well-exposed and always knife-sharp: there is no suggestion whatsoever of any transitional contacts (contrast Wegmann 1938, p. 101).

Perhaps the best exposures of the contact occur on the shore immediately east of Emma Havn where the porphyritic marginal phase of the Helene Granite is well-developed and contains a few small sharply bounded inclusions of basement granite near the contact which abruptly truncates a dolerite dyke of north-easterly trend in the basement.

A little to the east, amphibolite dykes in the Julianehåb Granite are, together with their host granite, intruded by small, irregular, sharply-defined apophyses of the porphyritic marginal phase of the Helene Granite. This marginal phase also forms a lobe cutting and sending thin zig-zag veinlets into a 16 metres wide amphibolite dyke.

These facts suggest that this embayment of country rocks is underlain at shallow depth by the Helene Granite.

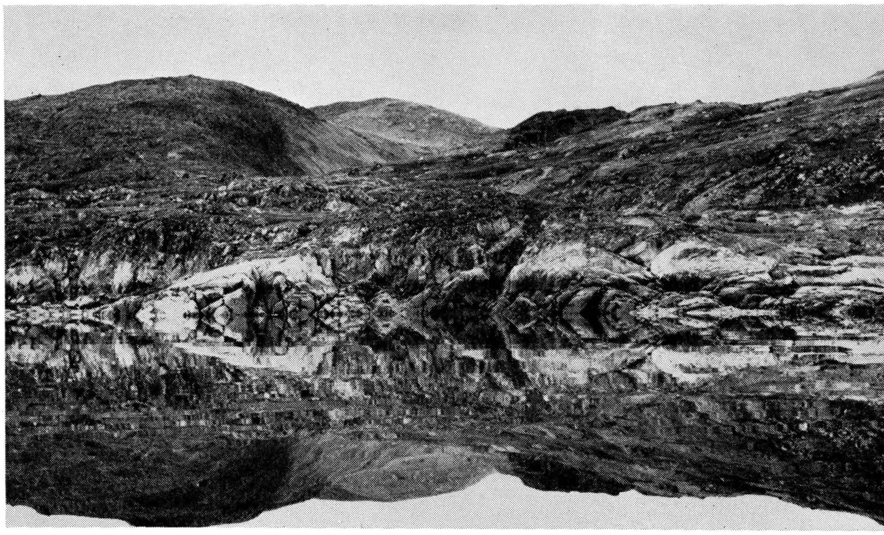

Fig. 14. View south from Torssukåtak of the external contact of the Helene Granite on the north-west side of the 251 m hill south-west of Bangs Havn. Helene Granite on the right, older rocks on the left. Below the summit of the hill in the background there is a distinct contrast between the light-coloured gravel screes of the Helene Granite and the darker older rocks. (Photo G.G.U., T.C.R.P.).

A little further east again the outer contact of the Helene Granite reappears on the shore, dipping outwards from the intrusion at 65°.

South-west of Bangs Havn the Helene Granite outer contact is very well displayed on the north-west and west side of a hill 251 metres high where it is obvious even from a considerable distance, being marked by the upper limit of yellow gravel screes (fig. 14). It is knife-sharp and dips outwards from the complex at various angles down to 40°. The marginal facies of the Helene Granite is absent here.

Close to the contact just south of the fault a large block of country-rock is completely enclosed by the granite which sends veins into the block sometimes following a pronounced jointing of north-easterly trend. This block may be a xenolith or the remnants of a roof pendant. The first interpretation is favoured by the fact that the outlines of the block and the boundary of the country-rock opposite match almost exactly, as if the block had been detached from the adjacent walls of the intrusion.

Immediately east of the 251 m summit small short apophyses of Helene Granite penetrate a dolerite of north-easterly trend.

Throughout its extent in Alángorssuaq and Nunarssuit the Helene Granite has effected little contact metamorphism of the basement. Slight recrystallization and the production of small amounts of new

Fig. 15. View south from the top of the 251 m hill south-west of Bangs Havn, showing the contrast between Nunarssuit Syenite terrain (large dome-shaped outcrops surrounded by gravel) on the right and Julianehåb Granite terrain (rougher light-coloured rock surfaces) on the left. The distant hills are Nunarssuit Syenite. (Photo G.G.U., T.C.R.P.).

biotite are the only contact phenomena noted in the country-rocks near the granite.

(d) External contact of the Nunarssuit Syenite.

The attitude of the Nunarssuit Syenite outer contact is not clear but appears to be vertical or dip outwards at a steep angle. Its approximate position is easily seen from a distance because of differential weathering, the syenite forming large rounded brown-weathering outcrops surrounded by patches of brown gravel, the Julianehåb Granite forming light-gray angular outcrops which do not weather to gravel (see fig. 15). Its exact position however is not readily fixed for along much of its length the marginal facies of the syenite passes into the basement granite through a transition zone up to 40 metres wide. The latter occasionally bears a brown hornblende not usually seen in either the Julianehåb Granite or the Nunarssuit Syenite. Slight evidence of introduction of soda from the syenite into country rock near the contact is afforded by sporadic small poikilitic or acicular sodic amphiboles but there is little sign of a marginal accumulation of volatiles like that around the Kûngnât complex except 1–2 km south of Kangerdluluk where pegmatites with quartz, sodic amphibole, and felspar are fairly abundant in both the outer part of the syenite and the adjacent Julianehåb Granite.

On the shores of the Malenefjeld isthmus the marginal facies of the syenite is rather fine-grained and lies in sharp contact with the Julianehåb Granite, abruptly transecting migmatitic structures in the latter.

The Gardar dolerites are highly recrystallized and sharply transected by the syenite. In the field the hornfelsed dolerites are compact, dark purplish-gray rocks, often weathering to a reddish-brown colour and finer-grained than their parents. In extreme cases they are completely recrystallized granular aggregates of plagioclase (An_{60-66}) colourless pyroxene and brown hornblende (X: very pale brown, Y = Z: reddish-brown) together with a little foxy-red biotite and ore. When less recrystallized they retain their ophitic texture although reddish-brown biotite is developed and augite (which is uralitized in the normal dolerite) is replaced by aggregates of colourless pyroxene.

(e) Outer contact of the Malenefjeld Granite.

Wegmann's (1938 p. 100) claim that the younger granite at Malenefjeld passes very gradually into Julianehåb Granite has not been substantiated. On the south coast of the Malenefjeld isthmus (i. e. at Qagssîssaq) the Malenefjeld Granite bears a sharp contact against basement migmatites and for about two metres from the contact becomes fine-grained. Veins of the fine-grained phase cut the country-rocks. On the north side of the isthmus the contact is again sharp and well exposed. It dips at about 30° west and for about one metre from it the intrusion becomes fine-grained. For a short distance to the north-east it runs under the sea but where it is next exposed on the shore west of Malenefjeld it is still sharp though the marginal facies of the intrusion is absent. Along the foot of the north-western slopes of the mountain the Malenefjeld Granite possesses a thin crumbly syenitic margin and the contact is difficult to discern though in one place it is manifestly sharp. A north-easterly dolerite dyke follows the contact closely in this neighbourhood and has been thermally altered by the granite with the consequent formation of new biotite.

North-east and east of Malenefjeld the contact is obscured by a considerable development of peripheral pegmatites and aplites: the former may be banded, the latter may be spotted by poikilitic soda-amphibole. Veins of these pegmatites and aplites occur as far as 400 m from the main granite mass. They are particularly conspicuous to the east on Qipingajâp nûa where they extensively penetrate an east-west dolerite dyke that has been metamorphosed with resultant growth of new biotite. In spite of these veins the sharp contact of the Malenefjeld Granite can occasionally be observed, as on the coast on either side of the channel between the Nunarssuit mainland and Qipingajâp nûa, where it dips steeply outwards.

Fig. 16. View from the southern slopes of Naujat qáqât looking south-west. Julianehåb Granite in the bottom left-hand corner: the Alángorssuaq Gabbro forms the low ground in the lower half of the picture: the Helene Granite of Alángorssuaq makes up the ridge in the middle distance: its contact with the gabbro is clearly visible slightly right of and below the centre of the photograph. Behind the banks of sea mist occupying Torssukátak the hills of Nunarssuit rise up to the skyline. (Photo G.G.U., W.T.H.).

V. INTERNAL CONTACTS OF THE COMPLEX

(a) Relations between the Alángorssuaq Gabbro and the Helene Granite.

Although the actual contact of the Helene Granite with the gabbro in central Alángorssuaq is often concealed it is easily mapped: the granite is almost fully exposed and the steep hills it gives rise to sharply contrast with the low ground occupied by the more deeply eroded gabbro (fig. 16).

Near the south-eastern end of the gabbro outcrop, a few hundred metres roughly south-west of the south-western extremity of the large lake at which the gabbro outcrop terminates, the contact is seen to be knife-sharp and vertical. It lies almost normal to the planar structures due to mineral parallelism in the gabbro nearby, though for a few centimetres from the contact these structures are destroyed by recrystallization. The granite becomes coarse-grained, almost pegmatitic, close to the contact and, like the adjacent gabbro, may contain large hornblende crystals a few centimetres long.

About 200 m west of the last locality, by a waterfall, the granite locally forms a minor aplitic phase against the gabbro. The contact is not seen but can be located within very close limits. It cuts steeply across a primary banding in the gabbro due to parallel mafic layers 1–4 cm thick. Aplitic veins like those in the granite cut across the banding in the gabbro.

Roughly 300 m north of the granite boundary and 150 m east of the powerful N.N.E. transcurrent fault crossing central Alángorssuaq a vein of graphic granite like some late-stage veins in the Helene Granite intrudes the gabbro and can be followed for a hundred metres or so towards the granite, in which direction it passes into a vein of normal Helene Granite and aplite several metres thick. The vein has sharp irregular boundaries and transgresses the banding of the gabbro. There seems no doubt that it joins on to the main mass of the granite and that but for discontinuous exposure it could be traced back to its parent.

Approximately 500 m west of the fault just mentioned the gabbro-granite contact can be seen to be vertical and sharp; exposures are good and the granite sends a vertical vein 15 cm wide into the gabbro.

West of this locality the gabbro is cut by a network of numerous thin leucocratic veins of uncertain origin. Their relationships to the Helene Granite are rarely seen but they are absent from the granite in the vicinity and one of them, a small microgranite vein, is abruptly transected by the margin of the granite.

The mappable boundary between the gabbro and Helene Granite terminates westwards at a large lake where it is ill-defined, the gabbro being extensively attacked by the granite to form a mixed-zone. In this mélange the granite envelopes innumerable rounded xenoliths of hybridized gabbro and penetrates the gabbro as irregular veins which often possess vague boundaries. It largely consists of rectangular alkali-felspars 1–2 cm long just like those in the normal granite, but sometimes loses quartz by reaction with gabbro. Pink aplitic veins traverse the hybrids.

(b) Relations between the Biotite-Granite and Alángorssuaq Gabbro.

The relations between the gabbro and Biotite-Granite close to the lake mentioned in the last paragraph are obscured by the activity of the Helene Granite but a number of veins intruding basic rocks on the west side of the hybrid zone seem derivatives of the Biotite-Granite.

Less ambiguous data are yielded by the tongue which the gabbro outcrop extends north-westwards from the western extremity of the largest of the lakes in Alángorssuaq. The boundary between this salient and the Biotite-Granite can be mapped uphill from heights of about

100 to 300 metres and can be shown to be more or less vertical. When exposed the contact is seen to be sharp. Against the boundary the Biotite-Granite may remain unmodified but more commonly, however, it passes into a marginal aplitic phase. Blocks of gabbro are enclosed by the granite which cross-cuts any planar structures that may be present in the gabbro and sends aplitic and pegmatitic veins into the latter.

(c) Relations between the Biotite-Granite and Helene Granite.

A few metres from the northernmost tip of the lake on the south-eastern side of the Biotite-Granite an aplite vein 3 m long and 5 cm wide intrudes modified Helene Granite in the hybrid gabbro-granite zone mentioned above. The western parts of the vein contain areas of pink Biotite-Granite with large felspars that project into the aplite. A few metres to the west, after a break in exposure, the margin of the Biotite-Granite intrusion is visible. There seems little doubt that this body is the parent of the aplite vein.

The contact between the Biotite-Granite and Helene Granite south of Angnikitsorssuaq is steep and transitional. Typical Biotite-Granite can be seen in the slabs—illustrated as "Nunarssuit Granite" in WEGMANN's (1938 p. 105) account—nearly a kilometre east of the landward termination of the inlet Angnikitsorssûp atâ. Moving south-westwards uphill from these slabs abundant exposures in Biotite-Granite show a gradual decrease in the grain-size of quartz whilst biotite becomes less conspicuous. About 150 m from the top of the hill this marginal phase apparently passes into a rather even-grained marginal phase of the Helene Granite of similar grain-size which when followed uphill rapidly becomes more coarse-grained and grades into typical Helene Granite without biotite, bearing felspars 1–2 cm long and quartz areas 0.5–1 cm wide.

A few hundred metres to the east the boundary between the two granites can be located within about ten metres but still seems transitional.

It is, however, not easy to decide whether the apparent passage between the two granites in this neighbourhood is due solely to close similarity of their marginal variants, or whether interaction has in fact taken place between them.

On the western shores of Alángorssuaq both granites are again seen to develop minor marginal variants but are separated by a strip of various granitic rocks wedging out to the east. The contacts of these granitic rocks are sharp, appear to be steep, and trend parallel to the general boundary between the Biotite-Granite and Helene Granite in the vicinity. Age relations are difficult to unravel. For example, at the head of the inlet the marginal phase of the Biotite-Granite can be seen at low-tide in sharp irregular contact with a finer-grained darker porphyritic granitic rock which becomes darker still for a few millimetres from the contact and shows a faint streaking near and parallel to the contact. Both rocks contain occasional small inclusions of an even-grained leucocratic granite, and the Biotite-Granite contains inclusions of a rock like the darker porphyritic 'granite'. Close to the northern edge of the dolerite dyke the darker porphyritic 'granite' is in contact with a more leucocratic porphyritic granite which forms veins trending roughly S.E. in the darker 'granite', encloses xenoliths of the latter, and can be followed for a few metres along the shore to the south of the dolerite dyke. Both these granitic rocks are cut by an aplite which is, in turn, cut by an even-grained granite, forming small steep lenses parallel to the general direction of the Helene Granite—Biotite-Granite boundary in west Alángorssuaq and not unlike some specimens of the Biotite-Granite.

South of this again, along the southern shores of the inlet, there is a medium-grained biotite-hornblende-granite which may be a marginal phase of the Helene Granite for it seems to pass into the latter. A similar rock occurs in northern Quiartorfik where it contains a wedge of fine-grained porphyritic granite up to 50 m wide.

Since its relations are not clearly demonstrated and conditions at the boundary of the Helene Granite in West Alángorssuaq are visibly complex this biotite-hornblende-granite variety is included with the various granitic rocks at the northern margin of the Helene Granite on Plate 3.

(d) Relations between the Biotite-Granite and Kitsigsut Syenite.

In the Ũmánánguaq skerries off north-west Alángorssuaq the Biotite-Granite and Kitsigsut Syenite are separated by a broad area in which abundant blocks of the syenite are enclosed and veined by the granite, both rocks becoming modified. Good exposures showing these effects occur on the island 900 m north-west of Rødtop and its neighbour immediately to the north. The vertical section afforded by the skerries in which the granite is seen attacking the syenite amounts only to a few metres and consequently the general attitude of the xenolithic marginal zone cannot be determined.

(e) Relations between the Nunarssuit Syenite and Helene Granite.

The contact between the Helene Granite and Nunarssuit Syenite is well exposed in Alángorssuaq. A little to the north-east of the island at Stærkodder Havn it can be seen very near the shore of Torssukátak where it is sharp, steep, and separates normal coarse Helene Granite from syenite which is much finer-grained than that in the interior of the intrusion to the east. From here it can be followed westwards across the peninsula. About 100 m from Torssukåtak it separates a relatively fine-grained quartzose marginal phase of the syenite from a medium-grained variety of the Helene Granite. Since these two rocks are not greatly dissimilar in the field the contact is not conspicuous but it can be seen to be vertical.

Close to the end and on the north-west shore of Stærkodder Havn, at the mouth of a small stream, the syenite passes into a marginal porphyritic phase with zoned oval or rectangular felspar phenocrysts 1–2 cm long and some inclusions of coarse-grained Helene Granite.

About 100 m N.N.E. of the north-eastern extremity of Stærkodder Havn the syenite is seen to develop a marginal relatively fine-grained quartzose phase against the granite which is coarser-grained and typical of the Helene Granite in Alángorssuaq. The contact dips east at 30 degrees in one place but close by is vertical. It can be discerned from a distance by the darker colour of the weathered syenite as compared with the granite.

Roughly 200 m further N.N.E. the marginal porphyritic phase of the syenite is again seen. A thin vein of it in the adjacent granite wedges out and gradually loses its phenocrysts with increasing distance from the parent syenite mass.

On a hill slope approximately 700 m N.N.E. from the north-eastern extremity of Stærkodder Havn the syenite becomes progressively finer-grained towards the contact (which is well exposed) and for a metre from its boundary shows a marginal phase. About half this rock consists of oval or rectangular felspar phenocrysts a centimetre or so long arranged haphazardly in a fine-grained groundmass of felspar, some dark minerals, and quartz. A few of the felspar phenocrysts lie partly within the adjacent granite, crossing the contact which is irregular on a small scale and rather vague. In the vicinity a xenolith of Helene Granite is enclosed by the syenite.

From the last locality the contact is easily traced N.N.E. to the oval lake where medium-grained quartzose syenite lies in sharp very steep contact with the Helene Granite. In the bare hill-slopes east of that lake the edge of the syenite is easily visible and about 1700 m E.S.E. of the south extremity of the lake is seen to be vertical, cutting normal coarse Helene Granite. From here eastwards for some distance a variant of the Helene Granite shown on Plate 3 interposes between the normal Helene Granite and Nunarssuit Syenite; about half-way along its length, at a small col, a sharp steep (70°) southwards-dipping contact between this variant and the syenite is beautifully exposed. Here lenticular hornblendic pegmatites are common in the marginal parts of their syenite parent and some also cut the contiguous granite variant which lies in sharp northwards dipping contact with normal Helene Granite. Two or three hundred metres to the east the contact of the even-grained granite with the syenite dips north at about 80°.

Continuing eastwards to Torssukåtak the syenite contact, though mappable, is often difficult to locate precisely with certainty. At a few places normal Helene Granite is seen next to a quartzose relatively fine-grained marginal phase of the syenite. But it sometimes seems possible that minor granite variants that could be confused with the marginal syenite may be present. Certainly a medium-grained granite with occasional felspar phenocrysts demonstrably occurs about a hundred metres from Torssukåtak, forming an outcrop a few metres wide between and in sharp contact with the normal granite and the syenite.

On the northern and southern shores of Torssukåtak, at Knækket, the contact is more or less vertical. Immediately west of Helene Havn the marginal porphyritic phase of the syenite is well-developed and for a metre or so from the contact (which is marked by concentration of mafic minerals in a zone 1–2 cm wide) the Helene Granite seems less quartzose than usual but otherwise shows no marginal modification.

Traced inland for about 1.5 km the contact retains these features but due south of Helene Havn more complex relations are encountered. Coarse-grained Helene Granite penetrates and encloses subangular blocks of rather fine-grained syenite (fig. 17) which sometimes contain scattered large felspars like those in the granite. Further east, however, the contact becomes simple again and dips steeply away from the syenite: the granite in the proximity of the syenite here is porphyritic and resembles the marginal facies east of Emma Havn.

North-east and east of the small lake east of the 300 m summit (Plate 2) hornblende-bearing pegmatites often cut and obscure the contact between the Helene Granite and marginal porphyritic syenite but where they are absent the contact is sharp and distinct.

The contact becomes complex again W.S.W. of the 251 m summit where the Helene Granite veins and encloses rounded blocks up to a metre wide of porphyritic syenite and is sometimes deficient in quartz, consisting only of felspar crystals up to 3 cm long, interstitial felspar and mafic minerals. Some syenite inclusions bear scattered large felspars like those in the granite.

East of Mercurius Havn the syenite encloses a block of Helene Granite 40 m wide.

South of Mercurius Havn the granite-syenite relationships are for the most part either obscured by the metavolcanic inclusion zone or inaccessible because of the steepness of the ground, but on the shore of

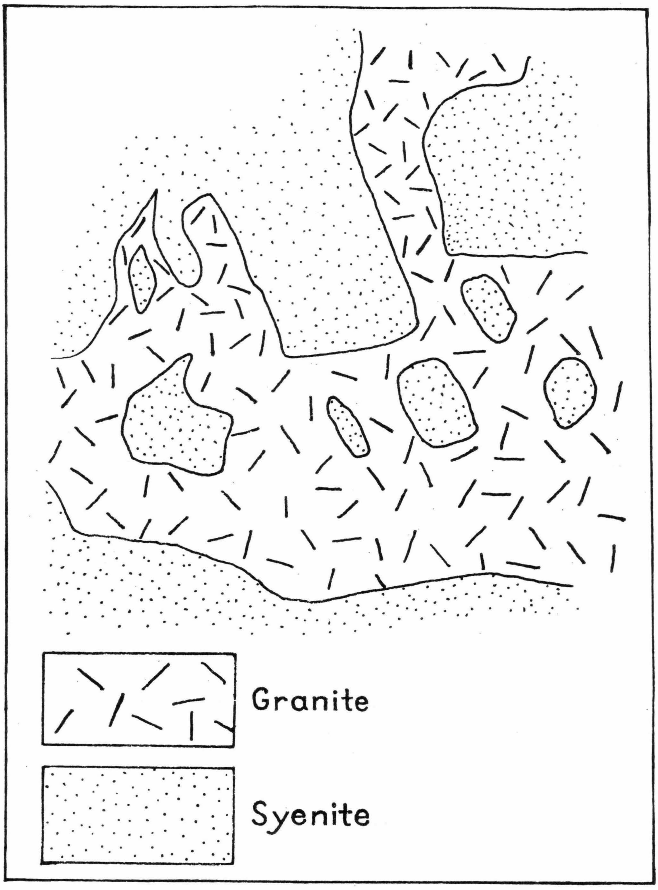

Fig. 17. Coarse-grained Helene Granite penetrating and enclosing subangular blocks of rather fine-grained syenite: south of Helene Havn. Drawn from a field sketch. (T.C.R.P.).

the inlet just south of Mercurius Havn a sharp contact between porphyritic syenite and Helene Granite is exposed. Neither rock veins the other and the outcrops contribute nothing to an understanding of the age relations. The same is true of the exposures of the contact in the valley a kilometre further south and the irregular contact between the fine-grained radioactive granite and the syenite. It was possible to climb within 10 m of the contact between the normal Helene Granite and the syenite in the col between the 690 m and 675 m summits north of Kitdlavât. This contact is sharp, dips east, but is otherwise uninstructive.

South from here as far as the "amphitheatre" south of Kitdlavât the contact is quite inaccessible owing to the steepness of the terrain (see fig. 23) but south of Kitdlavât and north-east of Kap Desolation a

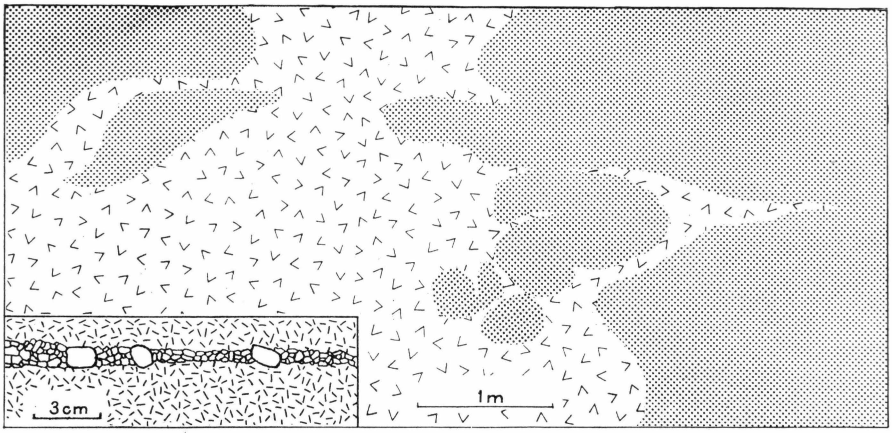

Fig. 18. Medium-grained syenite (stipled) penetrated and enclosed by quartz-poor Helene Granite. Note the round form of the syenite inclusions. The inset shows a thin vein of de-silicated Helene Granite in syenite, with large felspars which cannot have been carried in if the vein were injected in its present form. Drawn from a photograph assisted by field sketches. (T.C.R.P.).

sharp contact between medium-grained Helene Granite and porphyritic syenite can be closely examined.

The medium-grained granite within the inclusion zone around the inner part of the bay east of Kap Desolation is in sharp steep, eastwards-dipping contact with the coarse-grained quartzose syenite characteristic of this area on the east side of the inclusion zone. Whilst the syenite shows no marginal facies the adjacent granite becomes fine-grained against the contact and may well be a little younger than both the normal Helene Granite and the Nunarssuit Syenite.

East of Kap Desolation the Helene Granite contact west and south west of the metavolcanic inclusion zone dips at about 45° N.W. and relationships are suggestive of hybridization. At one place medium-grained syenite is veined by a rock consisting only of large sub-rectangular felspars and some mafic minerals presenting the appearance of a de-silicated Helene Granite. The veins measure up to 60 cm thick and are not angular but have the form indicated in fig. 18; some are so thin that their large felspars could not have been carried in by an intrusive vein. A similar rock contains occasional rounded inclusions of medium-grained syenite up to 3 m in width (fig. 19) which often bear scattered K-felspar phenocrysts up to 3 cm long and occasionally merge into the surrounding "de-silicated granite" through a transition zone up to 50 cm wide.

East of this syenite, at the east end of a small peninsula, moderately coarse-grained syenite lies in sharp steep contact with an even-grained granite of similar grain size. Neither the syenite nor the granite

Fig. 19. Coarse de-silicated Helene Granite veining and enclosing medium-grained syenite. The latter contains scattered large felspars similar to those in the Helene Granite. Approximately 2 km N.E. of Kap Desolation. (Photo G.G.U., T.C.R.P.).

form marginal phases, though in the same general locality the granite is fairly variable, containing some patches resembling the normal Helene Granite, others like the marginal phase of the Helene Granite and still others like the relatively fine-grained felspar-phyric syenite. The K-felspar phenocrysts in the syenite areas are rounded or subrectangular in outline and the biggest are 5 cm. in length, larger than any found in the Helene Granite or Nunarssuit Syenite.

VI. XENOLITHIC INCLUSION ZONES

(a) Field occurrence.

Zones within the Nunarssuit Complex containing abundant xenoliths mainly of basic metavolcanic rocks have a considerable bearing on the problems of the form and mode of emplacement of the complex. The most important of them coincides approximately with the contact between the Helene Granite and Nunarssuit Syenite in the western part of the complex and in places actually separates these two units. Its northern termination can be readily examined on the northern shores of Torssukátak. On the north-east side of the island at the entrance to Stærkodder Havn normal coarse Helene Granite contains haphazardly orientated medium- or fine-grained xenoliths of basic metavolcanic rocks and banded metasediments of psammitic to pelitic composition up to several metres long with well-defined boundaries and angular or subangular outline. Field evidence of metasomatism is slight. Some metavolcanic blocks bear thin black reaction rims, and wisps rich in relatively coarse-grained biotite penetrate some inclusions. Close to the xenoliths the granite gradually becomes even-grained and finer-grained; it sometimes sends wedges into banded metasedimentary xenoliths following the banding of the blocks and prising them open by forcible intrusion (fig. 20).

The inclusion zone can be followed along the shores of Torssukátak on the adjacent mainland for about one kilometre, crossing the boundary between the syenite and granite. Although the syenite is unusually coarse a few hundred metres east of the termination of the xenolithic zone, bearing felspar crystals up to 4 cm long, it mainly consists of felspars 1–2 cm long within the zone. Most of the xenoliths in the zone are metavolcanic rocks, often with stellate aggregates of felspar columns 1–2 cm long and epidotic vesicles of similar length. They generally measure a metre or less in width, and are angular, well-defined and haphazardly arranged. Many are cut by a network of syenite veinlets. Some banded semipelitic metasediments occur and a block of quartzite 15 m long is present about 500 m south-east of the syenite-granite contact at Torssukátak.

Outside the xenolithic zone the syenite contains a large quartzite inclusion beside a stream 200 m N.E. of the northern extremity of Stærkodder Havn, and another isolated quartzite xenolith occurs 900 m N.N.E. of that extremity in the syenite near the important N.N.E. tear fault crossing Alángorssuaq.

In Nunarssuit the zone is outstandingly developed and between Mercurius Havn and Kap Desolation it can be clearly seen to be always inclined eastwards as is particularly evident in the northern wall of the "amphitheatre" immediately north-west of Kitdlavât where the dip of the zone is 30–35 degrees. Many xenoliths are lenticular and the long axes of these invariably lie within the plane of the zone. The steep in-

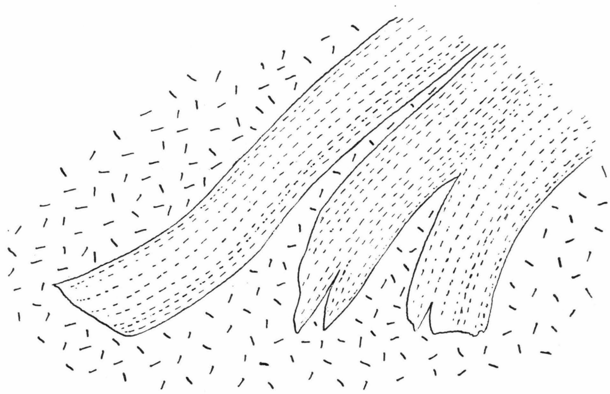

Fig. 20. Xenolith of banded semipelitic and psammitic schist several metres long wedged open by mechanical intrusion of Helene Granite along the foliation of the xenolith. Island on S.E. side of Stærkodder Havn. (W.T.H.).

accessible nature of the cliffs in which the zone occurs presents no mapping problem for exposure is complete and the xenoliths, being almost wholly dark-coloured metavolcanics, are easily distinguished at a considerable distance from their paler host. They are most abundant in the vicinity of Mercurius Havn and in the westward-facing cliffs immediately to the south, where they measure up to 100 m in thickness (figs. 21 and 22), and are most sparse in the north-western precipices of Kitdlavât (figs. 23 and 24).

Isolated inclusions occur in the Nunarssuit Syenite and Helene and Kitdlavât Granites close to the xenolithic zone. Those in the Kitdlavât Granite occur near the base of the intrusion and when lenticular are arranged with their lengths parallel to the eastward-dipping lower contact of the body.

Veining of inclusions by syenite and Helene Granite is fairly intense. Occasional xenoliths within the granite are highly disrupted and contaminate the surrounding granite (fig. 25).

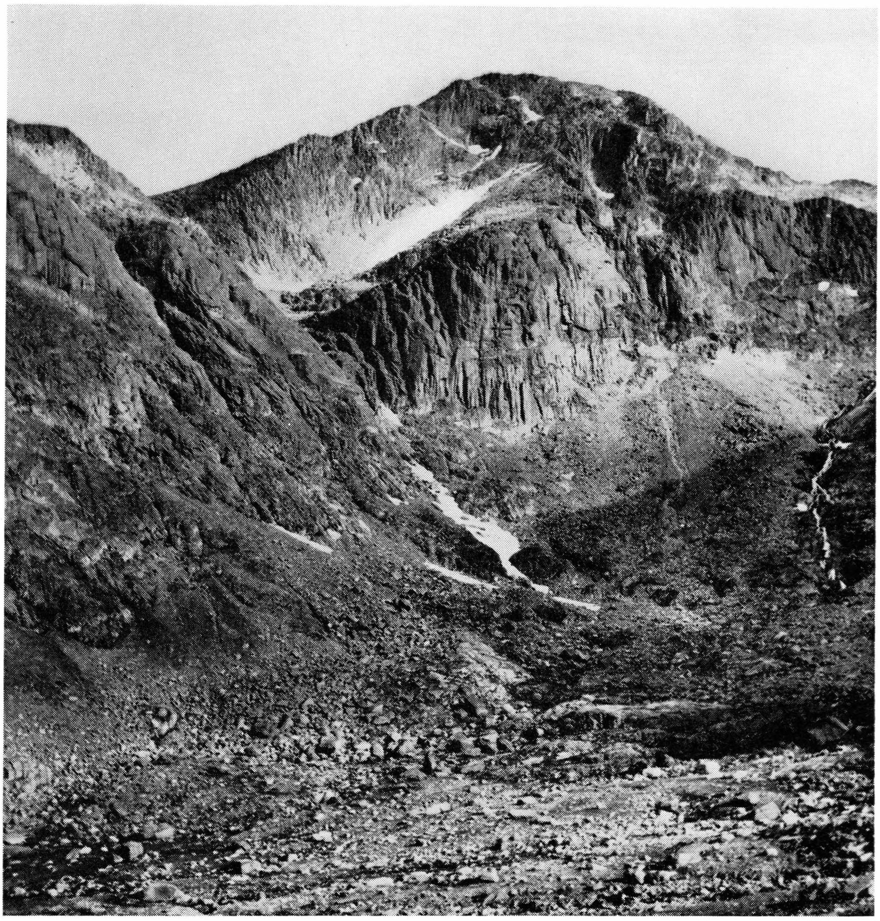

Fig. 21. View of the north-western cliffs of the 728 m mountain 2.5 km south of Mercurius Havn. The summit is formed of Kitdlavât Granite. The contact between this and the darker overlying Nunarssuit Syenite may be seen running left from the crest of the ridge a little to the left of the summit. The lower contact of the Kitdlavât Granite nearly reaches the skyline at the right-hand side of the picture. Below this dark metavolcanic lenses can be seen in the syenite just above the top of the scree. At the top of the buttress on the left the light Kitdlavât Granite is again visible with darker syenite above and below. The metavolcanic inclusions and the contacts of the Kitdlavât Granite are shown in fig. 22 which is a key to this photograph. (Photo G.G.U., T.C.R.P.).

A few scattered metavolcanic inclusions in the syenite on the coast between Amitsuarssuk and the entrance to Tasiussaq are believed to represent the southern continuation of the Mercurius Havn — Kap Desolation zone.

On the Iserfiluk peninsula in south-west Nunarssuit two xenolithic zones, of which the upper and most important continues south-east to

Fig. 22. Key to fig. 21. The metavolcanic lenses are indicated in solid black. The contacts of the Kitdlavât Granite are also drawn in. (T.C.R.P.).

Agdlerûssat avangnardlît, contain mainly metavolcanic inclusions though in the south metadolerite forming concordant bodies in metavolcanics, faintly striped white or glassy quartzite, and finely-banded semipelitic metasediments are not uncommon. As mentioned in Section III (e) the syenite surrounding many of these inclusions is a leucocratic variety unlike that in the Mercurius Havn zone but some inclusions lie wholly in normal Nunarssuit Syenite. The xenoliths measure up to 100 m or more in length and many of them are lenticular; the long axes of these are arranged in the plane of the zones which dip E.N.E. at about 30° (figs. 26 and 27). Some xenoliths show measurable planar structures; these also dip E.N.E. but at rather more variable angles. Another striking feature of the zones is that they are wider and their xenoliths are more densely packed on the crests of ridges than at sea-level (fig. 28). Indeed the lower zone is confined to the upper part of the west end of the Iserfiluk ridge and never reaches sea-level.

Outside the zones described xenoliths are rare. In the hills about 1.5 km south of Helene Havn there are a few isolated lenses of streaky metavolcanic rocks and deorientated striped glassy quartzite inclusions sometimes enveloped by a leucocratic variety of syenite. A single fine-grained grey metavolcanic inclusion occurs in the syenite of Thorstein Islænder, the largest island in the Ydre Kitsigsut skerries.

Fig. 23. Cliffs on the northwestern side of the summit of Kitdlavât. In spite of shadows on some parts of the rock face scattered inclusions of dark metavolcanic rocks may be distinguished. In the extreme left of the picture there is a larger mass of metavolcanic rock. (Photo G.G.U., T.C.R.P.).

Fig. 24. Detail of fig. 23. The angular metavolcanic inclusions can easily be seen in this picture: they are of the order of 25 m long. (Photo G.G.U., T.C.R.P.).

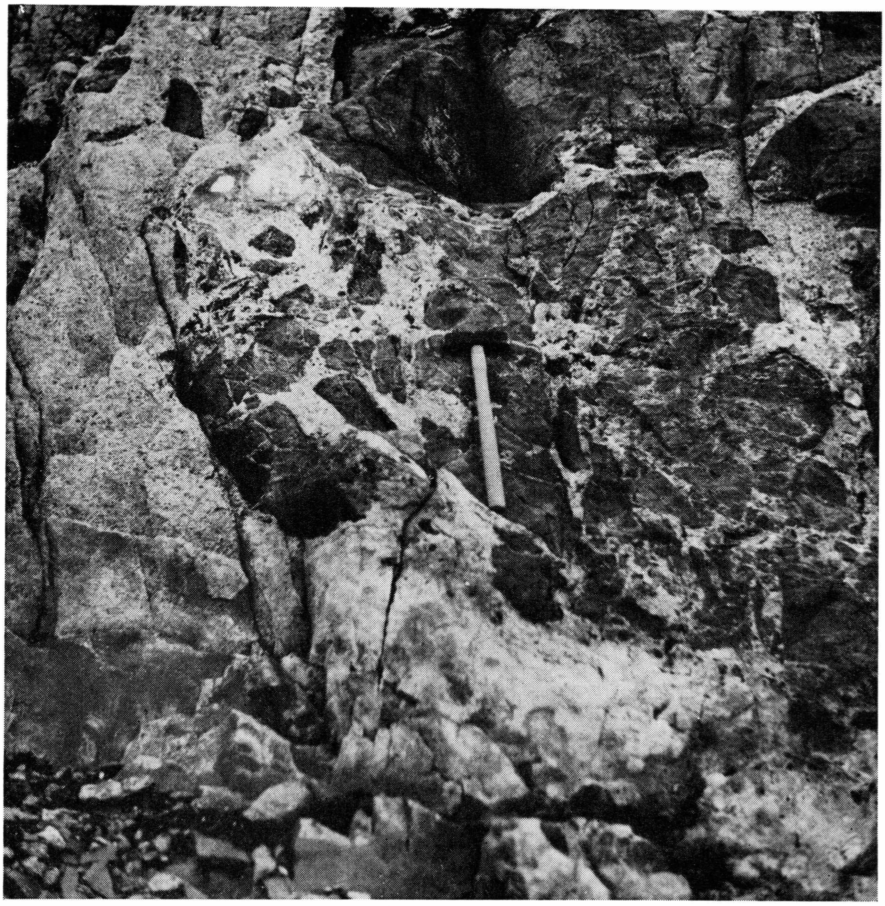

Fig. 25. Metavolcanic rock disrupted and brecciated by Helene Granite. 3 km south of Mercurius Havn. (Photo G.G.U., T.C.R.P.).

(b) Petrography of the xenoliths.

(i) Metavolcanic xenoliths.

The metavolcanic inclusions consist wholly of basic rocks. Contact metamorphism is most intense at the margins and decreases towards the centres of the biggest blocks. Most of the slices examined have been thermally altered to a high degree and their dark minerals are remarkably fresh.

The porphyritic varieties contain abundant elongated felspar crystals up to 2 cm long often arranged in parallelism or, as near Mercurius Havn and in Alángorssuaq, in stellate aggregates. When barely altered by thermal metamorphism they comprise saussuritized plagioclase phenocrysts with faint lamellar twinning in a fine-grained aggregate

Fig. 26. The southern slopes of Iserfiluk, S.W. Nunarssuit. Large lenticular metavolcanic xenoliths in a zone dipping eastwards in the Nunarssuit Syenite. Leucocratic syenite surrounds and veins some of the inclusions. (Photo G.G.U., T.C.R.P.).

Fig. 27. As fig. 26, from another angle. The sketch was drawn as a key for a photograph which was destroyed. (T.C.R.P.).

of pale-green hornblende and chlorite, plagioclase, epidote and ore. At a higher grade of contact alteration their matrix is recrystallized to plagioclase, biotite (X: pale straw Y = Z: reddish-brown) and khaki green hornblende; an epidote mineral may occur as highly poikiloblastic areas formed by coalescence of small grains; the felspar phenocrysts are recrystallized to clear granular andesine or labradorite aggregates retaining the original outline of the phenocrysts: scapolite and a clear isotropic mineral may be present. The matrix of the most highly hornfelsed rocks consists of brown or reddish-brown often poikiloblastic hornblende, foxy-red biotite (X: pale-brown Y = Z: reddish-brown), labradorite and some small grains of colourless pyroxene frequently

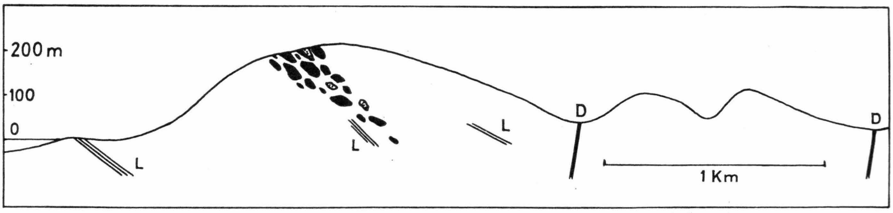

Fig. 28. Diagrammatic east-west section of the peninsula south of Iserfiluk. L denotes zone of mineral layering, D a dolerite dyke. The xenolithic inclusion zone dips east and wedges out downwards. (T.C.R.P.).

enclosed by hornblende. A little ore may be present and quartz occurs in one slice. The felspar phenocrysts are recrystallized to single plagioclase individuals about An_{60} which can be twinned on albite, carlsbad and pericline laws.

Like the porphyritic varieties, vesicular and amygdaloidal metavolcanic rocks are widespread, especially in the Mercurius Havn zone. The vesicles and amygdales are lenticular, up to 1 cm or so long, and often show flow-alignment. They contain one or more of the following minerals: labradorite or andesine, epidote, pale-green diopsidic-pyroxene up to 3 mm grain-size, colourless clinopyroxene; sphene, apatite and ore can be accessory constituents. The surrounding rock closely resembles the groundmass of the porphyritic varieties.

Massive medium- or fine-grained rocks are common. Dark gray, sometimes with purple tints in hand-specimen, they occasionally bear nodules and veinlets of epidote or pyroxene. Doleritic types retain their ophitic texture though plagioclase (An_{60-66}) is partly or wholly recrystallized and brown hornblende usually replaces the original pyroxene; the brown hornblende in its turn is partly replaced by fresh granular pyroxene which in one specimen directly replaces original pyroxene without the intervention of hornblende; ore, if present, is usually associated with a little reddish-brown biotite.

(ii) Metasedimentary xenoliths.

Some xenoliths are medium-grained, glassy, colourless or white quartzites with rounded quartz grains. A number are finely-banded medium- or fine-grained semipelitic schists with a planar foliation. Various other rocks with similar structure and texture near Stærkodder Havn seem also to be metasediments but have been metasomatically modified by the enclosing granite. One, with planar folia 1 mm or so thick, consists of granular twinned andesine without zoning, abundant scapolite, small aligned plates of reddish-brown biotite, accessory apatite, ore, and green spinel, the last almost ranking as an essential constituent. Another consists of thin alternate folia rich in either cloudy plagioclase, perthite, reddish-brown biotite, or rounded quartz grains like those composing nearby quartzite xenoliths. A few folia contain green clinopyroxene, perthite, quartz and a pale drab brown hornblende.

(c) Provenance of the Xenoliths.

In his diary Ussing assigned the xenoliths near Stærkodder Havn and Mercurius Havn to the Igaliko sandstone and associated lavas. This is not surprising in view of their petrography and Ussing's comparatively little knowledge of the pre-Gardar schists.

The present writers, however, believe that the xenoliths were derived from the tract of green schists in Kobberminebugten where, near at hand, there are quartzites, metasedimentary schists and abundant regionally metamorphosed volcanic rocks, including plagioclase porphyrites (as remarked in Section II), which on contact metamorphism would give rise to rocks just like the xenoliths. The present outcrops of the Igaliko sandstone and lavas are relatively remote from Nunarssuit. Moreover, the metavolcanic xenoliths often contain nodules of epidote or pyroxene derived from epidote, and nodules of epidote are characteristic of the Kobberminebugt metavolcanics. Also it may be significant that the green schist outcrop in northern Alángorssuaq trends generally N.E. but close to the Biotite-Granite swings north-south into line with the trend of the xenolithic zones within the complex.

VII. MINERAL LAYERING

(a) Alángorssuaq Gabbro.

Near the Julianehåb Granite the Alángorssuaq Gabbro is neither banded nor laminated but both these structures develop as the Helene Granite contact is approached (see Plate 3). Roughly one kilometre S.S.E. of the northern extremity of the gabbro outcrop slight banding concordant with lamination in the gabbro dips south-west at 45 degrees. Moving southwards from here, the area marked by these two structures widens rapidly in an east-west direction until at the Helene Granite contact it covers all but the eastern and western ends of the gabbro outcrop. Concomitantly the banding becomes more pronounced.

The mafic layers are usually between one and four centimetres thick, though some measure up to 30 cm in thickness. Generally they are between 5 and 30 cm apart. Some of the broader ones are almost wholly composed of pyroxene. Occasional thin lenses of olivine-rock occur concordantly within the layering.

The lamination, which is often highly pronounced, is due to the plane parallelism of tabular felspars (often about 0.5 cm long) and elongated dark minerals. Within the plane of parallelism, however, the long axes of these minerals are quite haphazardly arranged.

Lamination and banding usually occur concordantly together, though they can occur separately. They dip at moderate angles (between 30 and 50 degrees) towards the Helene Granite and show an orderly disposition when mapped. In the eastern half of the intrusion they strike N.W.. Close to the Helene Granite their strike follows the trace of the gabbro-granite contact, though the plane of the latter steeply transects them in vertical sections. Thus they show a very crude and imperfect arcuate arrangement, corresponding to the vaguely arcuate form of the whole gabbro outcrop, and seem directed towards a deep focus within the interior of the complex to the south.

On a small scale also the banding is regular: well defined "current-bedding", slumping, and trough banding appear to be absent. Within a single exposure most layers, considered individually, are of constant thickness, though compared with one another their thicknesses are

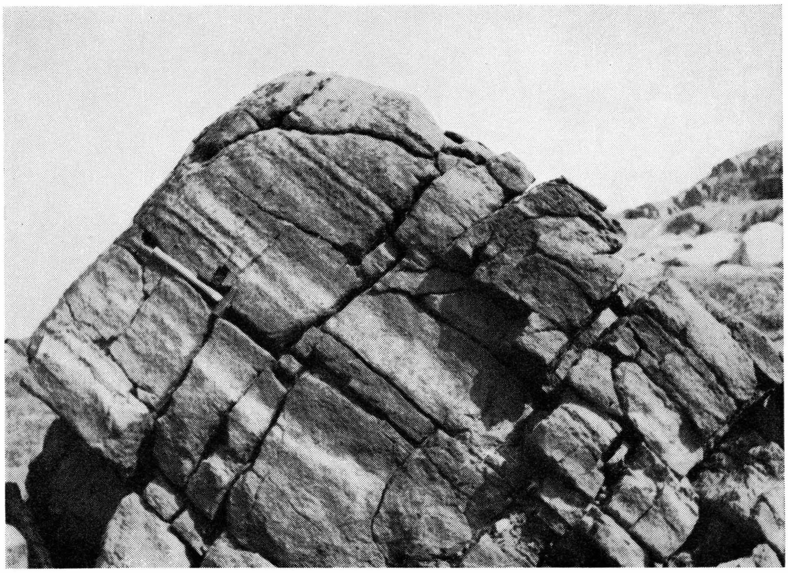

Fig. 29. Banding in gabbro, dipping S.E.; near the Helene Granite and about 400 m east of the major transcurrent fault crossing central Alángorssuaq. (Photo G.G.U., W.T.H.).

variable. The layering is generally planar on the scale of a single exposure (fig. 29) but close to the Helene Granite and just east of the powerful N.N.E. dextral tear fault crossing central Alángorssuaq repeated mafic layers 2 cm thick and 5 to 15 cm apart are down-warped into a shallow synform less than a metre in amplitude. Since each mafic or leucocratic layer considered separately is of constant thickness this structure resembles a simple flexure fold. A few hundred metres to the east of the last locality repeated layering dipping at 30 to 40 degrees is gently corrugated. Here again the thickness of each individual layer is constant, though compared with each other the layers are of variable thickness.

(b) Helene Granite.

The north-western outcrops of the Helene Granite locally display an unusual mineral layering that has already been briefly described, together with analogous structures in the two Tigssaluk granites 25 km north of Ivigtut, by Harry and Emeleus (1960) who ascribe these features to accumulation of dark and accessory minerals during crystallization of granite magma. A more comprehensive field description of the layering in the Helene Granite is now given; distinction can be drawn between layering essentially comprising normal Helene Granite and mafic bands on the one hand, and on the other hand layering in which, besides those two components, textural variants of the Helene Granite are conspicuous members.

Mafic layers in normal Helene Granite.

Mafic layers from roughly one to twenty centimetres in thickness occur in the normal Helene Granite at many places near the western shores of Alángorssuaq. Those up to about two centimetres in thickness are simply concentrations of the dark minerals and accessories found in the surrounding granite and the crystals composing them are roughly the same size as those of corresponding species in the normal granite.

Many of the thicker layers, however, are medium-grained mafic rocks of fairly even texture in which quartz and felspar never attain the dimensions that they reach in the adjacent granite. In these layers dark minerals are abundant, perthite is fairly common as rounded crystals, and some quartz, also in rounded grains, is present; zircon, sphene, apatite, fluorite and ore are frequent accessories, orthite is scanty. The dark minerals are mainly deep green hornblende and a green 2V(+) clinopyroxene in various proportions. Either of these two minerals can occur separately but they are commonly associated and the pyroxene is often partly replaced by green hornblende. Brown biotite is sometimes present and fayalitic olivine can occur. In thin-section under the microscope all the minerals composing the layers resemble in their general optical properties the crystals of corresponding mineral species in the normal granite.

Preferred form orientation of minerals is seldom apparent in the layered rocks. Indeed, it is rare throughout the entire outcrop of the Helene Granite. But sometimes elongated xenoliths occur in the layered granite and these are arranged in parallelism with the layering. This is seen close to the western shore of Alángorssuaq, opposite the promontory on the east coast of Quiartorfik, where gray quartzo-felspathic cognate xenoliths with an oval outline up to one metre long are abundant in the granite and invariably arranged with their lengths parallel to contiguous very steeply dipping mafic layers. Similar xenoliths are common in the southern half of Quiartorfik where they also are aligned parallel to immediately adjacent mafic layers though a few metres from the layering they can be orientated in any direction. At this locality, near a lake in the interior of the island, directional structures concordant with associated subhorizontal layering are seen in the felspars of the granite. On the other hand, similar structures that occur locally about 600 m south of the easternmost point on Quiartorfik lie at right angles to associated mafic bands.

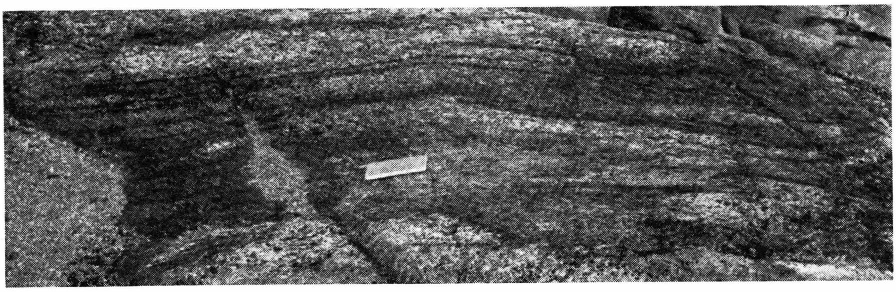

Fig. 30. Layering in the Helene Granite a few metres from the shore of west Alángorssuaq. The notebook is 17 cm long (Photo G.G.U., W.T.H.).

Fig. 31. Moderately inclined planar layering in Helene Granite, near the western shores of Alángorssuaq opposite Quiartorfik. The notebook (right centre) is 17 cm long. (Photo G.G.U., W.T.H.).

The mafic layers in the normal Helene Granite may be rhythmically repeated within a single exposure to give a succession of up to about thirty subparallel bands a fraction of a metre apart or, less commonly, they may occur as isolated, frequently branching, individuals. In both cases their cross-section can be either symmetrical—both edges being equally vague or equally sharp—or asymmetrical, one edge being sharp whilst the other grades upwards into normal granite over distances of up to 20 cm.

The rhythmically repeated successions are usually more or less planar but some are pronouncedly arcuate in vertical profile and resemble the trough-banding described from Skærgaard by Wager and Deer (1939).

Roughly planar repeated layering (e. g. fig. 30) is seen at a number of places. These mafic layers can be traced continuously for distances of up to 14 metres and generally terminate by gradual wedging out. Most of them dip gently (figs. 31 and 32) but steep dips are common

Fig. 32. Planar gently inclined banding in the Helene Granite of west Alángorssuaq near the inlet east of the southern tip of Quiartorfik. The notebook in the lower part of the photograph is 17 cm long. (Photo G.G.U., W.T.H.).

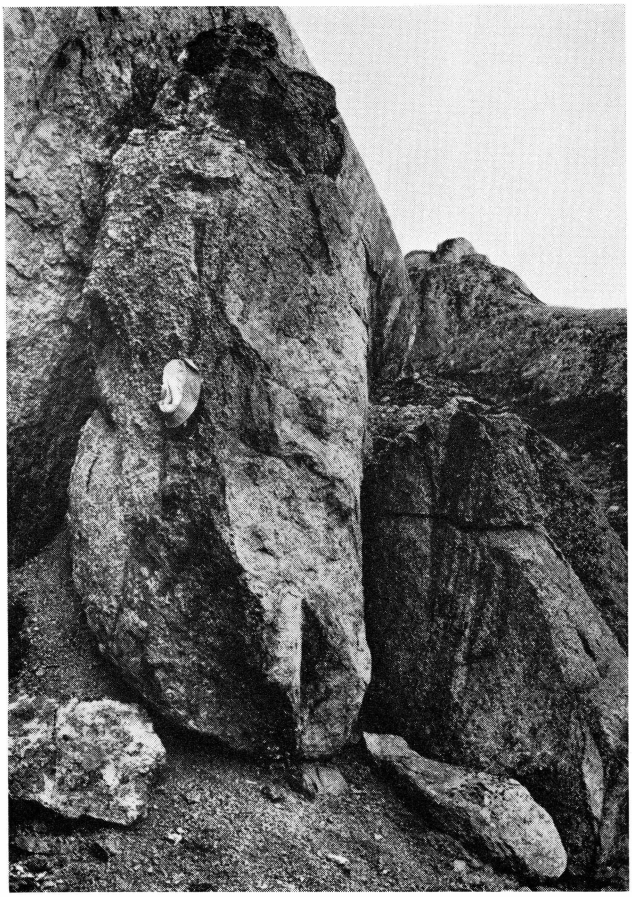

Fig. 33. Steep layering in the Helene Granite of west Alángorssuaq 700 m S.E. of the northern extremity of Quiartorfik. The hat gives scale. Note parallelism of bands and the manner in which they thin out and branch. (Photo G.G.U., W.T.H.).

and some are nearly vertical (figs. 33 and 34). Although their direction of dip varies considerably from place to place they seem more often than not to be inclined towards the interior of Alángorssuaq but this apparent general tendency is not pronounced. Many of them branch repeatedly. The off-shoots are often thinner than the parent layer from which they diverge gently at a low angle in a manner reminiscent of current-structures in sedimentary rocks. They usually spring from only

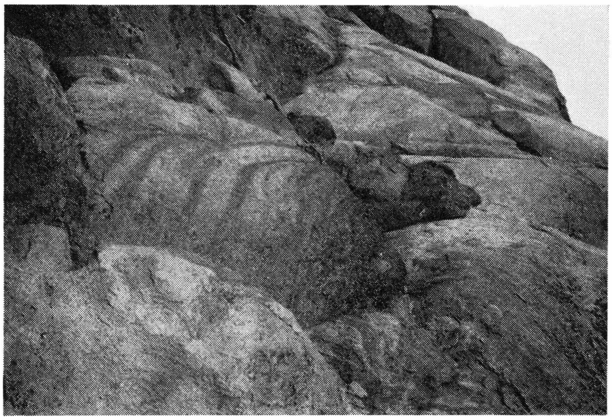

Fig. 34. A gently inclined surface showing steep layering near the exposure illustrated in fig. 33. (Photo G.G.U., W.T.H.).

one side of their parent layer and, where it bifurcates, the latter can become locally thinner than usual. In some exposures, where several layers in a sequence branch repeatedly, the branches all run in the same general direction. Occasional structures recall the truncation of foreset by bottomset beds in current-bedded sandstones (fig. 35) and, like such sedimentary structures, are orientated with the truncating layers uppermost.

The planar rhythmic sequences may include a few mafic layers with arcuate profiles: these are generally convex downwards but can be arched as in fig. 36.

As already stated in the general description of the layering, some mafic layers are asymmetrical, having one sharp and one gradational boundary. When such bands occur more than once in a rhythmic planar sequence the direction of grading is uniform and invariably upwards except, of course, where the layering is very steeply inclined. Certain examples of this gravity stratification are strikingly obvious. Others, however, are only revealed by careful observation. For instance, one, close to the sea on the north side of a small peninsula 1200 m west of the summit 287 m high in S.W. Alángorssuaq, easily escapes notice at close quarters. But from a distance of 50 to 100 metres, and especially when the rocks are wet, eight roughly planar parallel units about 70 cm thick can be vaguely discerned in the normal Helene Granite. Lamination or flow structures are absent from the exposure. The units, which strike

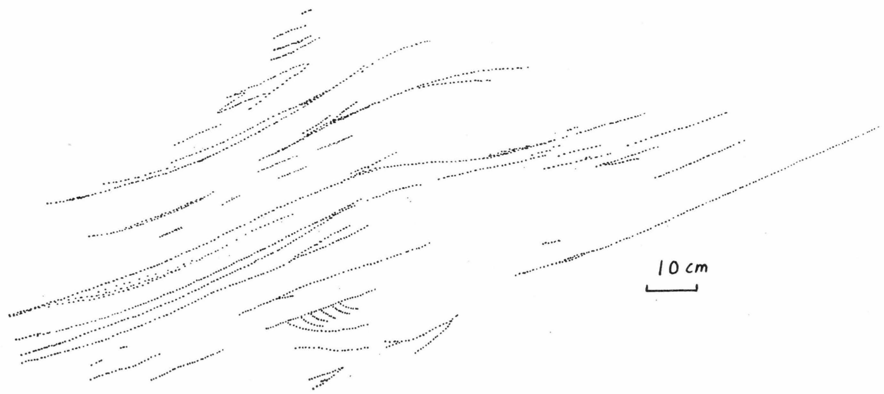

Fig. 35. Gently inclined mafic layers in Helene Granite, south-west shores of Quiartorfik. Near the bottom of the drawing a small structure which recalls the truncation of foreset beds in current-bedded sandstones is seen. Drawn from a colour transparency. (W.T.H.).

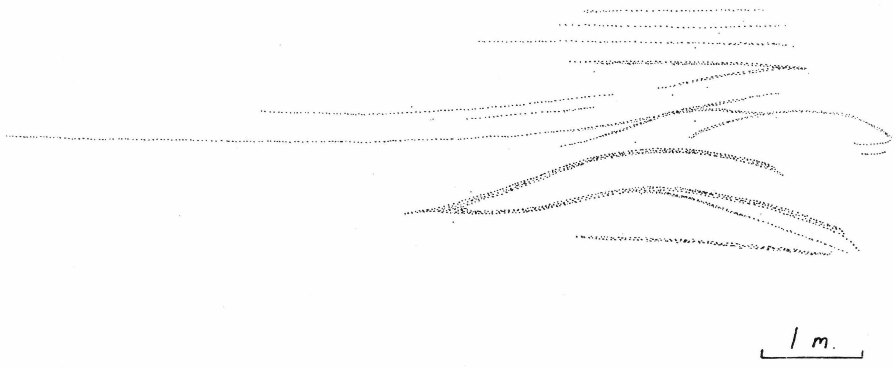

Fig. 36. Vertical exposure in Helene Granite showing subhorizontal layering by the side of a small lake in the interior of southern Quiartorfik. Drawn from a field sketch. (W.T.H.).

N.N.E. and dip steeply towards the interior of the complex, are defined at their bases by a slight concentration of dark minerals in the normal Helene Granite. The concentrations gradually fade out in an upwards direction.

Rhythmically repeated layering that recalls the trough banding in the Skærgaard gabbros described by Wager and Deer (1939) is seen near the south-west coast of Quiartorfik where it can be studied in three

Fig. 37. Rhythmic layering resembling trough banding in the Helene Granite near the south-west coast of Quiartorfik. The exposure illustrated has a vertical extent of about 8 metres. (Photo G.G.U., W.T.H.).

dimensions (fig. 37). The mafic layers are curved about a subhorizontal axis at least twenty metres long. In profile normal to the axis they terminate at a steep line which is fairly regular on the left-hand side of the photograph just referred to but less regular on the right-hand side. No contact can be discerned in the granite along these two boundary lines: the granite between the mafic layers seems perfectly continuous with that surrounding the structure.

As illustrated in fig. 37 the traces of the mafic layers describe smooth arcs that, on the whole, are synform though undulations can be developed. They show a marked tendency to bifurcate. Many of them thin out laterally and some are deflected upwards towards their extremities. Gravity stratification, always grading upwards, is a common feature. In the centre of fig. 37 a small structure recalling the truncation of foreset beds in current-bedded sandstones can be seen.

On Alángorssuaq, about 600 m south of the easternmost point on Quiartorfik, there is a small trough-like multiply-banded structure a little more than a metre wide in cross-section (fig. 38) formed by concentrations of dark minerals, including abundant clinopyroxene. In longitudinal section it extends subhorizontally for at least several metres and its traces, though showing minor irregularities, are more or less straight.

Fig. 38. Small trough-like structures about a metre wide formed by concentrations of dark minerals in the Helene Granite of west Alángorssuaq, approximately 600 m south of the most eastern point on Quiartorfik. The structure is seen mainly in vertical profile but a strike section is visible in perspective on the right of the photograph. The pocket notebook is 17 cm long. (Photo G.G.U., W.T.H.).

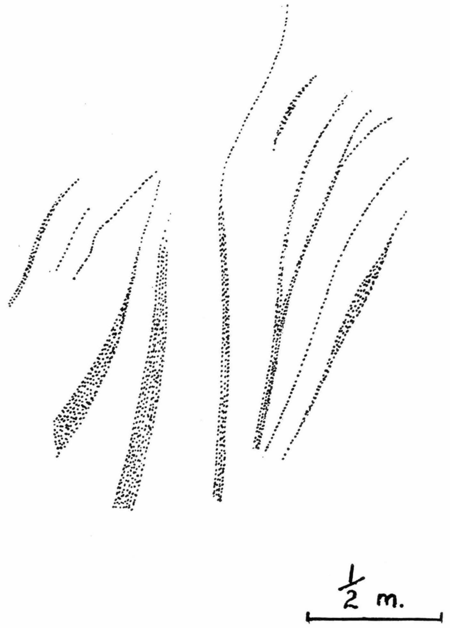

Fig. 39. Horizontal surface showing vertical mafic layers in the Helene Granite near the western shores of Alángorssuaq opposite the southern part of Quiartorfik. Drawn from a field sketch. (W.T.H.).

Fig. 40. Mafic layer in the Helene Granite near the south-west shore of Quiartorfik. The hammer handle (foreshortened) is about a metre long. (Photo G.G.U., W.T.H.).

Isolated mafic layers are not so frequently found as rhythmic sequences. Many of them bifurcate (fig. 40), sometimes in a very complex pattern (fig. 41), and a contorted, disrupted appearance also is common. Generally they wedge out rapidly: especially is this true of the contorted examples, which are seldom more than a metre in length. The traces of some isolated layers describe graceful arcs like those illustrated by Harry and Emeleus (1960, fig. 10).

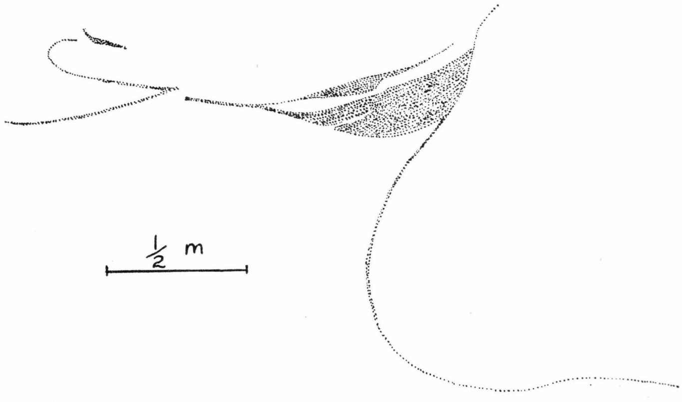

Fig. 41. Disturbed mafic layer in Helene Granite; shores of west Alángorssuaq roughly mid-way between Ikerasatsiaq and Quiartorfik. Drawn from a field sketch. (W.T.H.).

In the Helene Granite of Nunarssuit mafic layering is rare. The only really noteworthy occurrence is immediately west of Helene Havn where there is a thin succession of upwardly-graded mafic layers (see fig. 42).

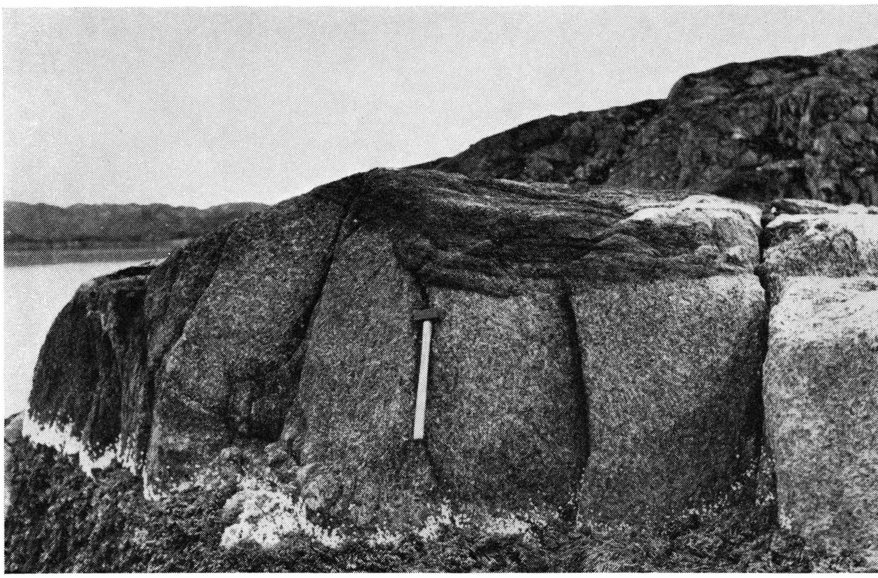

Fig. 42. Mafic layering in the Helene Granite on the shore of Torssukátak immediately west of Helene Havn. Note the grading in the mafic bands. The hammer handle is 50 cm long (Photo G.G.U., T.C.R.P.).

Owing to erosion, the thickness of the succession is not certain but it cannot exceed a metre and the width of the zone is not more than 10 m. The layers are slightly saucer-shaped, spaced approximately 10 cm apart and dip south at a low angle. They consist of clinopyroxene, fayalite, hornblende, perthite and quartz, with accessory ore, zircon, orthite and fluorite. The mafics and accessories (excepting fluorite) occur in very much higher proportions than in the normal granite and the clinopyroxene and fayalite have the appearance of primary precipitates. Hornblende, however, is of uncertain status. It is plentiful, forms relatively large (5–7 mm) anhedral grains which enclose both fayalite and pyroxene and tends to be dominant in the upper parts of the layers. To some extent at least it is a replacement of pyroxene and its abundance is probably simply due to such processes rather than the accumulation of a primary precipitate. The perthite is interstitial to the mafics. Quartz occurs both as independent grains and as vermicular intergrowths with perthite.

In an isolated occurrence of layering 2.5 km west of Mercurius Havn, steep mafic bands form arcuate structures which are illustrated in fig. 43. At Emma Havn weak banding in a zone about a metre thick, extending laterally for 3–4 m, comprises even-grained mafic wisps and crescentic lenses in normal Helene Granite. The structures dip W.S.W. at moder-

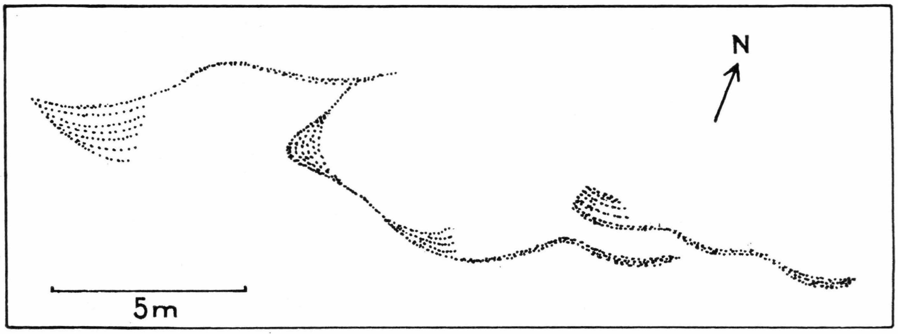

Fig. 43. Steep mafic banding as seen on a horizontal surface in the Helene Granite 2.5 km W.S.W. of Mercurius Havn, Nunarssuit. Drawn from a field sketch. (T.C.R.P.).

ately steep angles. Nearby a single synformal crescentic structure roughly 2 m wide and 15 cm thick in the centre, consists of somewhat mafic even-grained granite in which the quartz can form bypyramidal crystals. Mafic minerals are especially concentrated in the outermost few centimetres around the margin of the crescent.

Mafic layers associated with textural variants of the Helene Granite in Alángorssuaq.

The layering so far dealt with concerns, except in a few instances, just the normal Helene Granite and mafic bands; at one or two localities only, for instance the xenolithic exposures in Alángorssuaq opposite Quiartorfik, it may be accompanied by some thin concordant microgranite layers. There is, however, another type of layering involving conspicuous bands of porphyritic granite and microgranite. A most striking example occurs in a low cliff close to the shore at the southwestern extremity of Alángorssuaq, near and opposite a narrow island about 1.5 km long. This exposure demonstrates a subhorizontal multiply layered sequence, many metres thick, composed of various granitic rocks and thin mafic bands (figs. 44 and 45). Although individual layers wedge out more rapidly, the unit as a whole can be traced for about 2.5 km around the lower slopes of a small hill with a summit 287 metres high. South of this summit, close to the sea, the cliff shows the following ascending sequence of subhorizontal layers. Medium-grained granite, containing very irregular small bodies of coarse granite, grades upwards over several metres into microgranite and wedges out westwards over one hundred metres or so. Succeeding this a layer of normal coarse granite is overlain by a complex zone several metres thick chiefly composed of numerous subhorizontal layers of medium-grained granite, some of which bear scattered gray perthite phenocrysts 1–2 cm long. The medium-grained rocks display a subhorizontal layering due to

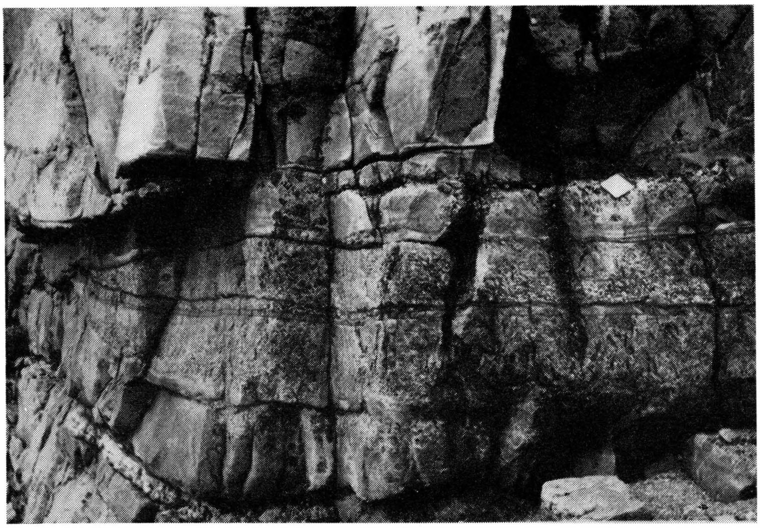

Fig. 44. Helene Granite. Part of a subhorizontal multiply layered-sequence in a low cliff close to the shore at the south-western extremity of Alángorssuaq and opposite a narrow island 1.5 km long separated from the mainland by the sound Ikerasatsiaq. Component granite layers can be seen wedging out westwards. The photograph shows subhorizontal microgranite layers (top and bottom), thin mafic layers and thicker granite bands. The slight distortion on the left of the picture is due to perspective. The notebook is 17 cm long. (Photo G.G.U., W.T.H.).

variation in grain size and dark mineral content. They are intercalated with thin layers of normal coarse granite, wedging out westwards over a few metres, into which they pass gradually downwards and also, sometimes, upwards. All these granitic rocks contain perthite, deep green hornblende, and green clinopyroxene. The average grain size of the microgranites is about 0.3 mm, that of the medium-grained granites varies between 0.3 mm and 1 mm.

Concordantly within this predominantly granitic complex zone there are a number of mafic layers from 1 mm to 1 cm thick, and a few pegmatitic layers with quartz centres, marginal micrographic structure, and some amazonite. The mafic bands can be vague, disturbed, and impersistent, or roughly planar and continuous for many metres. Two of them, 1 mm apart and each 0.5 cm thick, extend for several metres without noteworthy divergence or variation in thickness.

The mafic layers contain abundant deep green hornblende and bright green clinopyroxene, both minerals tending to lie with their *c* axes parallel to the layering but haphazardly orientated in the plane of layering. Other constituents are quartz, perthite crystals up to 1 cm long of the exsolution type commonly found in the Helene Granite, and accessory zircon, ore, sphene, orthite, biotite and apatite.

Fig. 45. Close-up of layering in the Helene Granite at the same locality as fig. 44, showing from below upwards: normal granite, microgranite, mafic, normal granite, mafic, microgranite, and mafic layers. The mafic layer near the centre of the photograph encloses felspar phenocrysts aligned parallel to the layering, and on the right of the photograph the depression of the mafic bands beneath two of these phenocrysts is faintly visible. The hammer handle is about 0.5 m long. (Photo G.G.U., W.T.H.).

The basal portion of one layer chiefly consists of green clinopyroxene crystals up to 1 mm long whilst in its upper part deep green hornblende is almost the sole dark mineral present.

Some mafic layers lie in contact with rectangular perthite phenocrysts 1–2 cm long in superincumbent granite. These phenocrysts, which enclose small scanty green clinopyroxene and hornblende crystals, can either penetrate the underlying mafic layer without disturbing its base, or depress it as in fig. 46. In the second case the mafic layer may become slightly thinner beneath the phenocrysts and thicker between them in a manner inviting comparison with the effect of dropping a pebble onto soft subaqueous sediments.

A small exposure at another interesting locality a few metres from the western shore of Alángorssuaq E.N.E. of the southern end of Quiartorfik shows a mafic layer several centimetres thick overlain by normal granite including a thin aplitic band. The mafic layer rests with sharp

Fig. 46. Close-up of layering in the Helene Granite at the same locality as fig. 44, showing from the bottom upwards, on the left-hand side of the photograph: normal granite passing upwards into microgranite, a thin sharply defined mafic layer, microgranite, a thin mafic layer overlain by a vague zone with large felspars followed by a thicker mafic layer and normal granite. Note how the thin mafic layer a few mm thick in the middle of the left-hand part of the photograph is depressed beneath superincumbent felspar phenocrysts several cm long. Similar though less pronounced effects are seen under the small felspars at the base of the uppermost normal granite layer near the left-hand margin of the photograph. (Photo G.G.U., W.T.H.).

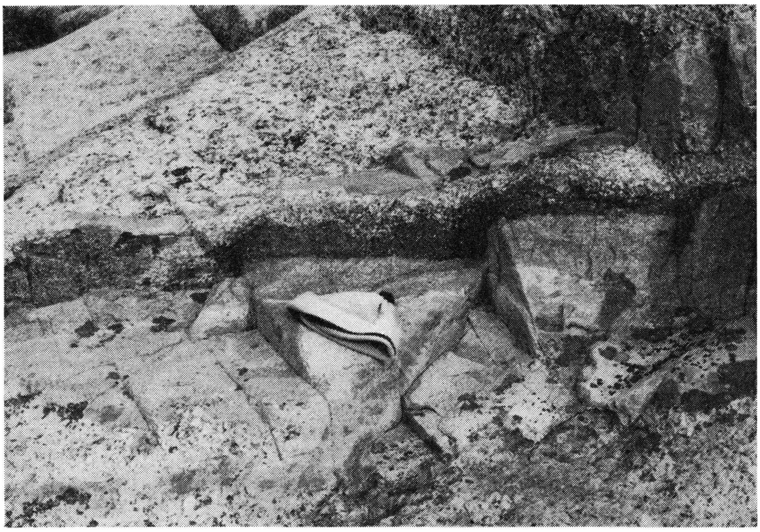

Fig. 47. Mafic layer associated with both normal and micrograniti c Helene Granite roughly 600 m south of the eastern point on Quiartorfik. The normal granite is seen at the top and bottom of the photograph. Hat for scale. (Photo G.G.U., W.T.H.).

contact on a microgranite layer underlain by normal granite (fig. 47). Its upper boundary can be sharp—in which case rectangular felspars in the overlying granite may project into the mafic layer—or gradational over several centimetres. A sample of mafic rock from the base of such an upward gradation contains abundant fairly fresh fayalitic olivine with the features of a primary precipitate, a good deal of pale green clinopyroxene, perthite, quartz, and accessory zircon, ore, orthite, apatite.

A similar association of microgranite, normal granite and a mafic layer occurs near the last locality.

(c) Kitsigsut Syenite.

On Tulugartalik and, to a lesser extent, on some of the other islands of the Indre Kitsigsut, the Kitsigsut Syenite is commonly banded by concentration of pyroxene in numerous thin subparallel layers generally inclined towards the south at about 30–40 degrees though steep northerly dips have been observed in the northern part of the skerries.

The mafic layers on Tulugartalik occur in the dark variety of the syenite (see Section III) as more or less planar rhythmic sequences and are usually no more than 40 cm apart though they can be more widely spaced. Here, as in other parts of the skerries, mineral parallelism is generally absent, but the subidiomorphic felspars of the syenite near the anchorage locally show a slight tendency to alignment in an east-west direction.

Individual mafic layers can be followed, sometimes with interruptions, for many metres. Some bifurcate gently (fig. 48). Not uncommonly a mafic layer is seen truncating an underlying and more steeply dipping

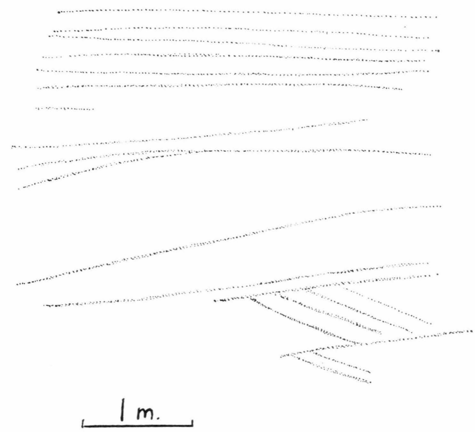

Fig. 48. Banded Kitsigsut Syenite near the anchorage, shores of Tulugartalik, Indre Kitsigsut. (W.T.H.).

Fig. 49. Banded Kitsigsut Syenite, showing gravity stratification. Near the inlet, interior of Tulugartalik, Indre Kitsigsut. (Photo G.G.U., W.T.H.).

set of parallel layers (fig. 48). Gravity stratification is a fairly common feature (fig. 49).

Highly contorted impersistent vague mafic bands can be seen at certain places in both the pale and dark varieties of the syenite, presumably owing their form to movements prior to final consolidation of the intrusion. They are not uncommon in the northern islands of the skerries and seem to be more a feature of the pale gray syenite than of the dark gray variety.

It may be noted that a large mass of basic and ultrabasic rock described as a xenolithic block in Section III (c) which occurs on an island nearly $^1/_2$ km north of the anchorage at Tulugartalik is strongly banded by concentrations of various minerals, including augite, in numerous thin parallel gently inclined layers.

In the Ydre Kitsigsut weak layering can be seen on the west side of Thorstein Islænder. The thin mafic bands are spaced 10–20 cm apart and are either inclined steeply eastwards or vertical.

(d) Biotite-Granite.

Mineral layering in the Biotite-Granite occurs at only one small locality in west Alángorssuaq at the tip of the little promontory south of Angnikitsorssûp atâ. This exposure, which lies on the shore near the high-tide mark, displays numerous subparallel mafic layers about

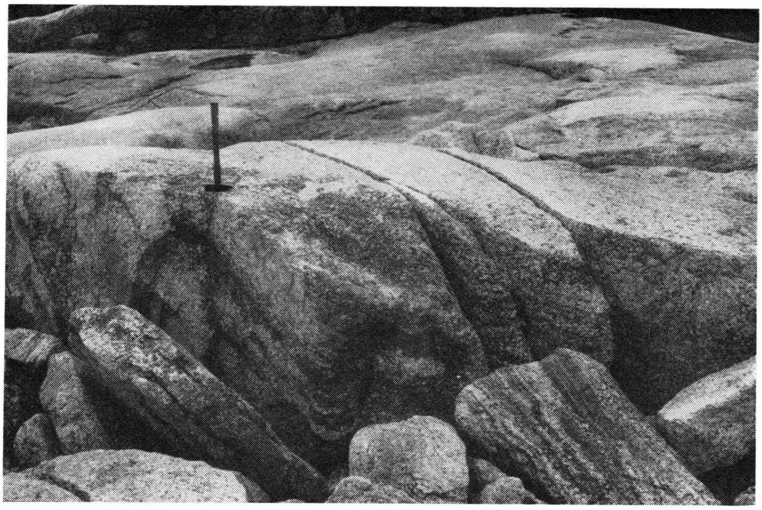

Fig. 50. Mafic layers in Biotite-Granite (see text). The layers in the fallen block (lower right) have been displaced along a "reversed fault" prior to final consolidation. The hammer handle is about 0.5 m long. (Photo G.G.U., W.T.H.).

3–10 cm thick disposed in a shallow synform structure that can be traced for several metres. The layers (fig. 50) contain the following minerals.

Biotite is abundant in haphazardly orientated plates several mm long, bearing numerous small well-shaped apatite and zircon inclusions, the last being surrounded by thin pleochroic haloes. Other inclusions are orthite, pyrite and ilmeno-magnetite.

Green hornblende is abundant in subidiomorphic crystals averaging 2 mm in length.

Oligoclase is common as unzoned twinned crystals with poor outline several mm long, enclosing a few small antiperthitic patches.

Quartz in areas seldom more than 0.5 cm wide is plentiful. It lacks strain extinction but displays the deformation lamellae characteristic of quartz in the normal granite. Two generations appear to be present.

Fluorite, purple in hand-specimen but colourless in slice, is a very common accessory, forming interstitial areas up to 1 mm or so wide, and filling cracks in felspar and sphene.

Pink sphene occurs as occasional xenomorphic crystals 0.5–1 mm long either moulded onto biotite or associated with quartz and felspar. Sphene also forms thin reaction rims surrounding some ore grains. Orthite and apatite may occur; euhedral prisms of the latter can be enclosed by the former.

No preferred orientation of mineral form is apparent in the banded Biotite-Granite exposure, and the mafic layers have obviously crystallized at about the same time as the associated granite.

(e) Nunarssuit Syenite.

General Distribution.

Although the most striking and interesting feature of the Nunarssuit Syenite is the repeated layering already mentioned in Sec. III it is only locally developed. The best examples occur in S.W. Nunarssuit, where it is more or less confined to three zones (see fig. 28) the most important one being the lowest. At the same structural level as the last, layering also occurs east of Mercurius Havn and to a slight extent at two localities in the Kitdlavât mountains. The only other locality where repeated layering is seen lies 2 km south of Peru Havn but the structural level of this occurrence cannot be related to that of any of the layered zones in S.W. Nunarssuit.

Apart from these instances and the weak banding in the leucosyenites noted in Sec. III which requires no further description, the syenite is devoid of repeated layering though it can contain isolated mafic streaks.

The layered zones of S.W. Nunarssuit strike between N.W.–S.E. and N.N.W.–S.S.E., whereas the layering east of Mercurius Havn and south of Peru Havn trends approximately N.N.E. Thus the overall plan of the layering in the syenite as a whole is arcuate about a centre slightly east of Eqatdliartarfik in central Nunarssuit. Towards this focus the layers dip roughly eastwards at angles between 15 and 45 but normally 30–35 degrees. It is noteworthy that the minimal dip—about 15°—is that of the layering south of Peru Havn and in the uppermost zone of S.W. Nunarssuit, the two occurrences nearest the centre just mentioned.

The lowest zone of S.W. Nunarssuit.

The lowest layered zone in S.W. Nunarssuit has a lateral extent of 4.5 km and a thickness of up to about 75 m. Although it forms a recognisable unit in the field individual layers and rhythmic units are not continuous throughout the zone but die our laterally within distances up to 100 metres or so, their place being taken after a short break by another rhythmic unit at approximately but not necessarily precisely the same level. The zone exhibits a wide variety of layered structures comparable with the depositional features of sedimentary rocks. In describing them below the nomenclature of sedimentation is employed without reservation.

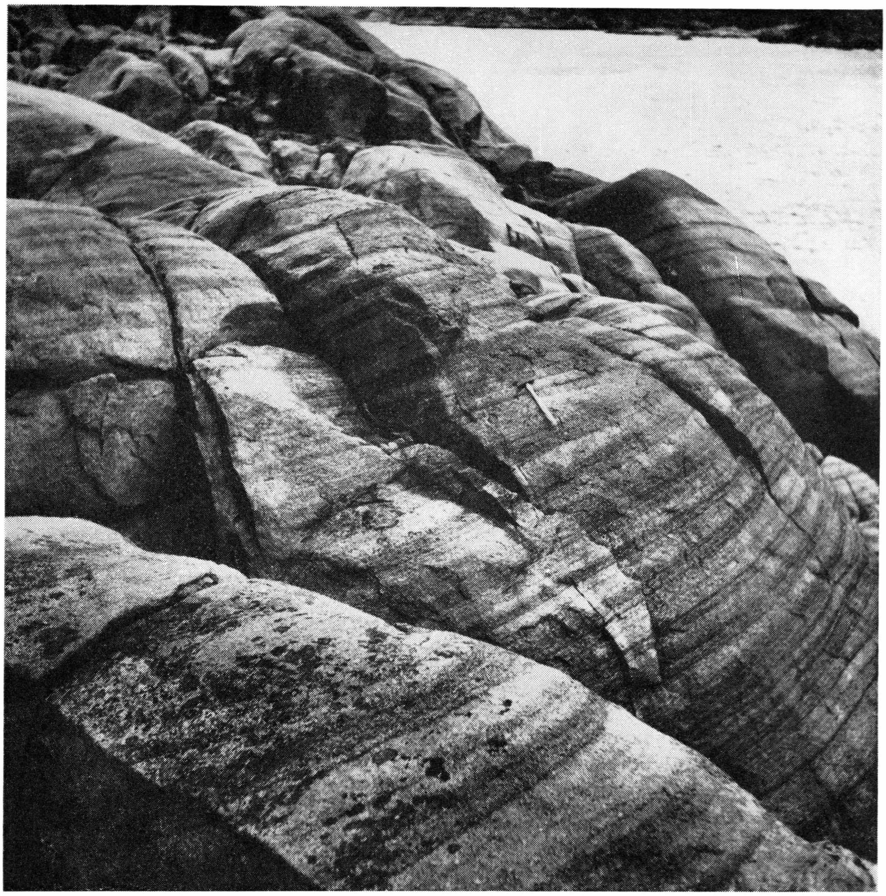

Fig. 51. Well-developed plane-parallel rhythmic mafic layering in the Nunarssuit Syenite on the north side of Tasiussaq, Nunarssuit. The hammer handle is 50 cm long. (Photo G.G.U., T.C.R.P.).

The structures are due to concentration of mafic minerals in plane-parallel layers weathering to a dark rusty-brown colour due to the high iron content of the minerals and thus being most conspicuous on slightly weathered surfaces. The mafic layers vary in strike between N.W.–S.E. and N.–S. When best developed they are 10–30 cm apart and 4–8 cm thick (figs. 51 and 54). Often but by no means always they are graded, a feature that is almost invariably of normal type—the graded layer has a well-defined base and passes gradually upwards into less mafic rock (figs. 52 and 53). The layers are usually separated by normal syenite but in some rhythmic successions about a metre thick they are parted by relatively mafic syenite so that a cursory glance from a distance conveys the impression of one single thick mafic band instead of a repeated sequence.

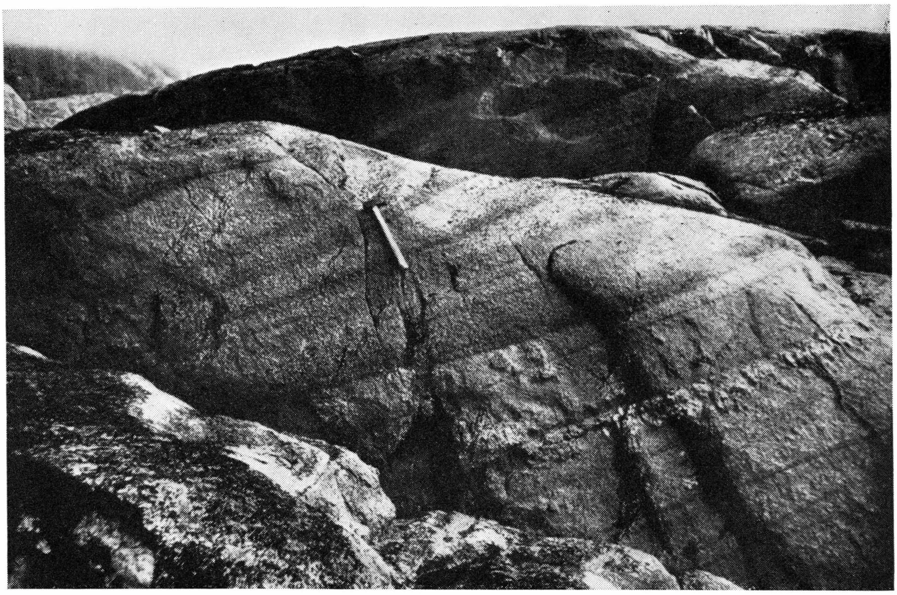

Fig. 52. Plane-parallel mafic layering in the Nunarssuit Syenite just north of the entrance to Tasiussaq. Note the gravity stratification. The hammer handle is 50 cm long. (Photo G.G.U., T.C.R.P.).

The stumpy form of the felspar and equant habit of the mafic minerals precludes the development of mineral parallelism in the layered successions except in rare cases where felspar has a weak preferred orientation parallel to the layering.

Discordances—truncation of a layer, or more often a set of layers, by the lowest member of a superincumbent series of rhythmically repeated layers—characterize this zone as compared with the other two zones in S.W. Nunarssuit, and sometimes give rise to structures exactly like current-bedding in sediments (see figs. 54, 55 and 56).

In conjunction with outwash channels highly pronounced discordances occur (see figs. 57 and 58). The channels cut abruptly across the normal planar layers on either side of them and thus differ from the trough banding described from Skærgaard and Kûngnât, for this phenomenon has not been recorded from either of those two intrusions. Thus the channels can be ascribed to erosion of a loose cumulate floor with greater certainty than the Skærgaard and Kûngnât troughs.

In addition there is some rather imperfectly developed trough banding closely resembling that in Kûngnât described by Upton (1960, p. 26 and fig. 15). The syenite close to a few of the trough structures contains lenticular mafic mineral concentrations up to a metre thick which appear to be the remains of troughs filled in by mafic minerals.

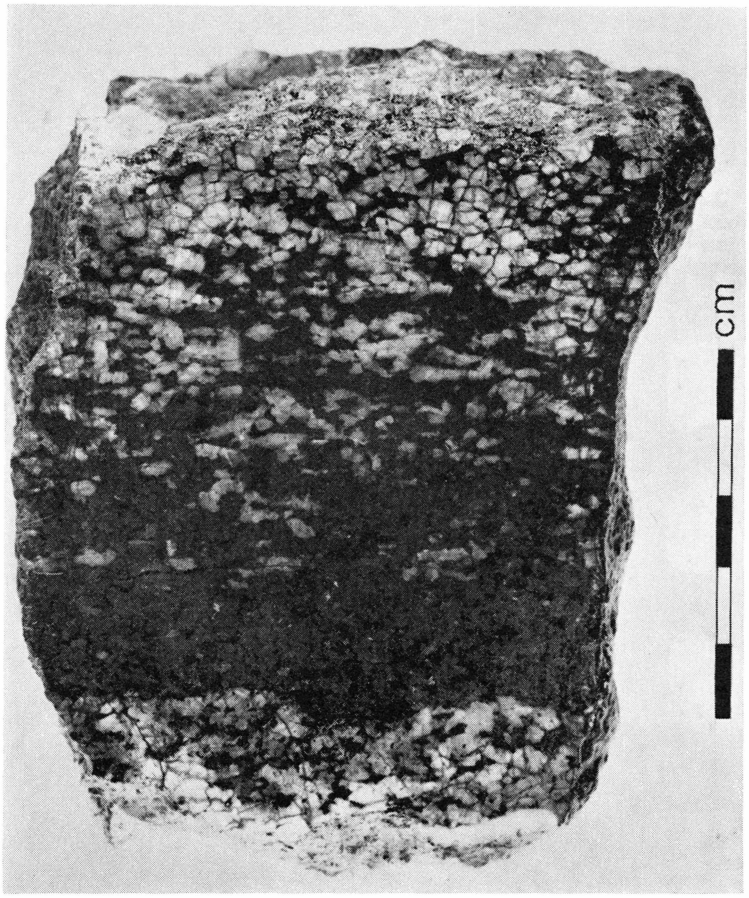

Fig. 53. Polished surface of a hand-specimen (no. 31083) showing well-developed grading in a mafic layer in the Nunarssuit Syenite. (Photo G.G.U., T.C.R.P.).

Fig. 54. Plane-parallel rhythmic banding in the Nunarssuit Syenite on the north side of the entrance to Tasiussaq. Note the discordance in the lower part of the photograph. (Photo G.G.U., T.C.R.P.).

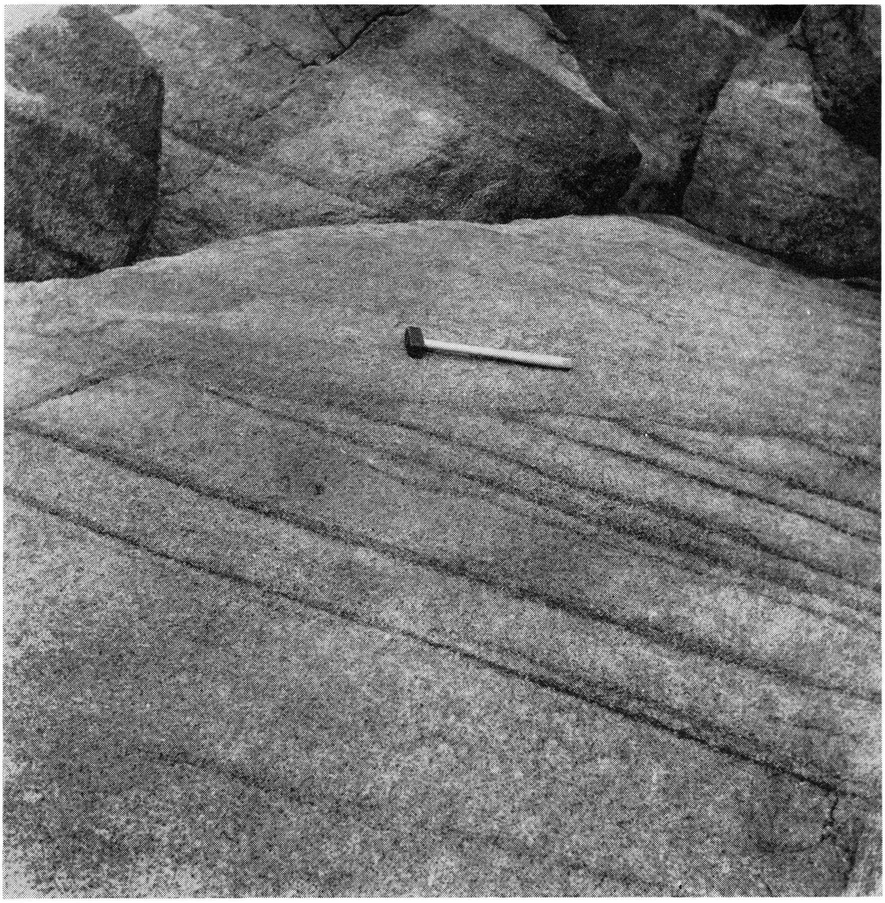

Fig. 55. Angular discordance resulting from the truncation of mafic bands by a thin layer which marks the base of the superincumbent series of layers. Nunarssuit Syenite; on the north side of the entrance to Tasiussaq. (Photo G.G.U., T.C.R.P.).

Fig. 56. Discordances in banded Nunarssuit Syenite on the south side of the entrance to Tasiussaq. (Photo G.G.U., T.C.R.P.).

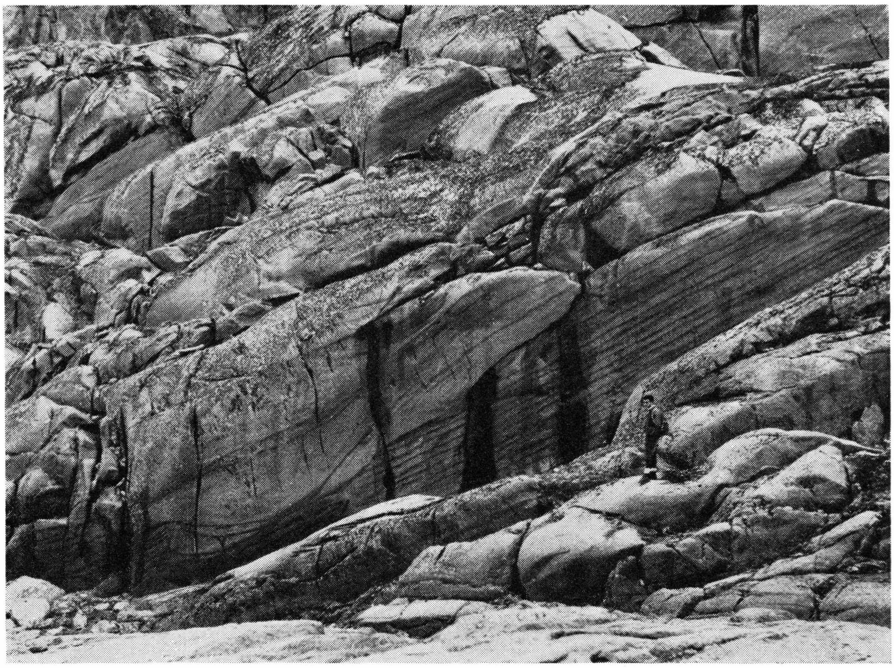

Fig. 57. Erosion channel cut in regularly banded Nunarssuit Syenite: south of the entrance to Tasiussaq. The channel is seen in the lower left-hand corner of the photograph. The even banding dips from right to left and can best be seen just above the figure. The broad dark vertical bands across the rock face are the result of water seeping down the face. (Photo G.G.U., T.C.R.P.).

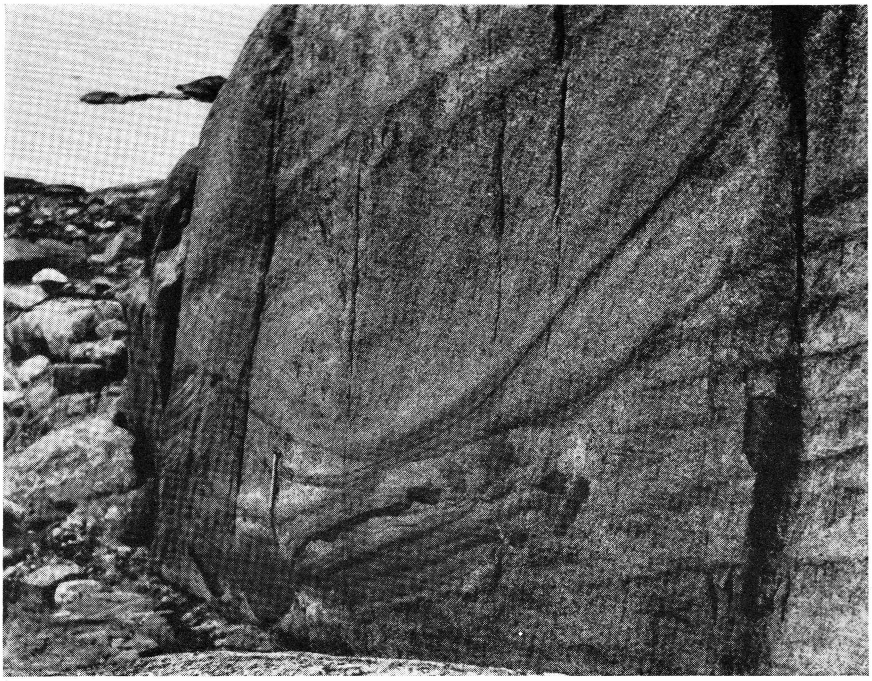

Fig. 58. Close-up of the same channel as that seen in fig. 57, looking approximately down the axis of the channel. In the right of the photograph some undisturbed even bands may be seen terminating and cut off by the trough structure. The block of mafic syenite seen a little below and to the right of the centre of the picture is about 50 cm long. (Photo G.G.U., T.C.R.P.).

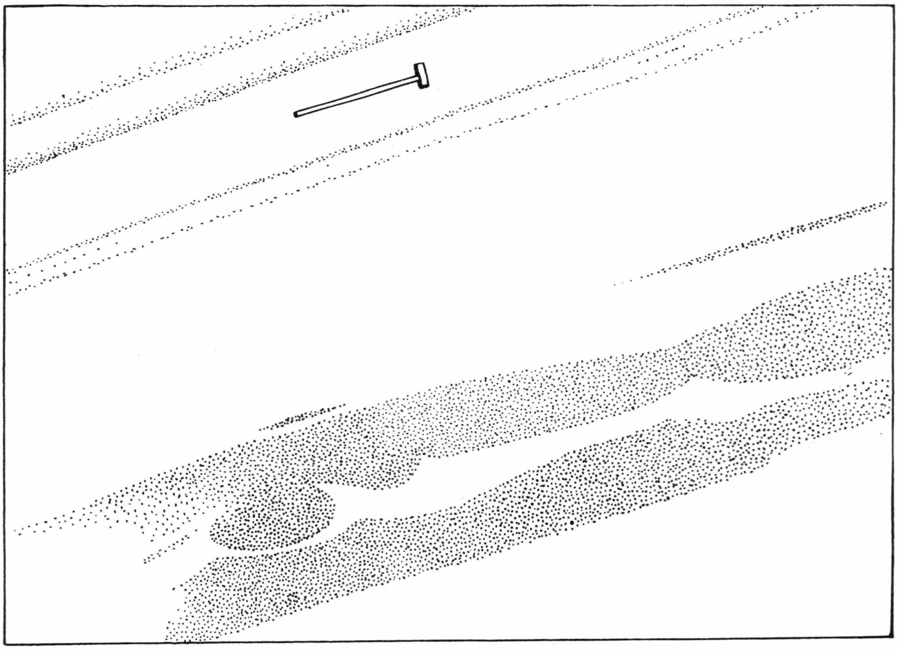

Fig. 59. Mafic layering in the Nunarssuit Syenite north of the entrance to Tasiussaq. The thicker layers in the lower part of the drawing have been disturbed with the resultant development of a load cast-like structure. Drawn from a colour transparency. (T.C.R.P.).

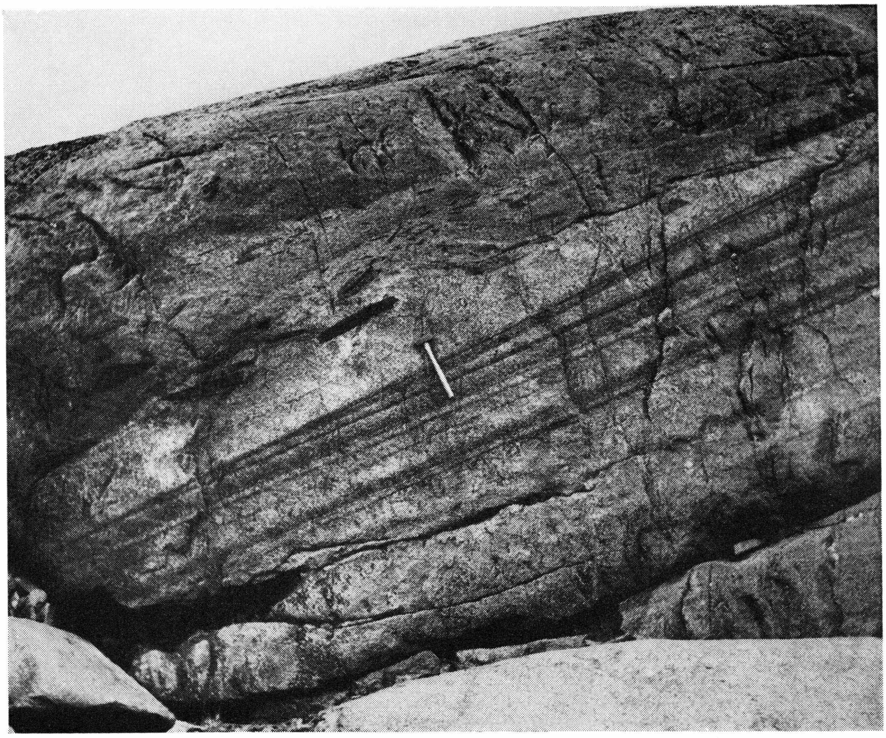

Fig. 60. Concordant breccia zone in banded Nunarssuit Syenite: north of the entrance to Tasiussaq. The hammer handle is 50 cm long. A block in the breccia about 60 cm above and a little to the left of the head of the hammer can be seen to contain a richly mafic band, showing that the mafic fragments are derived from banded syenite. (Photo G.G.U., T.C.R.P.).

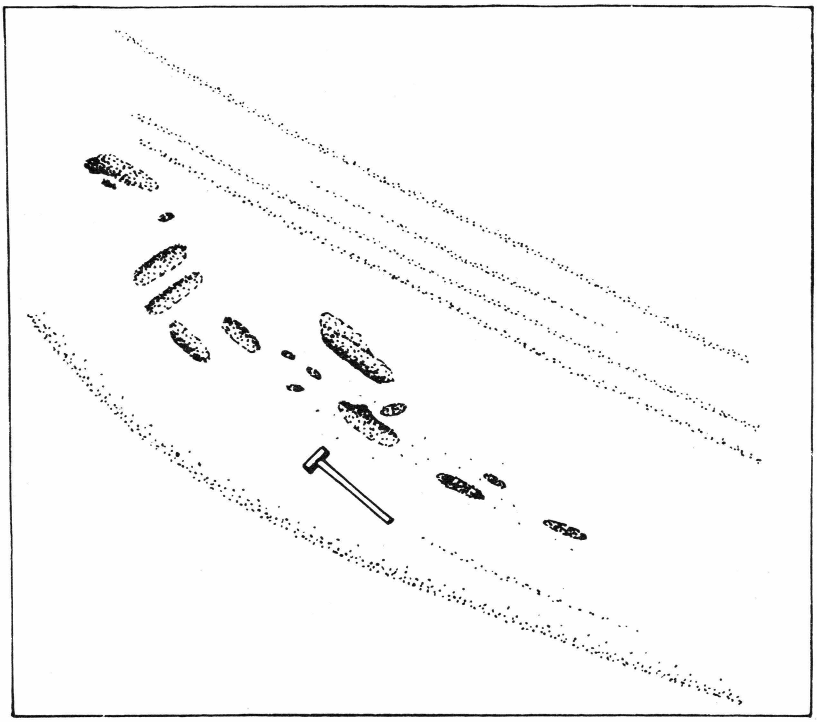

Fig. 61. Slump breccia in the Nunarssuit Syenite south of the entrance to Tasiussaq. The fragments in the breccia are of banded and gravity stratified syenite which was broken up during strong disturbances. Drawn from a field sketch. (T.C.R.P.).

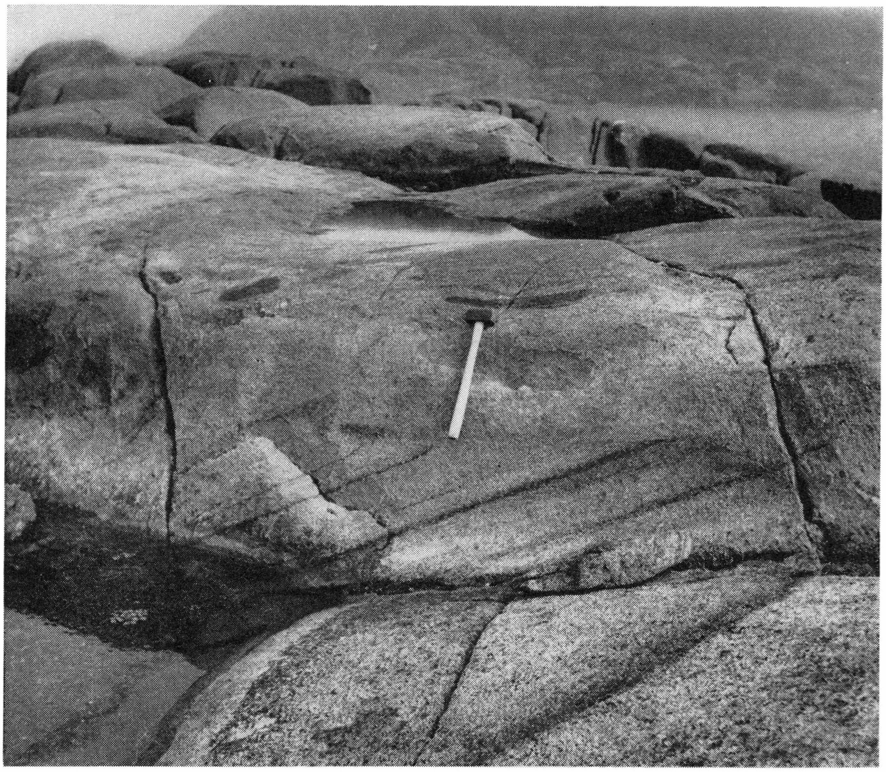

Fig. 62. Breccia zone strongly discordant to the mineral layering: in the Nunarssuit Syenite north of the entrance to Tasiussaq. (Photo G.G.U., T.C.R.P.).

Both the discordances and the outwash channels are taken as evidence of disturbance due to increased current action during formation of the banding. Even more spectacular evidence of disturbance is afforded by the slump structures and breccias usually seen near outwash channels and best displayed on either side of Tasiussaq. Fig. 59 shows disturbed layering which has formed load casts strikingly like structures in the Stillwater complex (Hess 1960, plate 7 lower figure).

Intense disturbance gave rise to breccias of the type shown in figs. 60, 61 and 62 containing elongate fragments of highly mafic syenite up to 50 cm long. Some of these seem to be fragments of disrupted mafic layers for they show banding or grading. Others (e. g. the large block in the outwash channel shown in fig. 58) must have been detached from the thick mafic lenses sometimes associated with trough banding for they are homogeneous and too thick to have been derived from the usual sort of layering in the syenite.

The breccias may lie concordantly above or below undisturbed banding (see figs. 60 and 61). On the other hand they sometimes trun-

Fig. 63. Exceptionally coarse syenite which forms a crude band in the Nunarssuit Syenite south of the entrance to Tasiussaq. (Photo G.G.U., T.C.R.P.).

cate such banding (fig. 62). In one layered sequence on the north side of the entrance to Tasiussaq the dip of each successive layer increases from about 35 to 45 degrees passing up the succession which terminates abruptly in a superincumbent breccia truncating the banding in places.

Concordantly within rather weakly layered syenite south of the entrance to Tasiussaq there are a few curious bands about 80 cm thick and of limited lateral extent which consist of exceptionally coarse syenite (fig. 63) containing hornblende interstitial to subrectangular poikilitic felspars up to 7 cm long enclosing prismatic pyroxene crystals.

The middle zone of S.W. Nunarssuit.

The middle zone of S.W. Nunarssuit lies a little below the xenolithic inclusion zone near Agdlerûssat avangnardlît and can be seen near the shore both north-west and south-west of that mountain. At both places the layered succession is only about 5 m thick though isolated bands occur concordantly above and below it. The succession is defined by highly mafic layers 6–20 cm apart and less than 4 cm thick, comprising dark minerals that are notably finer-grained than those in the normal syenite. It is often accompanied by a concordant lamination of roughly tabular felspars best seen in the upper only slightly mafic parts of the bands and in the intervening syenite. Grading is a common feature and is always normal. No discordances have been observed.

The uppermost zone in S.W. Nunarssuit.

The uppermost zone of layering is only a few metres thick and is restricted to a single locality just south of the small island in the fjord south of Tasiussaq. The layering in it closely resembles that in the middle zone although the mafic bands tend to be thinner and more closely spaced. Sometimes the layering is arched upwards in a gentle fold but the individual bands retain their thickness and parallelism throughout such structures.

Layering east of Mercurius Havn and south of Peru Havn.

East of Mercurius Havn and south of Peru Havn the layering consists of regular parallel moderately mafic bands up to 5 cm thick and 20 cm or more apart in otherwise normal syenite. Neither grading nor discordances have been seen.

Mineral composition.

Under the microscope the dark layers in the Nunarssuit Syenite are seen to consist chiefly of cumulus fayalite and clinopyroxene crystals which, in the more mafic bands and lenses, are smaller and more idiomorphic than the fayalite and pyroxene crystals in the normal syenite. Ore minerals are more abundant than in the normal syenite but are sometimes interstitial. Like the fayalite, they appear to have undergone some adcumulus growth.

Hornblende, in contrast, is rather scarce. Potash felspar fills interstices between the mafic minerals, forming optic units up to 8 mm long and containing as many as ten mafic mineral grains in those layers where the mafic minerals are not too densely packed. In passing upwards from a mafic layer into normal syenite, the felspar gradually assumes subidiomorphic form.

(f) Kitdlavât Granite.

A kilometre due east of the summit of Kitdlavât the Kitdlavât Granite is weakly but distinctly layered, owing to slight concentrations of pyroxene in plane-parallel bands 2–3 cm thick and 10–30 cm apart, striking 175 and dipping east at 35–45°. No grading is developed.

Near the base of the Kitdlavât Granite an imperfectly developed felspar lamination is sometimes discernable, dipping eastwards parallel to the floor of the laccolith and sometimes accompanied by impersistent concordant dark bands.

VIII. CONCLUSIONS

From the data presented so far the following general conclusions can be drawn about the development of the Nunarssuit complex.

(a) Magmatic origin of the complex.

The preceding sections of this paper show that the Nunarssuit complex presents the characteristic features of an igneous pluton and would be regarded as such by virtually all geologists. With this interpretation the present writers whole-heartedly agree but since WEGMANN (1938, p. 116) has ascribed the granites of the complex to metamorphism of country rocks and appears inclined towards a transformist view of the syenites it is necessary to state the main reasons for rejecting his ideas. Naturally the data already given cannot be adduced in full. Attention is drawn only to the general features enumerated below. None of these is necessarily conclusive in itself: but considered together they are impressive evidence that each member of the Nunarssuit complex was emplaced as a hot highly mobile intrusion that made room for itself largely by mechanical action, though there was some marginal metasomatism at certain places.

Evidence of mobility.

1. The external and internal contacts of the complex are generally knife-sharp. A notable exception is the transition zone between the Nunarssuit Syenite and the Julianehåb Granite basement in Nunarssuit which some transformists might take as suggesting a replacement *in situ* origin for the whole syenite mass. Indeed, if WEGMANN had noted this zone it would be easier to understand how he reached his transformist interpretation of the complex. But the zone—like the modified schists near the Biotite-Granite in the Ũmánánguaq skerries and the hybridized gabbro area between the Helene Granite and Biotite-Granite—is best explained as a result of metasomatism at the periphery of igneous mass in view of the evidence for the magmatic origin of the main mass of the syenite. Moreover, intrusive syenite with indefinite boundaries are known from other Gardar

complexes. Upton (1960 p. 23) mentions a 10–15 m wide transition zone between the Western Layered Syenite of Kûngnât and the surrounding gneisses and Pulvertaft (1961 p. 40) has found a similar passage along the border of the Puklen intrusion a few kilometres from the Nunarssuit complex. In both cases there is no good reason to doubt the intrusive nature of the syenites concerned.

2. The boundary between the complex (including the Biotite-Granite and Helene Granite) and the basement is highly discordant. Particularly striking is the manner in which it abruptly truncates the numerous Gardar dykes in the basement. Structures in the basement do not—even vaguely—continue into the complex.

3. The two bodies whose outcrops constitute by far the largest part of the visible complex, the Nunarssuit Syenite and the Helene Granite, are remarkably homogeneous considering their size. They are, in fact, much more uniform than many bodies to which a magmatic origin is attributed.

4. The members of the complex often develop relatively fine-grained and frequently porphyritic marginal phases which differ from the interiors of their parents only or chiefly in texture. The marginal phase often present at the Helene Granite boundary cuts the country rocks with knife-sharp contact, sends apophyses with sharp boundaries into the country rocks, and does not vary in composition according to whether it lies against a basic mass or Julianehåb Granite. The fine-grained marginal modification of the Biotite-Granite north-east of Angnikitsorssuaq forms demonstrably dilational veins in schists of the peripheral xenolithic zone that occurs there.

5. Other evidence of forcible intrusion is illustrated in fig. 20 which shows a metasedimentary xenolith wedged open by an apophysis from the enclosing Helene Granite. Furthermore, near Helene Havn the Helene Granite forms veins in country rock and appears to have mechanically detached and engulfed a block of its country rocks by stoping.

6. Xenoliths are restricted to certain relatively small areas of the complex in which they are usually abundant. They possess sharp boundaries and can be angular. In the Helene Granite and Nunarssuit Syenite near Stærkodder Havn they are highly deorientated and have obviously been transported some distance, for they include a wide variety of different rock types quite haphazardly distributed within the xenolithic zone.

Evidence of steep thermal gradients.

At the one place where the Alángorssuaq Gabbro has been seen in contact with the basement the latter has very locally been remobilized and highly recrystallized. Unlike the Nunarssuit Syenite which has thoroughly recrystallized Gardar dolerites in the basement close to its margin, the Helene Granite and Biotite-Granite have produced little thermal metamorphism in their basement country rocks. This may be because the basement had already been regionally metamorphosed under amphibolite facies conditions or because the mineral assemblages concerned, for instance those in the Julianehåb Granite, are stable over a wide range of temperatures. Within the complex, however, xenoliths of the inclusion zones have suffered intense contact metamorphism by the enclosing Helene Granite as well as the Nunarssuit Syenite, and many have been recrystallized to assemblages indicative of pyroxene hornfels facies conditions. The considerable decrease in grade of thermal metamorphism passing from the margins to the centres of the larger xenoliths demonstrates a steep thermal gradient hard to envisage if the enclosing rocks had formed by metasomatic replacement *in situ* of older rocks. Steep thermal gradients are much less feasible in replacement bodies than in igneous plutons intruded, like the Nunarssuit complex, into cold rocks, for the replacement process must be much slower than the crystallization of such plutons.

Evidence of liquidity.

From the preceding paragraphs it can be taken as established that the Nunarssuit complex was emplaced as a series of hot mobile intrusions. It remains to consider whether these were initially either fluid magmas, using that term in the customary way regardless of the ultimate origin of the melts, or pasty mobilized and homogenized migmas.

The lamination and mineral layering discussed below in sub-section (c) cannot have formed in highly plastic mobile migma. Flow structures, lineation and schlieren can conceivably develop in such an environment but not the regular rhythmic layered sequences, the delicate patterns remiscent of sedimentary structures, and the thin persistent mafic layers described in Section VII from the Helene Granite and Nunarssuit Syenite which can only have arisen during sedimentation in a liquid environment. These must therefore be the result of either crystallization from fluid magma or metasomatic replacement *in situ* of sedimentary rocks. The second possibility, as we have seen, can be eliminated, and additional reasons for doing so will be given later in sub-section (c).

Ability of the magmatic hypothesis to explain all features of the complex.

The measure of the validity of a hypothesis is its ability to account for a set of phenomena without inconsistencies or leaving unexplained facts. In this the magmatic hypothesis is more successful than the transformist interpretation when considering the Nunarssuit complex. A number of features have just been used as evidence for the magmatic origin of the complex. It seems worth pointing out that the other features of the complex, though not adduced as such evidence, can be satisfactorily interpreted in magmatist terms. To illustrate this several phenomena will be selected at random.

For instance, an approximate sequence of crystallization of minerals can sometimes be made out from textural evidence in the members of the complex and the broad picture thus obtained is consonant with magmatic crystallization. Thus hornblende and quartz are clearly later than pyroxene in the Nunarssuit Syenite; in the Helene Granite hornblende and biotite are later than clinopyroxene, and quartz occurs in two generations, the first forming subidiomorphic phenocrysts.

Zones of reddening up to many metres wide, sometimes connected with joints but more often highly irregular in pattern, ramify through the Helene Granite at a number of places. They are occasionally associated with thin quartz veinlets and appear to be due to a haematitization of the normal granite which might well be deuteric.

The discordant Helene Granite vein with sharp boundaries that cuts the Alángorssuaq Gabbro east of the major N.N.E. transcurrent fault near the Helene Granite margin and passes into graphic granite with increase in distance from the Helene Granite (Sec. V (a)) seems an obvious magmatic apophysis.

The concentration of pegmatite and aplite veins in the basement near the margin of the Biotite-Granite north-east of Angnikitsorssuaq is best explained by the activity of residual fluids derived from the adjacent granite.

The leucosyenite around metavolcanic inclusions in S.W. Nunarssuit and south of Helene Havn mentioned in Sec. III, which is confined to the neighbourhood of the xenoliths and bears sharp contacts against the normal syenite, can be interpreted as follows. With cooling and consequent contraction of the syenite massif the metavolcanic wedges tended to collapse in some places through lack of physical support. Openings and fractures consequently formed around the metavolcanics and became filled and enlarged by the late residual liquid left after the crystallization of the bulk of the syenite. The petrographic facts are not inconsistent with this idea. In addition to its lower content of dark minerals, the leucosyenite contrasts with the normal syenite in lacking fayalite and possessing zircon instead of apatite as a constant accessory. Furthermore the pyroxene is a green variety resembling the outermost zones of some pyroxenes in the main syenite.

The leucocratic sheet east of Mercurius Havn which reappears north of the entrance to Tasiussaq can best be regarded as an injection into incompletely solidified syenite, for its upper boundary is rather vague east of Mercurius Havn, and at the entrance to Tasiussaq the leucosyenite veins in the porphyritic syenite and the inclusions of the latter in the leucosyenite exhibit forms suggesting that the porphyritic syenite was quite plastic when the leucosyenite was emplaced.

On the other hand the lenticular pockets of leucosyenite south of Peru Havn and north-east of Agdlerûssat avangnardlît are tentatively interpreted as representing local patches of residual melt which differentiated slightly during crystallization. This would account for their sharp upper contact against, and downwards passage into, the normal syenite.

(b) Age relations between members of the complex.

Clearly, the Alángorssuaq Gabbro is older than either the Biotite-Granite or Helene Granite. The Kitsigsut Syenite also is older than the Biotite-Granite though its relations with other members of the complex are not known.

There is some reason to believe that the Biotite-Granite is younger than the Helene Granite but for the most part the mutual field relations of these two granites are equivocal.

The Nunarssuit Syenite is undoubtedly younger than the Helene Granite in Alángorssuaq but in many parts of Nunarssuit these relationships are reversed and the Helene Granite invades the syenite on a scale that would seem to preclude the possibility of the granite having simply been remobilized by the syenite in a back-veining effect. These puzzling age relationships might be explained in different ways.

1. The Helene Granite in Alángorssuaq was consolidated when the Nunarssuit Syenite arrived but in Nunarssuit remained locally mobile long enough to envelope blocks of syenite when the latter was at the same time still sufficiently plastic to detach large K felspars from the granite.
2. The normal Helene Granite is a multiple intrusion.
3. The normal Nunarssuit Syenite is a single intrusion that reached its present position later in Alángorssuaq than in Nunarssuit.
4. The normal Nunarssuit Syenite is a multiple intrusion.

The writers favour the first of these alternatives, for the third alternative seems hardly feasible and there is no supporting evidence for the second and fourth. As previously remarked, the normal Helene Granite and Nunarssuit Syenite are remarkably homogeneous and no internal contacts have been found within them. Exposures are admittedly interrupted by Torssukåtak but it would be highly coincidental if the crucial evidence was concealed by this waterway and, moreover, internal contacts would not be expected to cut across the structure of the complex in the manner that Torssukåtak does.

However, it is difficult to explain precisely why the Helene Granite should exhibit the differential mobility that has been advocated. Perhaps the granite cooled more slowly in Nunarssuit than in Alángorssuaq because it was nearer the centre of the complex. Perhaps, in addition, the overlying xenolithic inclusion zone provided a blanket locally inhibiting loss of heat. Further explanations could be advanced but they would be purely speculative for no evidence can be adduced to support them.

The Malenefjeld Granite is nowhere seen in contact with the other members of the complex; so its age relations cannot be established with certainty. However, it is probably younger than the Nunarssuit Syenite, for petrographically it rather resembles the late soda-granite bodies within the Nunarssuit Syenite and it contains an augite syenite inclusion at Qagssîssaq. On its north-west side the Malenefjeld Granite has a thin skin of augite syenite which is not a late injection but an earlier phase into which the granite grades.

(c) Origin of the mineral layering.

Textural relations show that the mafic layers in the Alángorssuaq Gabbro, Helene Granite, Biotite-Granite, Kitdlavât Granite, Kitsigsut Syenite and Nunarssuit Syenite crystallized at roughly the same time as the rocks adjacent to them were formed. Moreover, an abundance of clean rock-surfaces demonstrates that the layering is an integral part of each of these intrusions; there are no intrusive contacts between layered and non-layered units. For instance, the layers of normal granite between rhythmically repeated mafic layers in the Helene Granite are inseparable from the surrounding non-layered granite, into which they can be traced without a break.

Evidently, the origin of the layering must, in essence, be that of the member of the complex in which it occurs. The magmatic origin of the complex has already been argued for in Section VIII (a): it follows then that the layering must also be magmatic.

Evidence supporting this conclusion is provided by the layering itself. From the descriptions in Section VII it can be seen that most of the detailed structures shown by the layering could only arise in a fluid medium. Frequent comparisons can be drawn between them and structures such as current- and graded-bedding found in sedimentary rocks. Disregarding for the moment the arguments for the magmatic origin of the complex given in Section VIII (a) only two explanations seem possible. Either the layering is a relict feature faithfully preserved when the complex arose by metasomatic replacement of sedimentary rocks *in situ*, or it formed in liquid magma. The difficulties raised by the first explanation seem insuperable.

In the first place the large-scale pattern of the layering bears no relation to structures outside the complex but shows a general connexion with the pluton as a whole since the layers tend to be inclined towards the interior of that body. Thus in the Alángorssuaq Gabbro they (and associated lamination) are inclined towards a deep focus within the Helene Granite or Nunarssuit Syenite; in the Kitsigsut Syenite they usually dip southwards; in the Helene Granite there is a vague tendency for them to be inclined towards the interior of Alángorssuaq, and in the Nunarssuit Syenite their plan describes an arc about a centre east of Eqatdliartarfik in central Nunarssuit.

In the second place, it may well be asked, how could a replacement process preserve delicate sedimentary structures so successfully when in general it must have involved drastic chemical changes and a thorough homogenization of large volumes of the crust? This problem becomes particularly acute in considering those mafic layers which are so clearly defined that, under the replacement hypothesis, they would seem to have been emphasized by metamorphic differentiation, a process contrary to homogenization.

In the third place, rocks which show the sort of sedimentary structures seen in the Nunarssuit Syenite and which on transformation could yield the layered syenite are not known in the area. The Igaliko sandstone is confined to a down-faulted tract 100 km east of Nunarssuit, and even if it had once covered the Nunarssuit area it would have been at a very much higher level than the layered zones in the syenite. Well-preserved sedimentary structures on the scale of those in the syenite have not been observed in the metasedimentary rocks around Kobberminebugt and would in any case have been modified or destroyed by the orogenic processes that affected the region before the Nunarssuit complex was intruded.

On the other hand, the structures described are closely comparable with those in many igneous plutons throughout the world and their genesis can be considered more fruitfully in magmatist rather than transformist terms.

It can be assumed that the intrusions reached their present structural level in the basement as more or less liquid bodies and that the roof of the complex may not have been far above the present erosion-level (see Section VIII (d)). The mineral layering in general formed after emplacement but before consolidation of the magma concerned, for on the whole it is undisturbed. Disruption and contortion of certain layers can be ascribed to movements immediately prior to final consolidation of the surrounding rock. So also might the attitude of some very steeply inclined bands.

Probably a number of magmatic processes have contributed to the formation of the layering. The rhythmic sequences proceed in roughly arithmetical progression, whereas according to Poldervaart and Taubeneck (1960) rhythmic banding produced by a single process should yield a geometrical or exponential progression as in metamorphic orbicules.

Nevertheless, certain broad conclusions can be drawn, although a detailed discussion of the possibilities must await a full petrological study. The layers can be taken to represent various levels of the cumulate floor of a magma chamber as the latter consolidated from below upwards. Gravitational settling of comparatively heavy olivine and pyroxene cumulus crystals was effective in forming mafic bands, as gravity stratification frequently testifies. The cooperation of magmatic currents in the syenite and granite intrusions is witnessed by the frequency of structures comparable with primary features of sediments deposited in flowing media. Upton (1961) has stressed the significance of magmatic flow in the formation of layering in certain South Greenland plutons.

However, the relative importance of current-structures within the complex varies from intrusion to intrusion. In the Kitsigsut Syenite they are comparatively poorly developed. In the Helene Granite they are strikingly represented by the structures resembling trough-banding of Skærgaard type; but they are not a feature of the complex subhorizontal layered sequence in S.W. Alángorssuaq. The mafic layers in that sequence, though thin, are planar and highly persistent and can be depressed beneath contiguous large perthite crystals as if the latter had settled under relatively quiescent conditions (fig. 46). Here, however, variation in volatile content of the magma or some control other than those just mentioned must also have been operative.

In the Nunarssuit Syenite there is abundant evidence of current action; unusually strong localized currents caused trough banding and outwash channels. Another feature of the syenite is slumping—due to sudden disturbances possibly induced by earthquakes—which like the outwash channels demand the existence of a notable thickness of crystal mush on the floor of the magma chamber. Some estimate can be given of the depth of this layer. The zones of slumping are 1–2 m thick, and to permit the formation of an outwash channel like that illustrated in fig. 58 there must have been at least 2 m of unconsolidated material.

These figures are comparable with those given by Hess (1960 p. 130) for the Norite Zone of the Stillwater complex (3–10 feet, normally about 5 feet) and by Upton (1960 p. 118) for the augite syenite of Kûngnât (about one metre).

From the Nunarssuit Syenite some impression can also be gained of the maximum angle of rest of the cumulate floor. Reference was made in Section VII (e) to the layered succession north of the entrance to Tasiussaq where the dip of each successive layer increases going up the sequence to a maximum of about 45 degrees just before the succession terminates abruptly in an overlying slump zone. This points to a value of about 45 degrees for the maximum angle of rest. Values of 40 and 50 degrees for the maximum angle of rest under normal conditions are given by Upton (1960 p. 116) for different members of the augite syenite complex of Kûngnât. It seems justifiable to assume that the Nunarssuit complex has not been tilted since it was emplaced.

(d) Structure and mechanism of emplacement of the complex.

The complex as a whole seems to be a discordant stock-like mass since its contact with the basement is discordant and for the most part roughly vertical or inclined steeply outwards. It would appear to be exposed at a fairly high structural level, considering the interpretation of the xenolithic inclusion zones advanced in Section VIII (e). In this respect it is worth noting that mineral layering in many ways resembling the Helene Granite layering occurs in one of the Tigssaluk granites north of Ivigtut at a height believed to be within about 200 metres of the original rocf of the intrusion (Harry and Emeleus 1960 p. 174). Moreover, the Kitdlavât Granite appears to have been intruded below a fairly thin roof because of its laccolithic form.

Major stoping can account far more satisfactorily than any other mechanism for the emplacement of the complex. Only the Alángorssuaq Gabbro provides any indication that ring fractures may have been influential. Piecemeal stoping can also be dismissed as an important factor. Xenoliths of one member of the complex in another member are only abundant in the comparatively small area where the Biotite-Granite and Helene Granite attack the Alángorssuaq Gabbro. Country rock xenoliths are very rare apart from the restricted inclusion zones and, although there has been some brecciation and assimilation of xenoliths south of Mercurius Havn, the zones provide very little evidence of piecemeal stoping.

The coastal situation and consequent concealment of the seawards extent of the Nunarssuit complex greatly handicaps any attempt to give structural reasons for the location of the complex; nevertheless two features seem significant—the north-east dyke swarm and the Qagssimiut fault.

Prior to the emplacement of the complex, Nunarssuit and the district to the north-east was invaded by a dense swarm of north-easterly, almost wholly dolerite dykes which represent a crustal stretching of about 2.25 km in the 14 km wide belt between Bangs Havn and the layered dyke in S.E. Nunarssuit (see Pl. 3). Dykes are much less numerous to the north-east and south-east of this belt which therefore appears to have been a zone of relative crustal weakness during Gardar times and thus may be partly responsible for the position of the Nunarssuit complex.

Another factor may have been the Qagssimiut fault. Of the many faults which traverse South Greenland the most important are the major east-west ones. The distribution of the Igaliko sandstone and associated lavas is in fact largely determined by them. Most of them moved during Gardar times; some were initiated before then (see Henriksen 1960). A powerful east-west fault (not operative after the intrusion of the north-east Gardar dyke swarm) runs from Qagssimiut westwards along Ikerasagssuaq, as mentioned in the introduction, and up to the Nunarssuit complex. Its relationship to the complex is closely comparable with that of a similar roughly east-west fault to the Ilímaussaq complex (see Plate I). In addition both the Igaliko batholith and the much smaller Grønnedal intrusion are similarly related to such faults. It would appear, then, that the major east-west faults exerted some influence over the location of the plutons, including the Nunarssuit complex.

Further to these general remarks some specific features of different members of the Nunarssuit complex should be briefly noted.

The Alángorssuaq Gabbro may have been emplaced along an arcuate fracture, considering the trend of its contact with the Julianehåb Granite which is approximately arcuate except near its western extremity where the Green Schist outcrop swings south to approach the complex. As the schists are less rigid than the Julianehåb Granite, the basement near the western end of the gabbro may have been comparatively weak and thus have favoured an outward extension of the complex. If the basement had been homogeneous in Alángorssuaq the northern margin of the gabbro might have been more truly arcuate. Supposing an arcuate fracture along the northern boundary of the gabbro and subsidence of the inner southern block about a hinge further to the south, the gabbro could have been emplaced without recourse to stoping.

A small point is raised by the local deflection of the gabbro—basement contact immediately west of the important N.N.E. tear fault crossing central Alángorssuaq. This fault was operative before the emplacement of the complex (indeed, the greater part of the movement on most Gardar faults in South Greenland took place before the major complexes were intruded) for it displaces the vertical Julianehåb Granite —Green Schist contact much more than the very steep gabbro-Julianehåb Granite contact. Thus the slight protrusion of the gabbro outcrop northwards along the fault might partly be due to the latter having served as a plane of weakness exploited by the gabbro during its intrusion.

The Biotite-Granite is a stock-like body. A marginal phase locally brecciates the Green Schist country rocks and the granite attacks the gabbro in Alángorssuaq but xenoliths are generally absent from the intrusion.

The Helene Granite boundary against the Alángorssuaq Gabbro might have been controlled by the primary structures in the latter, for it follows the strike of the layering in the adjacent gabbro.

Against the basement the Helene Granite contact is uneven and in no way suggestive of ring fracture—on the contrary, direct evidence of major stoping is available east of Emma Havn where the granite has detached a large block of country rock which now lies only a short distance from its original position in the walls of the intrusion (see Plate 2).

The contact between the Nunarssuit Syenite and the basement is likewise irregular and lacks the scalloped traces suggestive of ring fracture. In S.E. Nunarssuit it certainly defines a crude quarter-circle on the map but in detail that feature is too uneven to be advanced as evidence of a ring fracture. A marked embayment in the contact just west of Kangerdluluk is, in fact, suggestive of major stoping for it resembles the embayment east of Emma Havn where, as noted in the last paragraph, stoping is demonstrable.

It would seem more than merely coincidental that the boundary between the Nunarssuit Syenite and Helene Granite in the west roughly follows the major xenolithic zone despite deviations in two places—east of Kap Desolation and 2 km south of Mercurius Havn.

Somehow the zone appears to have locally guided the emplacement of these intrusions, a point that will be returned to in Section VIII (e). This effect may well have been reinforced by the dextral tear fault running N.N.E. from Stærkodder Havn which was in existence before the intrusion of the complex, as already remarked, and also may well explain the abrupt change in trend of the Helene Granite–Nunarssuit Syenite boundary at the oval lake in Alángorssuaq. From the west side of the lake the boundary runs S.S.W. to Stærkodder Havn parallel and close to the fault (see Plate 3) which has sheared the syenite, as at Stærkodder Havn, though without producing the intense mylonitization it has effected in the Helene Granite north of the lake. The fault therefore must have operated chiefly before the arrival of the syenite and it appears to have been used by the syenite during intrusion.

Because of its laccolithic form, the Kitdlavât Granite seems to have been intruded under a fairly thin cover whilst the surrounding Nunarssuit Syenite was still capable of yielding plastically, for otherwise it could hardly have arched its roof.

The irregular margin and complete freedom from xenoliths of the Malenefjeld Granite favour major stoping as the most likely mechanism for the emplacement of that intrusion, but the evidence is too slight for positive conclusions to be drawn.

(e) The significance of the xenolithic inclusion zones.

The provenance of the inclusions in the xenolithic zones has already been discussed in Section VI; now that the magmatic origin of the complex has been established their significance can be considered.

The xenoliths of the inclusion zones could not have been emplaced by the mechanism that Upton (1960) has proposed for the gneiss raft in the Kûngnât Western Layered Syenite—descent of a xenolithic block through magma of gradually increasing density until it becomes suspended in magma of the same density as itself. Being basaltic in composition they would be denser than syenite magma and in any case that hypothesis cannot account for the occurrence of zones at different levels one above the other in Nunarssuit. Two ideas can be entertained. The xenoliths in the Nunarssuit inclusion zones might either (1) have sunk down through the magma until they came to rest on the cumulate floor of the magma chamber or (2) be partially disrupted remnants of roof pendant wedges more or less in their original position.

The first hypothesis could explain the concordance between the zones and adjacent layering in the Nunarssuit Syenite, for collapsed roof blocks which descended through the magma chamber and settled on its floor would tend to be aligned in parallelism with the latter. Two episodes of roof collapse separated by upward growth of the chamber floor would account for the two different levels of the inclusion zones in S.W. Nunarssuit.

On the other hand, the second hypothesis is favoured by the fact that the inclusion zones in S.W. Nunarssuit widen with increasing altitude (see fig. 28) as if they are merely the extremities of roof pendant wedges now largely removed by erosion. In the Mercurius Havn zone, moreover, the xenoliths are often so tightly packed that they convey the impression of having been disrupted more or less *in situ*, though scattered xenoliths do occur and at the northern termination of the zone in Alángorssuaq the blocks are admittedly so deranged and ill-assorted that they must have moved some distance within the magma.

The position of the main xenolithic zone at the boundary between the Helene Granite and Nunarssuit Syenite also seems significant. In Alángorssuaq numerous xenoliths occur in both the Helene Granite and Nunarssuit Syenite yet the Helene Granite here had consolidated before the intrusion of the syenite. It would seem from this that the xenolithic zone represents the disrupted remnants of a screen or roof pendant wedge along which the Helene Granite and Nunarssuit Syenite were intruded. Such a strip of country rocks within the complex would tend to form a barrier to an ascending intrusion.

It is therefore strongly suspected that the xenolithic inclusion zones are relics of country screens or roof pendant wedges disrupted to various degrees by the intruding magmas but, for the most part, not far from their original position. The lack of assimilation shown by most xenoliths is perhaps some corroboration of this, for if the xenoliths had descended to great depths in the magma chamber they might be expected to have undergone considerable metasomatic attack by the surrounding magma.

IX. SOME COMPARISONS WITH OTHER AREAS

A full petrological and geochemical study of the Nunarssuit complex must naturally first be carried out before detailed comparisons can be made, but it seems useful to close this general and largely field account by drawing attention to certain similarities and dissimilarities between the complex and other intrusive areas.

(a) Comparisons between the Nunarssuit complex and other plutons in the South Greenland pre-Cambrian Gardar Alkaline Province.

The age of the Nunarssuit complex as compared with that of other Gardar intrusions was discussed in Section II of this paper where it was pointed out that the complex is one of the late-Gardar plutons, being more or less contemporaneous with the Ilímaussaq, Kûngnât, Puklen and Tugtutôq complexes.

With regard to size the Gardar intrusive complexes can be classified in two groups, one comprising the small bodies of Grønnedal, Kûngnât, Puklen and central Tugtutôq whose longest axes measure 4–6 km, the other comprising the major plutons at least 16 km wide. The Nunarssuit complex belongs to the latter group together with the Ilímaussaq and Igaliko "batholiths".

In Section VIII (d) it was suggested that the major east-west faults may to some extent have determined the locations of the Nunarssuit complex and other South Greenland Gardar plutons. It might further be suggested that tectonism may have exerted some influence over the chemical trend as well as the location of the plutons for chemically the Gardar intrusions fall into two groups, the undersaturated and the saturated, the first occurring in extensively faulted areas, the second being found in less faulted environments, as tabulated below.

Narssaq-Igaliko and Grønnedal-Ika areas	*Nunarssuit and Kûngnât environs*
Undersaturated complexes	Saturated complexes
Extensive faulting and crushing (graben of Igaliko sst.)	Few faults and little crushing
Numerous trachyte dykes	Trachytes rare

Layering, which is so commonly found in the Nunarssuit complex, is also a feature of the Gardar Province as a whole. As UPTON (1961 p. 10) remarks, the intrusive magmas of this province must have been highly mobile to permit not only extensive gravitative crystal differentiation but also the current activity that played such an important part in the development of many layered sequences. The mobility of the magmas may be connected with the fact that geochemically the Gardar intrusions comprise a fluorine province; BUERGER (1948) has discussed the function of fluorine in reducing the viscosity of magmas.

Like the Kûngnât complex the Nunarssuit complex does not exhibit a completely regular sequence of intrusions in order of decreasing basicity. This ideal sequence, often found elsewhere in the world, is interrupted by the Helene Granite, whilst in Kûngnât the gabbro is younger than syenite though older than the late-stage granites of the western centre. Unlike the Kûngnât complex, however, the Nunarssuit pluton, at least as far as the investigations up to present have revealed, apparently lacks cryptic variation. Nevertheless it must be borne in mind that this may be only because of the relatively restricted vertical extent of exposure and the present incomplete petrological picture of the Nunarssuit complex.

Petrographically, the Nunarssuit complex has many features in common with the other Gardar complexes.

The unaltered Alángorssuaq Gabbro forming the northern part of the gabbro outcrop seems to occupy a systematic position somewhere between the Kûngnât ring dyke and the Tugtutôq gabbros, from information kindly supplied by B. UPTON. It is also, incidentally, remarkably like the large Gardar dolerite dyke that runs W.S.W. up to Naujat qáqât in Alángorssuaq.

Pyroxene-fayalite-syenites in many ways similar to the Nunarssuit and Kitsigsut syenites are widespread in South Greenland. They form the greater part of the Kûngnât complex, the outer part of the Puklen intrusion, thick dykes and lenticular bodies to the north-east of Nunarssuit, the central part of one of the large composite dykes in Tugtutôq (UPTON, 1963), large irregular bodies in the Narssaq area (where much of the so-called nordmarkite of USSING (1912) is in fact pyroxene-fayalite-syenite), and the outer parts of the Ilímaussaq and Igaliko intrusions (Ussing 1912). In the Nunarssuit complex, as is evident from Plate 1, this type of syenite occupies an area very much greater than that of all its other Gardar occurrences considered collectively.

Excluding its development around Itivdliatsiaq and Amitsuarssuk the Nunarssuit Syenite seems very similar to some of the Western Layered Syenite of the Kûngnât intrusion and especially to rocks from about the lowest level of the lower unlaminated group. The Kitsigsut Syenite, however, is more reminiscent of the syenite from the eastern centre at Kûngnât. The analysis of the dark variety of the Kitsigsut Syenite (39458) presented in Table I may be compared with that of 27696 a from the eastern layered series of the Kûngnât complex (Upton 1960 p. 90).

The similarities between the syenites of the Puklen intrusion and the Nunarssuit complex have already been pointed out by Pulvertaft (1961 p. 49).

Soda-granites resembling the Malenefjeld Granite and the late-stage granites within the Nunarssuit Syenite are well-known in the Gardar Province. They occur especially in the Narssaq area where, judging from Ussing's (1912) description, the Ilímaussaq soda-granite in particular presents petrographic features almost identical with those of the soda-granites of south-east Nunarssuit. Other examples occur in the central complex of Tugtutôq, the western centre of the Kûngnât complex, and the Puklen intrusion, the soda-granite in the last being very like that of Malenefjeld and forming part of a differentiation series starting from pyroxene-fayalite-syenite (Pulvertaft 1961 p. 48).

Nothing comparable with the Helene Granite and the Biotite-Granite is known from the other Gardar centres. The genesis of these granites accordingly raises problems that at present are unique within the province.

(b) Affinities with the New England, Nigerian and Oslo regions.

Alkaline provinces containing alkali-gabbro, augite-syenite, pyroxene-fayalite-granite, biotite-granite, and soda-granite occur in many geological periods and many parts of the world, some well-known examples being the New England, Nigerian and Oslo provinces. The affinities of the Nunarssuit complex to these three intrusive areas will be briefly examined.

Whilst the large Helene Granite and Biotite-Granite intrusions distinguish the Nunarssuit complex from the other known Gardar centres they recall to mind the New England and Nigerian provinces in which biotite-granite is the most abundant rock-type, and pyroxene-fayalite-granite is common. The Cape Ann granite, Mass. (Warren and McKinstry 1924), is comparable in composition if not in texture with the

Helene Granite. Furthermore, the Blue Hills riebeckite-granite appears, from the literature, to be very similar to the Malenefjeld Granite. The Nigerian riebeckite-granites also broadly resemble the soda-granites of Nunarssuit although they commonly contain accessory pyrochlore and cryolite and lack aenigmatite, whilst in the Nunarssuit soda-granites aenigmatite is characteristic and pyrochlore and cryolite have not been observed. It should, however, be remembered that the pre-eminent cryolite deposits of Ivigtut occur in a small Gardar granite at Ivigtut some 40 km north of Nunarssuit.

Abundance of accessory fluorite in granite links the Nunarssuit complex—and other Gardar centres—to the Nigerian and New England provinces.

The Nunarssuit complex is about the same size as the largest intrusions in the Nigerian and New England provinces but ring fracture, which is a pronounced feature of those provinces, is at the most a minor factor in its emplacement. In this the Nunarssuit complex resembles most other known Gardar intrusions.

In Nigeria and New England augite syenite is developed but by no means attains the relative quantitative importance that it reaches in the Nunarssuit complex which in this respect is more closely related to the Oslo region. The last is in fact the only intrusive region where augite syenite occupies an area larger than that which it forms in Nunarssuit. Other parallels can be drawn. The Kitsigsut and Nunarssuit syenites are often larvikites meeting Barth's requirement (1944 p. 77) that such rocks must bear plagioclase. The larvikite-nordmarkite-ekerite sequence of the Oslo area matches the Nunarssuit Syenite—soda-granite (Malenefjeld Granite) sequence in which the nordmarkite and nordmarkite-ekerite of the Oslo region are represented by the sparsely developed quartz-syenite of S.E. Nunarssuit, though this is not present on the same scale as its Oslo equivalents. Whilst the trend towards felspathoidal rocks (lardalite) seen in the Oslo region does not take place in the Nunarssuit complex, nepheline syenite is abundant elsewhere in the Gardar Province.

The Helene Granite has no analogue in the Oslo region and though it may be tempting despite field distinctions to compare the Biotite-Granite of Alángorssuaq with the Drammen granite of the Oslo province, the Biotite-Granite forms an integral part of the Nunarssuit complex whereas the Drammen granite occupies a rather independent position geologically and chemically among the Oslo plutonites.

(c) The Helene Granite and the Scandinavian rapakivis.

Is the Helene Granite a rapakivi? Wegmann's (1938) comparison between the marginal Helene Granite and the Finnish rapakivis cannot be lightly disregarded for it was made when he was already familiar with the latter in the field. Nevertheless the Helene Granite is clearly not a rapakivi in the sense generally accepted by English-speaking geologists, for mantled K felspar ovoids are practically absent from the intrusion. READ (1957 p. 135), for example, says that the rapakivi granite proper is characterized by abundant large K felspar ovoids often mantled by a rim of small oligoclase crystals "and it is this striking phenomenon which is usually in mind when the rapakivi granites are considered". The same general opinion seems to be held in Russia also, from the description furnished by ZAVARITSKY (1956 p. 275).

Scandinavian geologists, however, use the term "rapakivi" in a sense that, paradoxically, is both broader and narrower than that just presented, broader in that some Finnish rapakivis only locally display typical ovoids, narrower inasmuch as the term is given an age-significance, a restriction deprecated by READ (*loc. cit.*).

It may then be asked: to what extent does the Helene Granite resemble the Scandinavian rapakivis?.

FROSTERUS (1902) states that, characteristically, rapakivi is a red granite that disintegrates easily and is porphyritic, containing rounded orthoclase crystals often surrounded by plagioclase rims. However, it is not this texture that he seems to regard as an essential feature of the rapakivis but rather their post-tectonic age: they are younger than the orogenic movements which affected all the other Finnish granites.

SEDERHOLM (1928) when dealing with the origin of the rapakivi texture, writes: "the typical rapakivi granite, which is characterized by the occurrence of well-rounded crystals of orthoclase, surrounded by a shell of oligoclase" ... "now ... rapakivi is only used for granites belonging to a definite group of late pre-Cambrian rocks" ... "The word rapakivi has, however, been used in different meanings, both as a petrological and a geological term. As the rocks of the different areas of genetically connected rocks possess very similar petrological characters, they have often been called rapakivi-granites, even when they lack the characteristics of the typical rapakivi". Thus, whilst adding that "it seems preferable to maintain the use of the word rapakivi as a designation of this peculiar texture ... the rounding of orthoclases and their coating with oligoclase" he clearly recognizes that the term has been used in other ways.

VON ECKERMANN (1936) begins his account of the rapakivi granite of the Loos-Hamra region with the following sentence. "The jotnian granites of the region, referred to by the author as the Rapakivi group, differ in many respects from the normal type of the Finnish Rapakivis, their characteristic texture, viz., the rounding of the orthoclases and their surrounding by oligoclase being mostly absent." He then proceeds to describe the granite, mentioning many features also seen in the Helene Granite, e. g. two generations of K felspar, some red phenocrysts of the earlier generation bearing granophyric marginal zones, two generations of quartz, constant accessory fluorite. He concludes: "All evidences, consequently,—tectonic, chemical, mineralogical and textural—go to show the true Rapakivi character of these rocks".

Sahama (1945) writes: "When rapakivi is distinguished from the granites in the geological text- and hand-books, published in different countries, the rapakivi variety ... 'wiborgite' ... is generally given as type example. This variety is conspicuously characterized by oval potash feldspar phenocrysts surrounded by oligoclase mantles. It is true that such a 'wiborgitic' texture is a trait very characteristic just of rapakivis and of them only, but every investigator who has occupied himself with them knows quite well that it cannot be regarded as being any real definition of the texture of rapakivis in general. The whole term 'rapakivi granite' is to be held as being as much a geological term as a purely petrographical one, and it is to be considered as being the common name for all the rock types of the granite area in question." He subdivides the rapakivi granite varieties into four types, only one of which—wiborgite—has oligoclase-mantled K felspar ovoids. Later he adds "Possibly the only circumstance common to most of the granite types of the rapakivi areas, and showing so wide a distribution in the rapakivi areas that it can be held as being characteristic of the 'rapakivis' is the appearance of quartz in two separate generations."

Savolahti (1956 p. 83) in a recent account of the rapakivi granite of the Ahvenisto Massif in Finland describes rapakivis as "medium- and coarse-grained, partly porphyritic granites disintegrating to 'moro'" and then goes on to review different writers' opinions regarding the common and characteristic features of rapakivi rocks, remarking that "The potash feldspar grains are most often more or less roundish (ovoids) and in many cases enclosed in a shell of plagioclase. In not nearly all the rapakivi types do potash feldspars enclosed in plagioclase occur." He then gives the other rapakivi characteristics, viz., red-brown colour due to staining by iron oxides, disintegration to 'moro', unoriented structure, scarcity of aplites and pegmatites, two generations of quartz and felspar, and the presence of fluorite and also zircon as accessories.

These authoritative statements all show that for Scandinavian—principally Finnish—geologists a rapakivi granite need by no means display the mantled K felspar ovoids which are taken by British and American writers as essential features of such granites. Therefore, the absence of rapakivi ovoids does not preclude a comparison between the Helene Granite and the Scandinavian rapakivis. Disregarding for the moment age criteria, a close parallel can in fact be drawn petrographically between the Helene Granite and certain Finnish rapakivis. The latter characteristically display the following features.—

Disintegration to "moro" under surface conditions—hence the term "rapakivi" which simply means "disintegrating rock" not "rotten rock" as is sometimes remarked.

Occurrence of quartz in two generations: phenocrysts which are typically bipyramidal, and anhedral grains in the groundmass.

Frequency of accessory fluorite and zircon.

Sharp contacts with country rocks.

Lack of foliation or lineation.

Scarcity of pegmatites and aplites.

Red colouration due to dispersed haematite.

All these are features of the Helene Granite, though red colouration is restricted to certain zones only, and the quartz phenocrysts never attain the degree of idiomorphism that they reach in the Finnish rapakivis, while orthoclase, and not microcline, is commonly the dominant K felspar in the Finnish rapakivis.

In particular, the Helene Granite closely resembles in texture the biotite rapakivi of the Ahvenisto Massif which was visited by the second author under the guidance of Drs. SAVOLAHTI and LEHIJÄRVI whose kindness is gratefully acknowledged. But in mineral composition the Helene Granite accords more with the hornblende rapakivi of Ahvenisto, especially where the latter contains pyroxene and fayalite. It may also be noted that HACKMAN (1934) records small quantities of pyroxene and fayalite in the Viborg massif where the fayalite may, moreover, sometimes be concentrated in isolated steep layers, though the extent to which these resemble some of the banding in the Helene Granite is unknown.

Turning now to the age-connotation of the term "rapakivi" as it is used in Scandinavia, the Scandinavian rapakivi and the Helene Granite are more or less undeformed pre-Cambrian plutons intruded into regions which had previously been tectonized but have remained stable since before Cambrian times. Their regional geological settings to this extent are broadly analogous. Certain details may also be comparable. The occurrence in the South Greenland Gardar province of anorthosites and the Helene Granite recalls the association of rapakivi and anorthosite found at several places in the Baltic Shield, for example, Nordingrä in Sweden (VON ECKERMANN 1938) and places near the Finnish-Russian border (VELIKOSLAVINSKY 1953). The rapakivis of the Ahvenisto Massif are surrounded by an arcuate outcrop of gabbro anorthosite and whilst SAVOLAHTI (1956 pp. 80–81) considers the latter to be much older than, and quite unrelated to the rapakivis, many Finnish geologists would disagree with him in this.

The relation between the Helene Granite and the Igaliko sandstone would, however, appear to differ slightly from that between the Jotnian sandstone and Finnish rapakivis. The last, although direct evidence has not been observed, are generally taken as being older than the Jotnian, whereas the Helene Granite most probably is slightly younger than the Igaliko sandstone. Notwithstanding this probable distinction, the occurrence of sandstones in similar geological settings in both regions is worth noting.

Geologically as well as petrographically, therefore, the Helene Granite can, in many ways, be compared with the Scandinavian rapakivis. The magmatic origin of the Helene Granite thus has bearing on the origin of the Scandinavian rapakivis although it has no direct significance for the problem of rapakivi texture.

Lastly, in view of these remarks, should the Helene Granite be called a rapakivi? The writers would answer this purely terminological question in the negative, for outside Scandinavia "rapakivi" means a granite with mantled K felspar ovoids. To extend the term to cover the Helene Granite would most likely mislead the majority of readers and unnecessarily augment the already considerable confusion in petrological nomenclature. Moreover, despite the parallels that have been drawn, general distinctions that may well have genetic implications do exist between the regional geological settings of the Helene Granite and Scandinavian rapakivis. The latter are often demonstrably sheet-like (e. g. laccolithic) bodies and are connected with the roughly east-west Hoglandian-Jotnian flexure crossing southern Finland, an association to which Polkanov (1956) ascribes major significance in discussing the origin of the igneous rocks concerned. This magma-tectonic association is separate and distinct from the platform alkaline provinces of Kola and the Oslo region with which the South Greenland Gardar Province has so much in common.

X. REFERENCES

Barth, T. F.W., 1944: Studies on the igneous rock complex of the Oslo region. II. Systematic petrography of the plutonic rocks. Skr. Norske Vid. Akad. I. Mat.-Naturv. Klasse, No. 9, pp. 1–104.

Berthelsen, A., 1961: On the Chronology of the Precambrian of Western Greenland. *in* Geology of the Arctic, ed. G. O. Raasch, Vol. I, pp. 329–338.

Buerger, M. J., 1948: The structural nature of the mineralizer action of fluorine and hydroxyl. Am. Min. v. 33, pp. 744–747.

von Eckermann, H., 1936: The Loos-Hamra Region. Geol. Fören. i Stockholm Förh. Bd. 58, H. 2, pp. 129–343.

— 1938: The anorthosite and kenningite of the Nordingrä-Rödö region. Geol. Fören. i Stockholm Förh. Bd. 60, H. 2, pp. 243–284.

Frosterus, B., 1902: Beskrifning till bergartskartan af kartbl. C2, St. Michel. Geologisk Öfversiktskarta öfver Finland, pp. 1–114.

Garde, T.V., 1896: Beskrivelsen af Expeditionen til Julianehaab Distrikt. Medd. om Grønland, Bd. 16, pp. 1–7.

Giesecke, K. L., 1910: Karl Ludwig Gieseckes Mineralogisches Reisejournal über Grönland. 1806–13. 2te, vollständige Ausgabe. Medd. om Grønland, Bd. 35, pp. 1–532.

Hackman, V., 1934: Das Rapakiwirandgebiet der Gegend von Lappeenranta (Willmanstrand). Bull. Comm. Géol. de Finlande, No. 106, pp. 1–82.

Harry, W. T. and Emeleus, C. H., 1960: Mineral layering in some granite intrusions of S.W. Greenland. Rep. Int. Geol. Congress, XXI session, Part 14, pp. 172–181.

Henriksen, N., 1960: Structural analysis of a fault in South-west Greenland. Medd. om Grønland, Bd. 162, Nr. 9, pp. 15–41.

Hess, H. H., 1960: Stillwater Igneous Complex, Montana. Geol. Soc. Am. Memoir 80.

Jacobson, R. R. E., Macleod, W. N. and Black, R., 1958: Ring-complexes in the younger granite province of Northern Nigeria. Geol. Soc. London, Memoir No. 1, pp. 1–72.

Moorbath, S., Webster, R. K. and Morgan, J.W., 1960: Absolute Age Determination in South-west Greenland. The Julianehaab Granite, the Ilímaussaq batholith and the Kûngnât Syenite Complex. Medd. om Grønland, Bd. 162, Nr. 9, pp. 1–14.

Oftedahl, C., 1948: Studies on the igneous rock complex of the Oslo region. IX. The feldspars. Skr. Norske Vid. Akad. I. Mat.-Naturv. Klasse, No. 3, pp. 1–71.

Poldervaart, A. and Taubeneck, W. H., 1960: Layered intrusions. Rep. Int. Geol. Congress, XXI session, Part 13, pp. 239–246.

Polkanov, A. A., 1956: Geologiya Khoglandiya—Iotniya Baltiiskogo Shchita. Trudy Labor. Geologii Dokembriya. Vyp. 6. A.N.SSSR. Moscow.

Pulvertaft, T. C. R., 1961: The Puklen Intrusion, Nunarssuit, SW Greenland. Medd. om Grønland, Bd. 123, Nr. 6, pp. 33–50.

Read, H. H., 1957: The Granite Controversy. London.

Sahama, Th. G., 1945: On the chemistry of the east Fennoscandian rapakivi granites. Bull. Comm. Géol. de Finlande, No. 136, pp. 15–67.

Savolahti, A., 1956: The Ahvenisto Massif in Finland. Bull. Comm. Géol. de Finlande, No. 174, pp. 1–96.

Sederholm, J. J., 1916: On Synantectic Minerals and Related Phenomena. Bull. Comm. Géol. de Finlande, No. 48, pp. 1–148.

— 1928: On orbicular granites, spotted and nodular granites etc. and on the rapakivi texture. Bull. Comm. Géol. de Finlande, No. 83, pp. 1–105.

Termier, H. and Termier, G., 1956: L'Évolution de la Lithosphere. I: Pétrogénèse. Paris.

Upton, B. G. J., 1960: The Alkaline Igneous Complex of Kûngnât Fjeld, South Greenland. Medd. om Grønland, Bd. 123, Nr. 4, pp. 1–145.

— 1961: Textural features of some contrasted igneous cumulates from South Greenland. Medd. om Grønland, Bd. 123, Nr. 6, pp. 1–31.

— 1962: Geology of Tugtutôq and neighbouring islands, South Greenland, Part I. Medd. om Grønland, Bd. 169, Nr. 8, pp. 1–60.

Ussing, N.V., 1912: Geology of the country around Julianehaab, Greenland. Medd. om Grønland, Bd. 38, pp. 1–376.

Velikoslavinsky, D. A., 1953: Petrologiya Vyborgskogo massiva rapakivi. Trudy Labor. Geologii Dokembriya. Vyp. 3. A.N. SSSR. Moscow.

Wager, L. R. and Deer, W. A., 1939: Geological investigations in East Greenland. III. The petrology of the Skærgaard intrusion, Kangerdlugssuaq, East Greenland. Medd. om Grønland, Bd. 105, Nr. 4, pp. 1–352. (Repr. 1962 with a list of further papers on the intrusion.)

Warren, C. H., 1913: Petrology of the alkali granites and porphyries of Quincy and the Blue Hills, Mass., U.S.A. Proc. Amer. Acad. Arts and Sci., v. 49, No. 5, pp. 203–324.

Warren, C. H. and McKinstry, H. E., 1924: The granites and pegmatites of Cape Ann, Massachusetts. Proc. Amer. Acad. Arts and Sci., v. 59, pp. 313–395.

Watterson, J. S.: Plutonic development of the Ilordleq area, South Greenland. Part I: Chronology, and the occurrence and recognition of metamorphosed basic dykes. Medd. om Grønland. Bd. 172, Nr. 7 (in press).

Wegmann, C. E., 1938: Geological Investigations in Southern Greenland, Part I: On the Structural Divisions of Southern Greenland. Medd. om Grønland, Bd. 113, Nr. 2, pp. 1–148.

— 1959: La flexure axial de la Driva et quelques problèmes structuraux des Calédonides Scandinaves. Norsk Geologisk Tidsskrift, Bd. 39, pp. 25–74.

Zavaritsky, A. N., 1956: Izverzhennye gornye porody. A.N. SSSR. Moscow.

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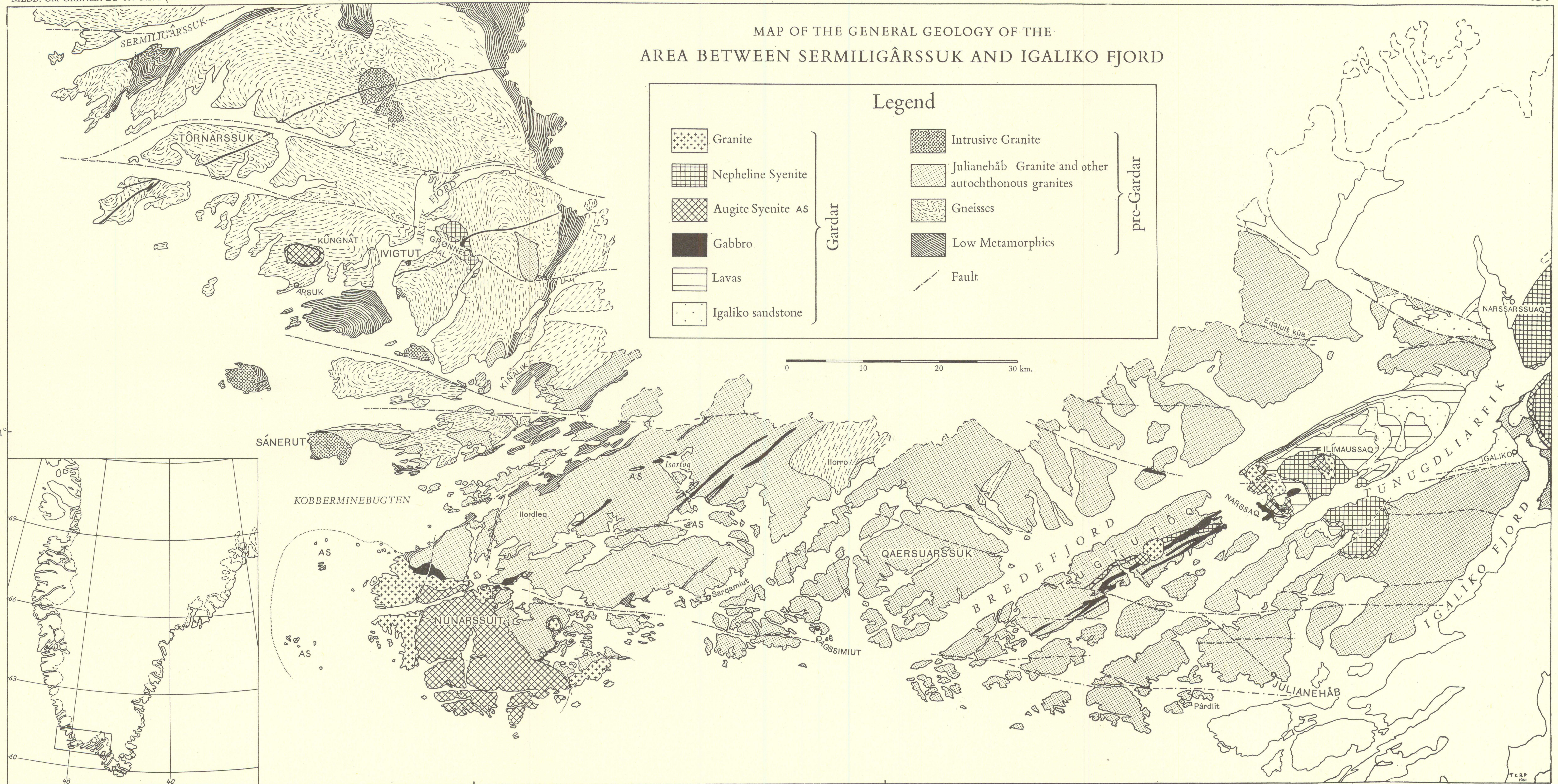
MAP OF THE GENERAL GEOLOGY OF THE
AREA BETWEEN SERMILIGÂRSSUK AND IGALIKO FJORD
Legend
Granite
Nepheline Syenite
Augite Syenite AS
Gabbro
Lavas
Igaliko sandstone
Gardar
Intrusive Granite
Julianehåb Granite and other autochthonous granites
Gneisses
Low Metamorphics
pre-Gardar
Fault
0 10 20 30 km.
SERMILIGÂRSSUK
TÔRNÂRSSUK
ARSUK FJORD
KÛNGNÂT
IVIGTUT
GRØNNEDAL
ARSUK
KINALIK
SÁNERUT
KOBBERMINEBUGTEN
Isortoq
Ilorro
Ilordleq
AS
Sarqamiut
QAERSUARSSUK
NUNARSSUIT
AGSSIMIUT
BREDEFJORD
TUGTUTÔQ
NARSSAQ
ILÍMAUSSAQ
IGALIKO
TUNUGDLIARFIK
IGALIKO FJORD
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GRØNLANDS GEOLOGISKE UNDERSØGELSE
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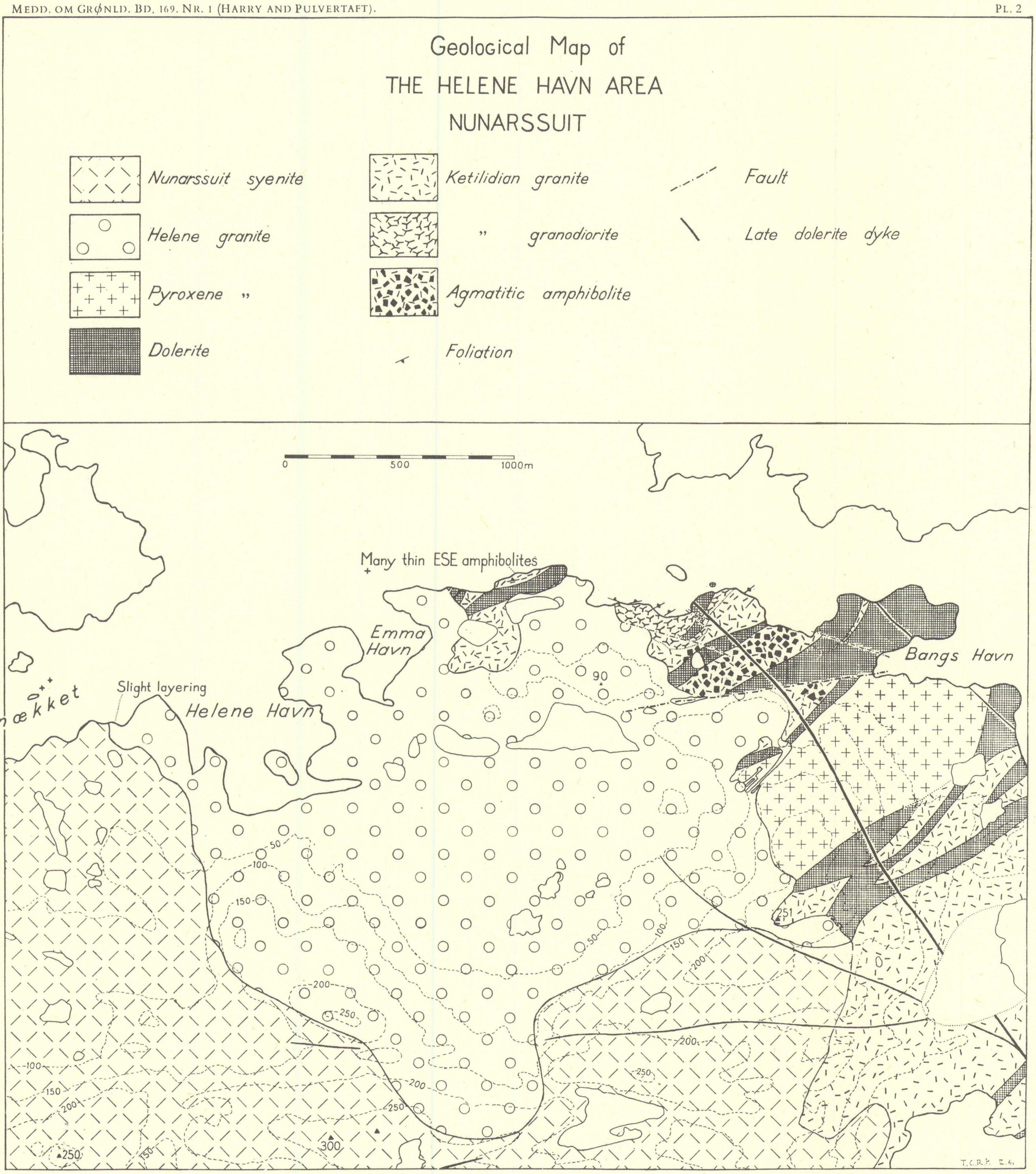
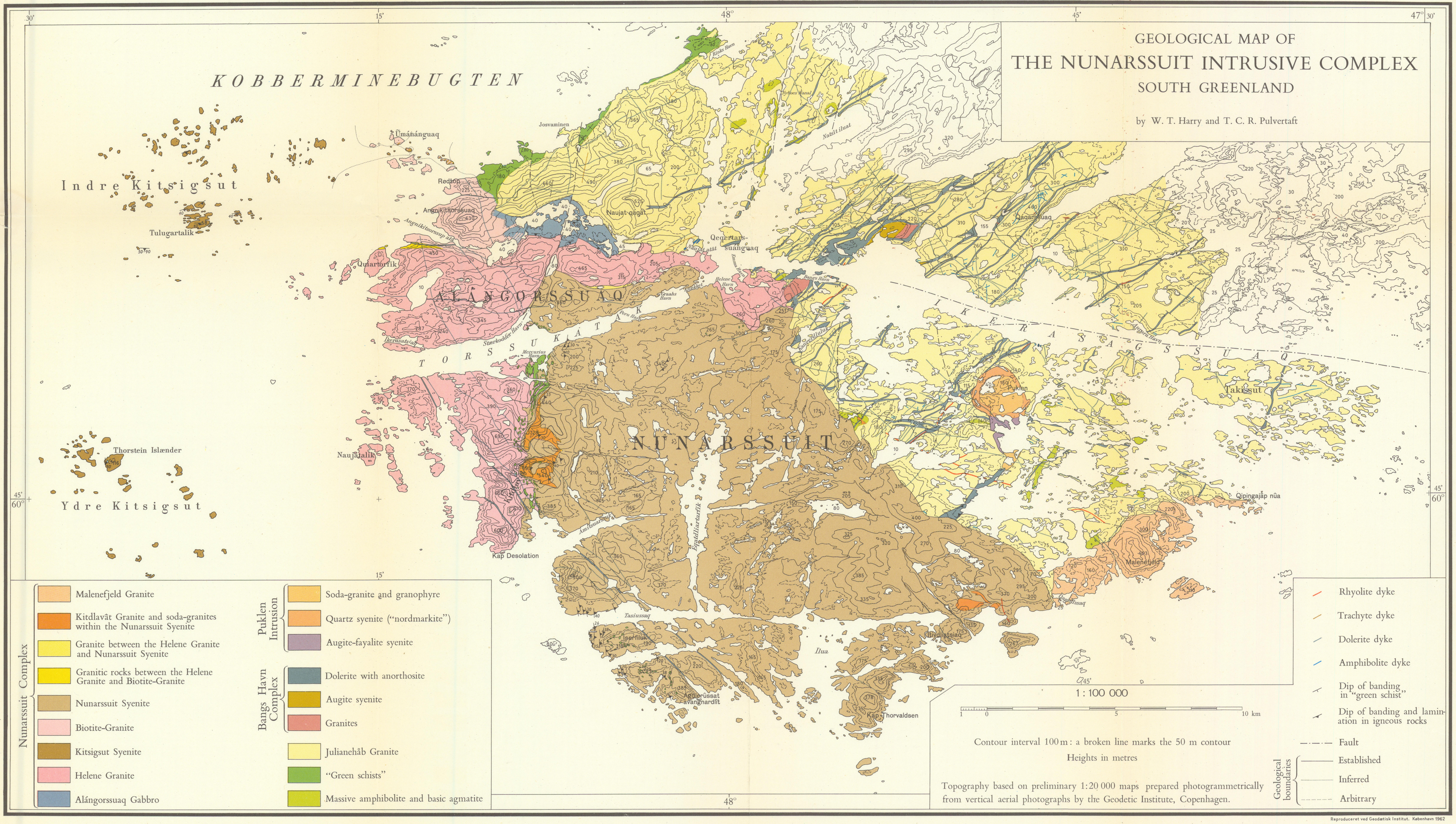


GRØNLANDS GEOLOGISKE UNDERSØGELSE

THE GEOLOGICAL SURVEY OF GREENLAND



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