GRØNLANDS GEOLOGISKE UNDERSØGELSE
RAPPORT Nr. 61



*The Geological Survey of Greenland*
*Report No. 61*

# The Precambrian geology of the Túngarnit nunât area, outer Nordre Strømfjord, central West Greenland

*by*

*Jens Winter*

KØBENHAVN 1974

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1 map

1974

## Abstract

Túngarnit nunât forms part of the Isortoq gneiss complex of the Nagssugtoqidian orogenic belt. The following rock-types occurring in the area are described: hypersthene-biotite gneisses, biotite gneisses, garnet-biotite gneisses, amphibolites, and marbles and calc-silicate rocks. These rocks were metamorphosed in the lower part of the granulite facies, but a down-grading took place locally because of late dextral shear-movements. The main Nagssugtoqidian deformation produced mesoscopic folds as well as large-scale structures, and thrusting is a common feature of the deformation. This combined with the later shearing caused a reorientation towards parallelism of the structural elements so that the lithological units now form an ENE trending 'linear belt'. After the main Nagssugtoqidian deformation and the late shearing, weak folds were formed with axial planes striking SSE, and the rocks were intruded by pegmatites. Precambrian lamprophyres cut the gneisses.

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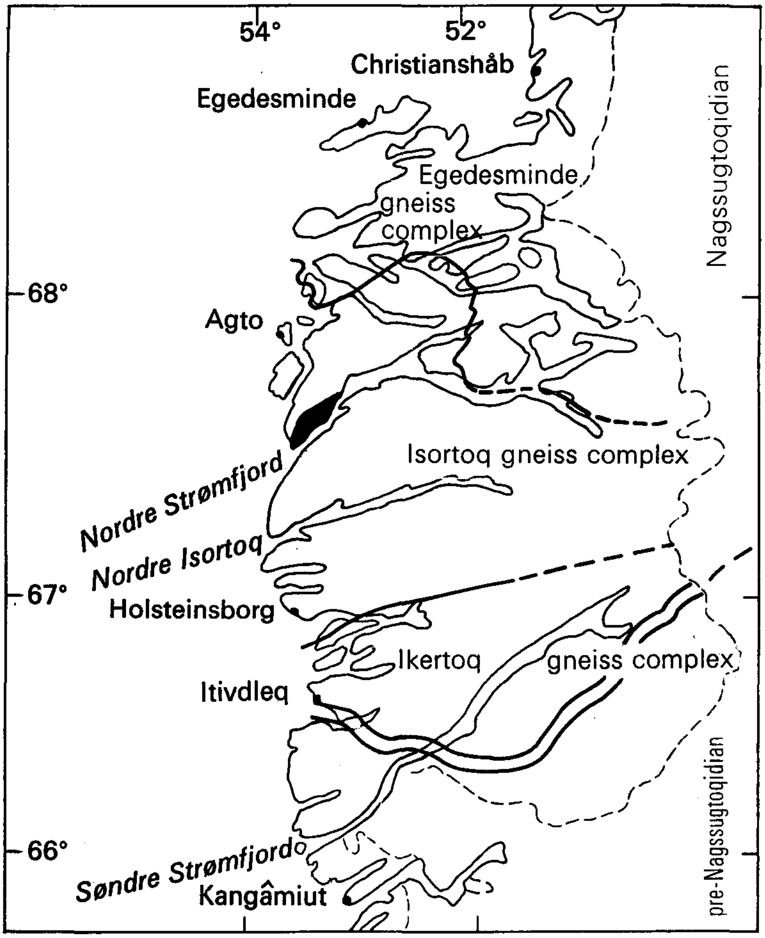


Fig. 1. Map of the southern part of the Nagssugtoqidian orogenic belt (partly from Ramberg, 1949). The Túngarnit nunât area is shown in black. The heavy lines mark the division between Ramberg's (1949) gneiss complexes modified by later work.

# INTRODUCTION

During the summers of 1968 and 1969 the author mapped the area of Túngarnit nunât on the northern side of the outlet of Nordre Strømfjord. This work formed part of a project by students from the Universities of Aarhus and Copenhagen, under the supervision of E. Bondesen, to map the Agto sheet 67 V. 1 N (1:100 000) for the Geological Survey of Greenland. The work was supported by the Carlsberg Foundation and the Research Foundation of the University of Aarhus. A series of progress reports have been given of the work (see Bondesen, 1970, for details).

# GEOLOGICAL SETTING OF THE AREA

Ramberg (1949) established the Nagssugtoqidian orogenic belt, named after the fjord Nagssugtoq (Nordre Strømfjord), and showed it to be younger than the gneiss complex south of Søndre Strømfjord. He divided the Nagssugtoqides between Søndre Strømfjord and Christianshåb into three main gneiss complexes based on the differences in metamorphic grade. The area described here is situated within the central granulite facies complex — the Isortoq complex (fig. 1).

Structural studies together with isotopic age determinations indicate that the Nagssugtoqides in fact covers the whole stretch from Søndre Strømfjord to Jakobshavn (Bridgwater *et al.*, 1973). Along this *c.* 300 km coastal area K/Ar ages fall within the range of 1790–1650 m.y. This age group does not mean that the rocks were formed from Nagssugtoqidian material; as Pulvertaft (1968) points out, it is reasonable to believe that most of the rocks of Ramberg's original Nagssugtoqides are reactivated pre-Nagssugtoqidian rocks.

Ramberg (1949) stressed the importance of the ENE structural direction within the three gneiss complexes, and Noe-Nygaard & Berthelsen (1952) pointed out the very striking feature that in the region around Nagssugtoq areas of simple, open, large-scale structures alternate with areas characterised by persistent ENE-trending lithological units creating a linear pattern, which was thought by Noe-Nygaard & Berthelsen to be due to a horizontal trend of the fold axes.

This prominent variation in structural style was also observed by Escher (1966) in the southern part of the Nagssugtoqides and by Sørensen (1970) in the Agto region. In the detailed mapping of the Agto area the relations between the different structural styles have been a puzzling problem.

The area described is situated within a belt of constantly ENE-striking lithological units (fig. 2).

# ROCK TYPES

The rocks of the area may conveniently be divided into the following three main groups: gneisses, basic rocks and discordant dykes.

## Gneisses

### *Hypersthene-biotite gneisses*

The hypersthene-biotite gneisses (enderbitic gneisses according to Tilley, 1936) are generally easy to recognise in the field because of their yellow-brownish weathering colours. However, a gradual transition to biotite gneisses without orthopyroxene often occurs. Only limited portions of granitic neosome have been formed in these gneisses. After the classification of Streckeisen (1967) the gneisses are of quartz dioritic composition.

Structurally the hypersthene-biotite gneisses are generally finely banded with thin alternating bands of leucocratic and melanocratic material. A well-developed biotite foliation is always present. The texture is granoblastic inequigranular, polygonal to interlobate, according to the terminology of Moore (1970). Mylonitic textures are also found.

The gneisses always contain the following minerals: quartz, plagioclase (oligoclase-andesine) often antiperthitic, hypersthene and biotite, and in addition microcline, hornblende, clinopyroxene and garnet may occur together with opaque minerals, zircon and apatite as accessory minerals.

The mineralogical composition of three typical hypersthene-biotite gneisses is shown in table 1.

### *Biotite gneisses*

The biotite gneisses show grey or white weathering colours. The composition of these gneisses is mainly quartz dioritic, but alkali feldspar (microcline) is more common in these gneisses than in the hypersthene-biotite gneisses. Granitic neosome is sometimes present but is not at all dominant. Biotite gneisses often occur as irregular patches within hypersthene-biotite gneiss terrain.

In the field the biotite gneisses can be structurally very variable; they can be homogeneous, finely banded, or intensively folded. Basic inclusions are very common. A biotite foliation is always prominent.

*Table 1. Modal compositions of three hypersthene-biotite gneisses and three biotite gneisses*

| GGU No. | Hypersthene-biotite gneisses | | | Biotite gneisses | | |
|---|---|---|---|---|---|---|
| | 105608 | 105684 | 105802 | 105602 | 105705 | 105829 |
| Quartz (vol. %) | 33 | 39 | 33 | 56 | 46 | 48 |
| Plagioclase | 34 | 50 | 48 | 37 | 40 | 25 |
| Microcline | | 1 | | | 5 | 6 |
| Biotite | 18 | 7 | 4 | 6 | 7 | 9 |
| Hornblende | | 1 | 7 | | 1 | 10 |
| Hypersthene | 14 | 1 | 7 | | | |
| Accessories | 1 | 1 | 1 | 1 | 1 | 2 |
| Counts | 700 | 900 | 800 | 1000 | 700 | 700 |

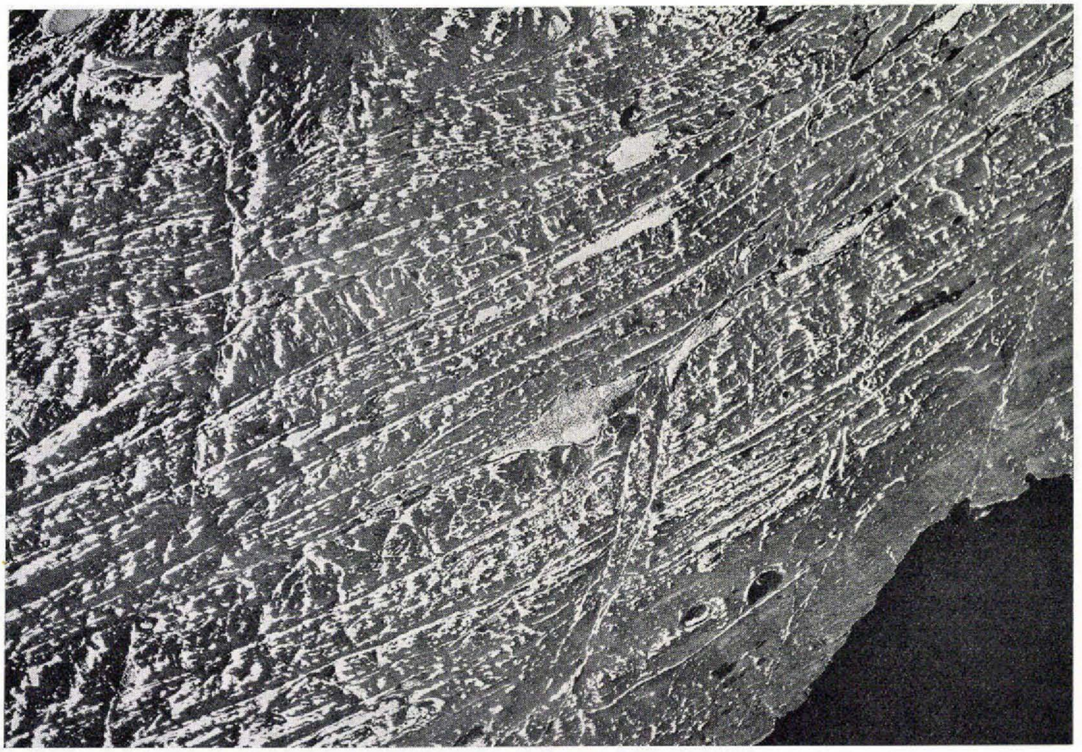

Fig. 2. Vertical view of part of the Túngarnit nunât area. Scale about 1:100 000. Aerial photograph No. GRE Route A 46 L–155. Copyright Geodetic Institute, Copenhagen. Reproduced with permission (A. 820/72).

The textures of these gneisses are granoblastic, inequigranular, interlobate but mylonitic textures are very common and many thin-sections show evidence of cataclasis.

Quartz, plagioclase (oligoclase-andesine), microcline and biotite are present in all samples and hornblende, clinopyroxene and garnet may also be present (table 1). The accessory minerals are opaque minerals, zircon and apatite.

*Garnet-biotite gneisses*

The garnet-biotite gneisses have a very variable texture and a highly variable mineralogical composition. Usually they are very coarse grained and rusty, but locally they made grade into a very fine-grained and almost completely white rock with a well-developed mesoscopically visible 'plättung' texture.

Granitic leucosome is very common, and the biotite foliation is rather irregular. More or less well-developed mylonitic textures are evident in thin-sections and plagioclase, microcline or garnet are often present as large porphyroclasts.

The thin-sections show strongly undulose quartz, plagioclase (oligoclase-andesine), microcline (often perthitic), garnet (with an observed maximum diameter of 10 cm) and biotite. Euhedral sillimanite is often present (up to 22 %), and graphite generally occurs in minor amounts, but locally may be abundant (20 % is recorded in one section). The accessory minerals are apatite, zircon, opaque minerals (iron sulphide) and, in one section, clinopyroxene and green spinel.

The modal compositions of six different rocks from this rock group are shown in table 2 illustrating the great variation in mineralogical composition.

*Table 2. Modal compositions of six samples of the heterogeneous garnet-biotite gneisses*

| GGU No. | 105603 | 105606 | 105654 | 105808 | 105933 | 122745 |
|---|---|---|---|---|---|---|
| Quartz (vol. %) | 37 | 49 | 43 | 12 | 26 | 47 |
| Plagioclase | 22 | 31 | 27 | 22 | 16 | 30 |
| Microcline | 20 | 5 | 11 | 33 | 6 | |
| Garnet | 4 | 7 | 5 | 21 | 8 | 14 |
| Biotite | 12 | 8 | 10 | 12 | 19 | 6 |
| Sillimanite | 3 | | 2 | | 22 | |
| Accessories | 2 | | 2 | | 3 | 3 |
| Counts | 1000 | 800 | 1200 | 1100 | 800 | 1200 |

## Basic rocks

### *Amphibolites*

Amphibolites as wide, continuous bands are very scarce in the area; however, thin bands (of a few decimetres) are common within all the gneisses. Agmatitic amphibolites are frequent in the hypersthene-biotite gneisses as well as in the biotite gneisses. All the amphibolite bands of the area show concordant relationships to the surrounding gneisses. The mesoscopic structure of the amphibolites may be banded or homogeneous. The textures are granoblastic equigranular polygonal. Cataclastic textures are very rare.

The mineralogy of the amphibolites show all possible graduations from 'true', amphibolite to pyribolite. The pyroxene content does not seem to be related to a metamorphic gradient within the area as on a regional scale pyroxene-rich and pyroxene-poor rocks are intermixed. Besides hornblende, orthopyroxenes and clinopyroxenes, the amphibolites always contain plagioclase (andesine to labradorite). Biotite and quartz occur in minor amounts in most of the samples while garnet, zircon and apatite are rare.

### *Marbles and calc-silicate rocks*

A large number of marble bands with thicknesses ranging between 3 cm and 30 m occur in the area. A common feature is that the bands are zoned with a calc-silicate selvage and a pure marble centre. Isolated boudins of marble or calc-silicate rocks are very common, and in many cases it is possible to show that the boudins are remnants of once continuous layers.

In the marbles there are numerous minor folds with irregular orientations which sometimes resemble flow structures. The textures in the coarse crystalline portions are granoblastic, inequigranular, polygonal, while in the fine-grained portions mylonitic textures are very prominent.

The mineralogical variation is considerable with calcite, diopside, biotite, phlogopite, forsterite, plagioclase (labradorite), Ca-rich scapolite, spinel and sphene being recorded.

### *Ultrabasic rocks*

In the various gneisses there are numerous concordant lenses of ultrabasic rocks, most of which are, however, quite small (a few metres). In some cases it can be shown that the lenses are boudins which originally may have formed continuous bands. The rocks are homogeneous hornblendites or pyroxene-hornblendites with granoblastic equigranular textures. Minor amounts of plagioclase, olivine, garnet or spinel were observed in a few thin sections.

## Late discordant dykes

*Pegmatites*

Apart from the concordant to subconcordant leucocratic veins in the gneisses two types of late rectilinear cross-cutting pegmatites occur in the area: (1) granitic pegmatites with quartz, microcline (often perthitic), plagioclase, and often a little biotite, and (2) quartz veins. These pegmatites show clear intrusive relationships to the surrounding rocks. They have a maximum width of a few decimetres.

*Lamprophyres*

In the south-western part of the area a number of small unmetamorphosed lamprophyre dykes are found (less than 50 cm in thickness and mostly only a few centimetres). The dykes are generally vertical and strike east-west.

The lamprophyres contain the following minerals: biotite, olivine, dark greenish brown amphibole and apatite (as phenocrysts), and orthoclase and calcite (in the groundmass). Sericite, chlorite, serpentine, ore and calcite occur as secondary alteration products. In some cases only the outline of the primary dark mineral is recognisable, the whole grain being replaced.

A potassium-argon age determination on biotite extract from sample GGU 105768 gave $1240 \pm 130$ m.y. (Ole Larsen, personal communication, 1971).

## Origin of the rocks

Conclusive evidence of the pre-metamorphic origin of the hypersthene-biotite gneises and the biotite gneisses cannot be presented on the basis of either structural or mineralogical criteria.

The garnet-biotite gneisses, however, with the local abundance of sillimanite, graphite and iron sulphides and the frequent interlayering of marbles are probably paragneisses.

The amphibolites are everywhere in the area concordant to the surrounding gneisses. Some of them may look like meta-dykes, but although it cannot be excluded that some of the amphibolites may originate from basic volcanics or basic intrusive dykes it is evident judging from the presence of two amphibolite bands grading along the strike into calc-silicate rocks and even pure marbles that at least part of the amphibolites were formed by metamorphism of sediments (Winter, 1970).

The numerous marble horizons are metamorphosed calcareous sediments and limestones, and the ultrabasic rocks are probably of igneous origin.

# DEFORMATION

The Nagssugtoqidian main deformation, called here the $F_N$ deformation, is seen as folding around NE to SW striking axes.

The whole area has been exposed to large scale transposition, which has led to parallelism of most of the structural elements. Because of this a conventional structural analysis with separation of fold phases by means of interference patterns and directions of fold axes and attitudes of axial planes is only partly applicable, and a division of the area into subareas of structural homogenity serves no purpose since the whole area is structurally homogeneous.

The garnet-biotite gneisses are the most useful marker horizons for mapping the large-scale structures; the amphibolites and marbles are of limited value for the structural analysis. Often the thin marbles are displaced, and intrusive relationships to the surrounding rocks are observed locally. The small-scale structures in the marbles have all kinds of different directions, many of them having very steep to vertical axes. The structures frequently give the impression of irregular flow structures.

## Pre-$F_N$ deformation

In a few localities isoclinal pre-$F_N$ folds are seen refolded by $F_N$. Such interference patterns are observed in all the concordant rock types. This supports the view that all these rocks are older than the main Nagssugtoqidian deformation.

Nothing can be said about the deformation that affected the rocks of the area before the main Nagssugtoqidian deformation ($F_N$). Except for a few later open folds, all measurable folds have sub-horizontal axes with ENE or WSW trends and sub-vertical axial planes, the latter in most cases dipping very steeply towards NNW. Some of these folds might well be of pre-$F_N$ age, but the strong $F_N$ phase has modified their directions so that they are now parallel to the numerous $F_N$ folds.

In adjacent areas, where the transposition caused by $F_N$ deformation is less intense, several pre-$F_N$ fold phases can be established (Sørensen, 1970).

## The $F_N$ deformation

The ENE direction is the typical Nagssugtoqidian trend caused by the Nagssugtoqidian main deformation. The $F_N$ deformation has been very strong in the present area and is believed to be due to a strong horizontal stress oriented NNW-SSE.

The general linear pattern of the area was thought by Noe-Nygaard & Berthelsen (1952) to be due to the horizontal position of the fold axes. This is, however, only partly true, since detailed mapping shows that only a limited number of major folds exist in the area (map 1). It has not been possible as a rule to trace the thin lithological units into folds, and it is believed that the linear pattern has mainly been produced by a great number of thrusts slicing up the rocks into steeply dipping units. There are numerous shear zones and mylonites parallel to the linear pattern. The units have apparently been stacked together to form an imbricate structure such that steeply inclined thin rock units can be traced for several kilometres with only slight changes in direction. This interpretation is also supported by the fact that in many places in the field low angle structural discordances occur and many bands wedge out. As a general rule the shear zones believed to be thrust planes are parallel to the foliation or make a very small angle (less than 10 degrees) with it.

Another point indicating thrusting is the fact that the lithological succession of the two large synformal structures of the area are 'inverted', since in both cases the hypersthene-biotite gneisses overlie the marbles and garnet-biotite gneisses, which may be interpreted as belonging to a younger sequence of rocks (Bondesen, 1968).

The northernmost of the synformal structures has the following lithological succession:

| | |
|---|---|
| *highest* | hypersthene-biotite gneiss |
| | garnet-biotite gneiss |
| | hypersthene-biotite gneiss |
| | garnet-biotite gneiss |
| *lowest* | marble |

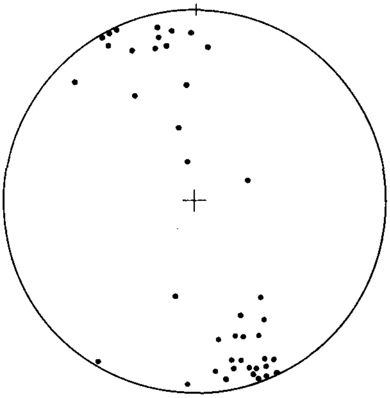

Fig. 3. Lower hemisphere, equal area projection of poles to axial planes of 39 mesoscopic $F_N$ folds.

Also in the southernmost synformal structure hypersthene-biotite gneiss occurs on top of metasedimentary rocks, marbles, and garnet-biotite gneisses (map 1).

The $F_N$ deformation has produced a great number of mesoscopic folds in the area. They are generally symmetrical, tight to isoclinal structures. The axial planes of the folds generally strike ENE and the dips are steep, as illustrated in fig. 3.

## Post-$F_N$ shearing

After the main Nagssugtoqidian deformation (the $F_N$ deformation) the rocks of the area were affected by horizontal shear movements along planes parallel to the foliation, i.e. the shear planes strike ENE. This shearing was most pronounced in the thin rock units NNW and SSE of the central gneiss ridge. The movement was dextral as shown by the rotation of garnets in the garnet-biotite gneisses.

The shearing caused the formation of cataclastic textures in the rocks and a local down-grading of the high metamorphic mineral assemblages, and furthermore the shearing might have been of some importance in the establishment of the parallelism of the structural elements of the area.

## Latest deformation

After the main Nagssugtoqidian deformation and the dextral shear movements very weak folding took place at right angles to the general trend, i.e. the axial planes strike SSE. The axes are steeply inclined (fig. 4), trending NNW or SSE depending on the orientation of the foliation before the folding. The folding gave rise to very open folds or flexures most easily recognisable where large foliation surfaces are exposed.

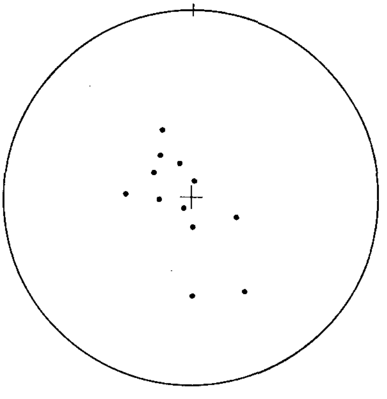

Fig. 4. Lower hemisphere, equal area projection of 12 fold axes from the latest folding.

In a single locality the interference between three fold-phases is seen (fig. 5), an early isoclinal fold, a tight $F_N$ fold and a late openfold.

The latest event in the tectonic evolution of the area was the development of a prominent NNE joint system. Many of these joints are now stream-eroded valleys.

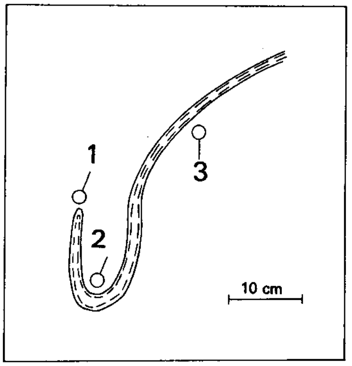


Fig. 5. Fold interference shown by thin amphibolite in garnet-biotite gneiss. 1 is an early isoclinal fold, 2 is a tight $F_N$ fold, and 3 is a late open fold.

# METAMORPHISM

## Main metamorphism

Strong deformation obliterates signs of earlier deformations and high-grade metamorphism likewise may obliterate all signs of earlier metamorphic episodes. Consequently it is difficult to say anything about any metamorphism prior to the main metamorphism of the Túngarnit nunât area.

The physical conditions existing during the peak of the main metamorphism can be fixed rather accurately from the following:

(1) granitic leucosome has been formed in the gneisses which means that these formed 'above' the minimum curve for the start of anatexis (see Winkler, 1967, fig. 40);

(2) the stable $Al_2SiO_5$-polymorph is sillimanite;

(3) almandine-garnet (and not cordierite) is present in pelitic rocks.

It can be concluded that the temperature was more than 650° C and the pressure more than 6 kilobars which is compatible with the results obtained from

Agto and surrounding islands (Sørensen, 1970). Further east in the Agto area Ramberg (1949) has reported the occurrence of cordierite. This might indicate a decrease in pressure eastwards.

Mineral assemblages resulting from the high-grade metamorphism are as follows:

Hypersthene-biotite gneisses: Quartz + plagioclase + biotite + hypersthene ± microcline ± hornblende ± diopside ± garnet.

Biotite gneisses: Quartz + plagioclase + microcline + biotite ± hornblende ± diopside ± garnet.

Garnet-biotite gneisses: Quartz + plagioclase + microcline + garnet + biotite ± sillimanite.

Amphibolites: Plagioclase + hornblende + diopside ± hypersthene ± biotite ± garnet ± quartz.

Marbles and calc-silicate rocks: Calcite ± diopside ± biotite ± phlogopite ± forsterite ± plagioclase ± scapolite.

Ultrabasic rocks: Hornblende + pyroxene ± biotite ± plagioclase.

These assemblages are appropriate to conditions of hornblende-granulite subfacies of the granulite facies (Fyfe *et al.*, 1958). This main metamorphism occurred simultaneously with the $F_N$ deformation.

As can be seen from the mineral assemblages and the description of the rocks of the area, rocks with granulite facies mineralogy occur together with rocks with amphibolite facies mineralogy. This is believed to reflect an original difference in water pressure between the various lithological units.

## Retrograde metamorphism

The dextral shearing was locally associated with a rather intensive retrogression of the high-grade mineral assemblages. Most of the reactions taking place between minerals during retrograde metamorphism are hydration reactions. One way of introducing water into a series of rocks and thus allowing retrogression to take place is by deformation, and a characteristic of the rocks of the area mapped is that the retrogression of the mineral assemblages is confined to the shear zones and to those rocks that have been subjected to the strongest movements. The rocks of the central gneiss ridge have unaltered minerals, while the rocks forming thin lithological units to the north-west and the south-east show very strong retrogression.

The textures of the sheared rocks are more or less mylonitic. Crushing and rounding of the mineral grains are very common features, and undulose extinction is shown by many minerals. Often some mineral grains have survived the cataclasis (and retrogression) and are now preserved as large rounded porphyroclasts in a relatively fine-grained and partly recrystallised matrix (fig. 6).

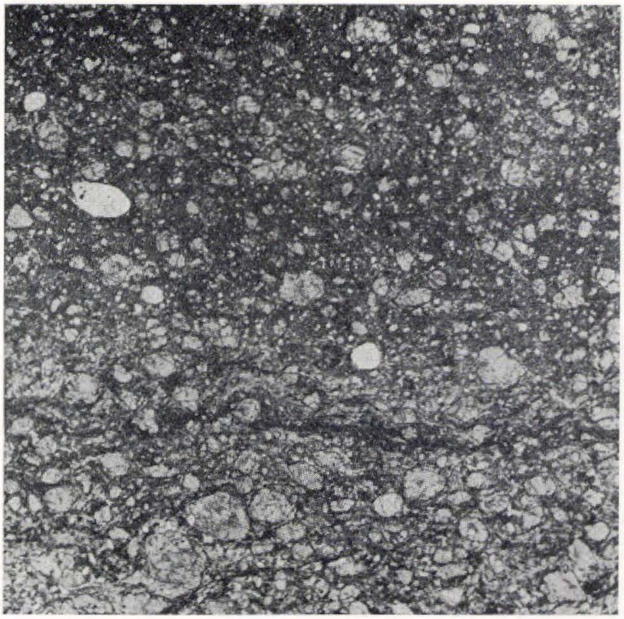

Fig. 6. Porphyroclastic texture in calc-silicate rock. The porphyroclasts are diopside and plagioclase, the fine matrix is composed mainly of calcite. GGU No. 105672, plane polarised light, × 5.

The retrograde alterations most commonly seen in the thin sections are as follows:

Hypersthene is (especially in the gneisses) often almost completely altered to uralite, opaque minerals and serpentine; diopside is generally better preserved but it may partly be replaced by hornblende; biotite and garnet are sometimes altered to chlorite; the olivine in the marbles is extensively replaced by opaque minerals and serpentine; and the plagioclase may show alteration to sericite or calcite. The secondary minerals normally form fibrous fringes around the primary minerals, and occasionally the primary minerals have been completely replaced by the alteration products.

This retrogressive metamorphism has had the strongest effects north-west and south-east of the central gneiss ridge.

## Latest metamorphism

The formation of chlorite in connection with crushing in the NNE-trending joint systems is a late and local metamorphic episode.

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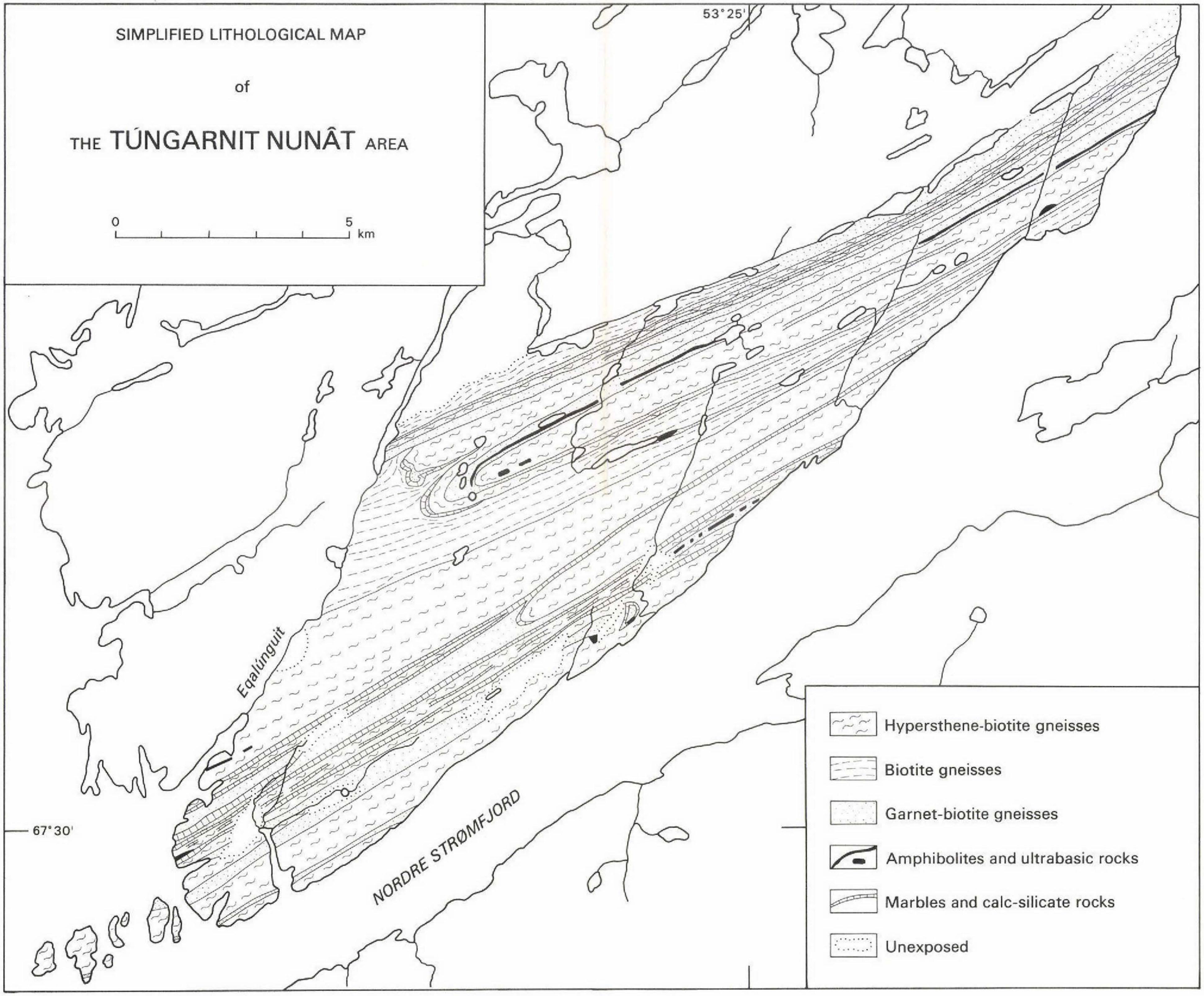
SIMPLIFIED LITHOLOGICAL MAP
of
THE TÚNGARNIT NUNÂT AREA
0
5
km
53°25'
67°30'
Eqalúnguit
NORDRE STRØMFJORD
Hypersthene-biotite gneisses
Biotite gneisses
Garnet-biotite gneisses
Amphibolites and ultrabasic rocks
Marbles and calc-silicate rocks
Unexposed