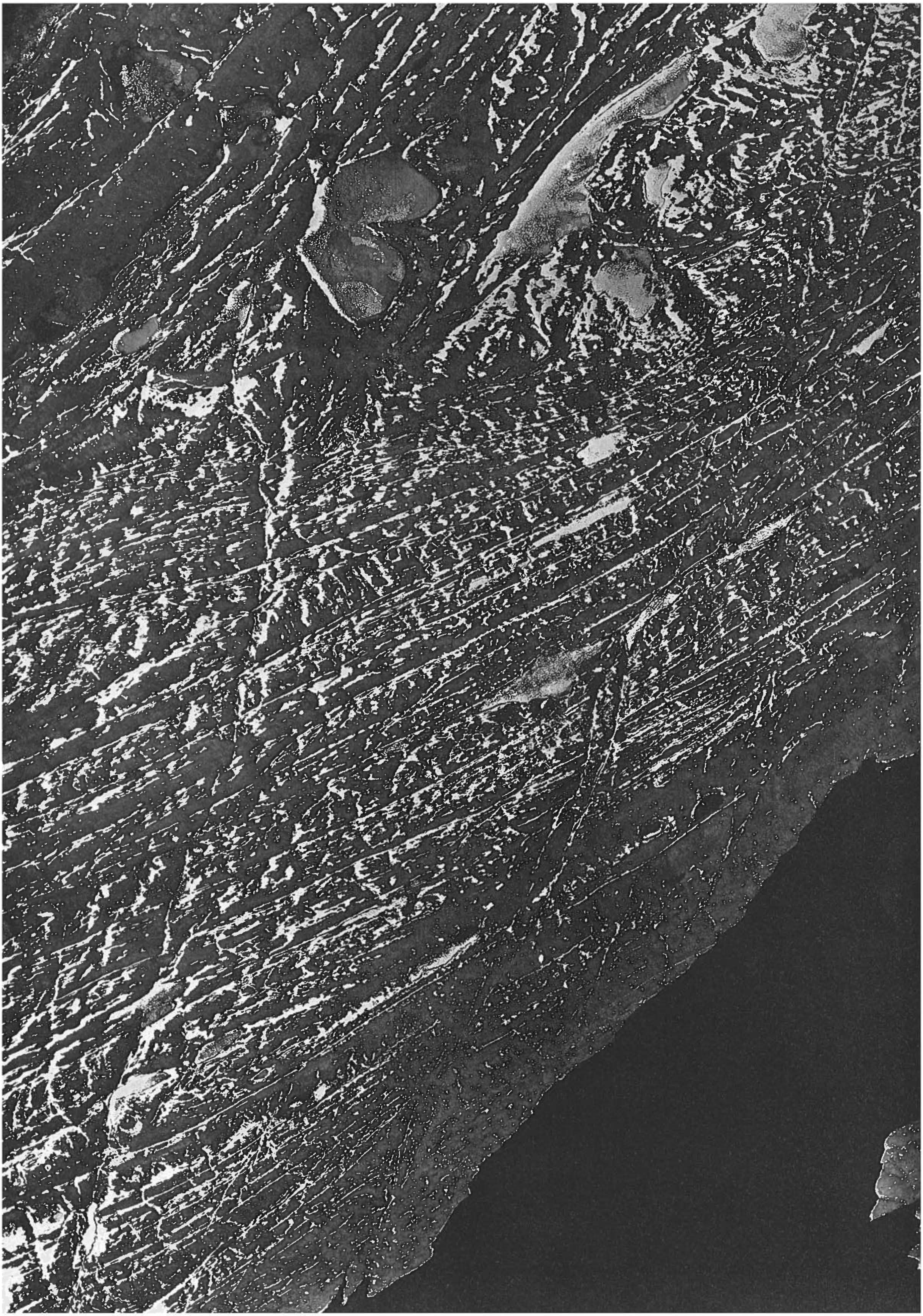

Nagssugtoqidian mobile belt in West Greenland

A. Escher
K. Sørensen
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Fig. 69. Aerial photograph of the western part of the Nordre Strømfjord linear belt showing the dominant ENE trend of the gneisses and the presence of a less deformed lens in the upper right corner of the photograph. Scale *c.* 1:40 000. Copyright Geodetic Institute.

Introduction

The rocks forming the northern part of the Archaean block in West Greenland are cut by dense swarms of dolerite dykes. Towards the north the dykes, together with their country rocks, are progressively deformed and metamorphosed resulting in a reorientation and parallelisation of dykes and country rock structures. These changes were the basis on which Ramberg (1949) distinguished a Nagssugtoqidian complex from a pre-Nagssugtoqidian (Archaean) complex in West Greenland. Similar observations by Bridgwater & Gormsen (1968) in South-East Greenland made it possible to correlate the Nagssugtoqidian mobile belt from West to East Greenland. It forms a *c.* 300 km wide belt characterised by a pronounced regional fabric oriented parallel to the boundary with the Archaean block (fig. 70). In West Greenland this regional fabric is cut to the north by the wrench fault zone which separates the Nagssugtoqidian from the Rinkian mobile belt. Although K-Ar dating of Nagssugtoqidian rocks gives ages within the range 1740–1650 m.y. (Larsen & Møller, 1968), U-Pb dating of zircons (Chessex *et al.*, 1973) suggests that the main phase of Nagssugtoqidian deformation and metamorphism is much older and probably took place at the beginning of the Proterozoic or at the end of the Archaean (fig. 71).

Included in the following account is a geological description of the north-eastern part of the Archaean block in West Greenland near the southern Nagssugtoqidian boundary.

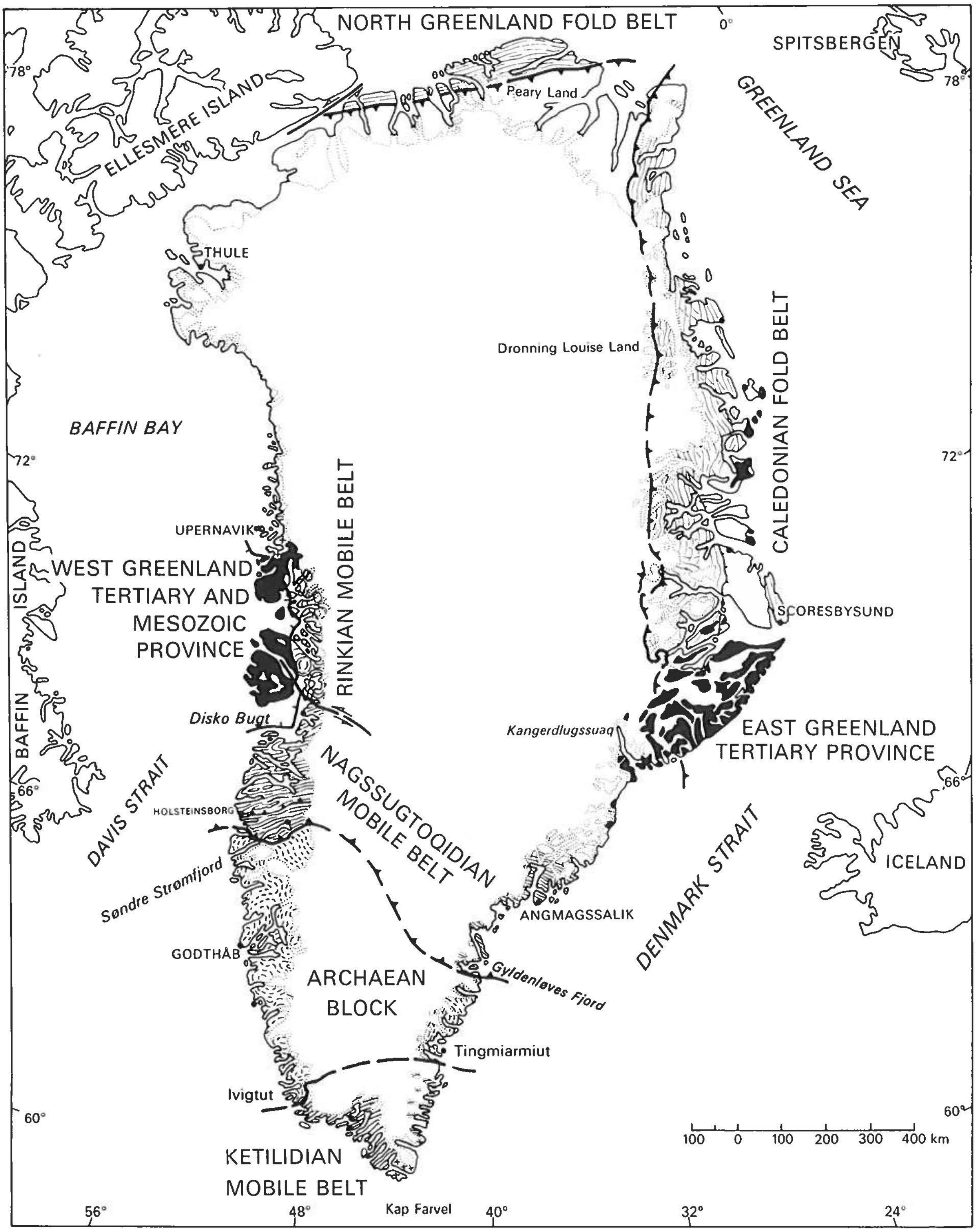


Fig. 70. The main geological divisions in Greenland.

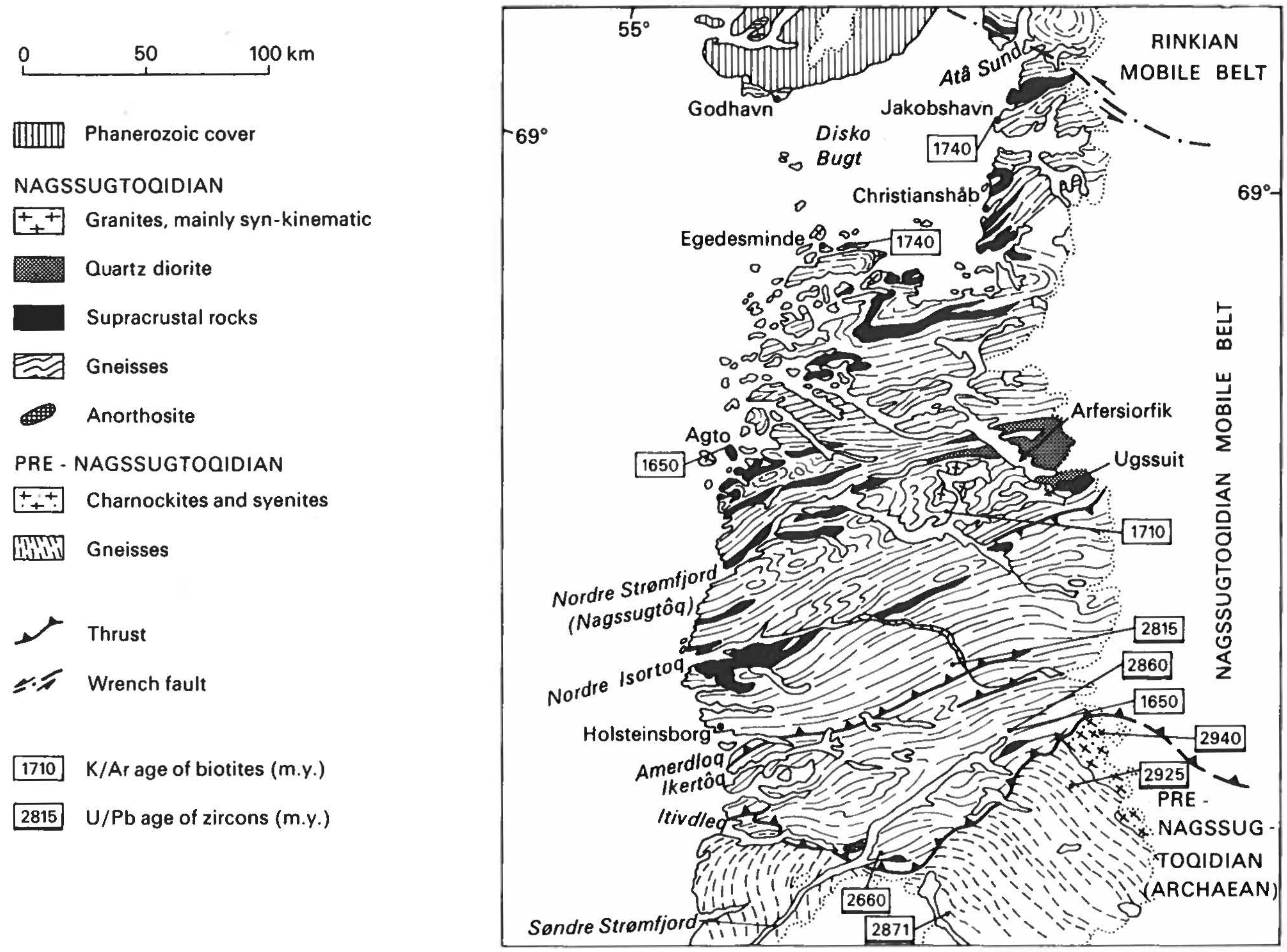


Fig. 71. Geological sketch map of the Nagssugtoqidian mobile belt in West Greenland.

Stratigraphy and lithology

The Nagssugtoqidian belt is made up mainly of reworked pre-Nagssugtoqidian basement gneisses and granites, locally with interlayered and folded belts of metasediments and metavolcanics (supracrustals). The basement gneisses are mostly amphibolite facies gneisses with granulite facies gneisses in the central part of the belt. Supracrustal rocks form thin belts interlayered and deformed together with basement gneisses. Nowhere has an unconformity been recognised, the original contact always having been obliterated by later movements. Basic to intermediate intrusives are mainly found in the southern and central part of the belt as deformed and metamorphosed dykes and sheets.

South of the Nagssugtoqidian boundary, the northern part of the Archaean block is composed mostly of granulite facies gneisses, probably derived from intrusive charnockites, syenites, and granites by shear-deformation.

The gneiss basement

The basement gneisses are mostly granodioritic to quartz dioritic. In the northern and southern part of the belt they are light grey amphibolite facies gneisses consisting mainly of plagioclase (An_{15}–An_{25}), microcline, quartz, biotite and green hornblende with minor amounts of garnet. In the central part of the Nagssugtoqidian belt, between Holsteinsborg and Agto (fig. 71), the basement is mainly composed of brownish granulite facies gneisses. These enderbitic gneisses contain the following principal minerals: plagioclase (An_{30}–An_{40}), quartz, hypersthene, biotite, and in places, brown hornblende. Potash feldspar is here present in antiperthite and as small amounts of interstitial material between plagioclase and quartz grains. Magnetite is present in most places.

South of the Nagssugtoqidian boundary, the northern part of the Archaean block is composed mainly of granulite facies gneisses similar to those in the central part of the Nagssugtoqidian belt. Non-foliated rocks of the same composition are present as well. These Archaean rocks consist mostly of quartz and feldspar. Andesine (antiperthite) is the dominant feldspar, K-feldspar perthite being rare. Mafic constituents are hypersthene, biotite, hornblende, clinopyroxene and magnetite. Kyanite has been found in small amounts at two localities. These enderbitic gneisses show generally an indistinct foliation which in most cases appears to be of cataclastic origin. Minerals which form porphyroclasts pre-dating the cataclastic imprint include: K-feldspar, andesine, quartz, biotite, hypersthene and diopside. Such a mineral composition indicates that the original rock was charnockitic or a metamorphic equivalent.

Throughout the Nagssugtoqidian and pre-Nagssugtoqidian gneisses basic inclusions occur. They vary from a few centimetres to a few metres in length and consist primarily of hornblende and plagioclase. Hypersthene is present only in those areas where the surrounding gneisses reach a granulite facies metamorphism. Most basic inclusions show a crude orientation of the hornblende producing a foliation.

Supracrustal rocks

Supracrustal rocks occur mostly in the central and northern part of the Nagssugtoqidian belt, north of the Ikertôq thrust zone (fig. 71). They form thin belts interlayered and deformed together with the basement gneisses. Nowhere has a basal unconformity been recognised, the original contact always having been obliterated by later movements. Three main groups of supracrustal rocks can be distinguished:

(a) A pre-Nagssugtoqidian group is composed mainly of garnet-biotite-sillimanite gneisses and leucocratic garnet-sillimanite gneisses. Foliated amphibolites are common, and locally very thin bands of impure marbles and calc-silicates are present. Graphite appears to be absent in these supracrustal rocks. This group is best known from the Agto area (Bek, 1970; Bondesen, 1970 b; Platou, 1970; Skjernaa, 1973), where it can be recognised in those parts which are less affected by Nagssugtoqidian deformation.

(b) Another pre-Nagssugtoqidian group has also garnet-biotite-sillimanite gneisses as the commonest rock type, but in addition contains widespread graphite as well as numerous, thick, pure marble horizons. The graphitic rocks often display a rusty red or brown weathering colour, due to the presence of pyrite and pyrrhotite. The quartzites show in a few places relic sedimentary structures. Amphibolites, hornblende schists and ultrabasic lenses are generally associated with the sequence. They are in some cases of igneous origin. On the other hand several might be regarded as para-amphibolites because of their close association with calc-silicate rocks (Winter, 1970).

This group of pre-Nagssugtoqidian supracrustals appears to be mainly metasedimentary. It is best known from the Agto area (fig. 72) where it occurs in tight synforms inside the linear belts (Bondesen, 1970 b; Linderoth, 1970). Fig. 73 shows two successions as established in the southern part of the Agto region. Similar supracrustal sequences are known from the Nordre Strømfjord, Nordre Isortoq and Ikertôq areas (Noe-Nygaard & Ramberg, 1961; Escher, 1966; P. B. Sørensen, 1970; Bridgwater *et al.*, 1973). In the area between Nordre Isortoq and Nordre Strømfjord they often form thick folded series in pre-Nagssugtoqidian 'islands', only slightly affected by Nagssugtoqidian deformation.

(c) A group of Nagssugtoqidian supracrustals formed in the time interval separating the last pre-Nagssugtoqidian period of metamorphism from the first Nagssugtoqidian metamorphic event. Only a few scattered occurrences of these rocks have been found. North of Egedesminde several small islands are made of garnet-biotite schist, staurolite schists, quartzites and zoisite-plagioclase amphibolites. Quartzites show relic cross-bedding, while in the amphibolites remnants of columnar jointing can be discerned (Ellitsgaard-Rasmussen, 1954). An occurrence of Nagssugtoqidian supracrustals has also been found in the Ugssuit area (fig. 71), where it occupies a series of open synclines. The rocks consist here of basic actinolite schists, quartzites and amphibolites. Well-preserved current bedding can be observed in the quartzites (Escher, 1966; Bondesen, 1969). A further two small synformal occurrences of Nagssugtoqidian supracrustal rocks were seen directly south of Søndre Strømfjord. The rocks are here mainly represented by anthophyllite schists, phyllites, marbles and metamorphosed pillow lavas (Escher *et al.*, 1970). All the rocks belonging to this third group of supracrustals are characterised by a slightly lower degree of metamorphism than the country rocks. On the whole they appear to be a mixture of metasediments and metavolcanics.

In the Egedesminde and Jakobshavn areas supracrustal rocks occur which are similar to the pre-Nagssugtoqidian metasediments described under (b) (Escher & Burri, 1967; Henderson, 1969). They are mainly biotite-garnet-sillimanite schists, siliceous gneisses, quartzites and amphibolites. Cummingtonite and staurolite schists were observed near Christianshåb. However, graphite is almost absent in these rocks and marbles occur only sporadically. Any correlation remains therefore speculative. It seems that the

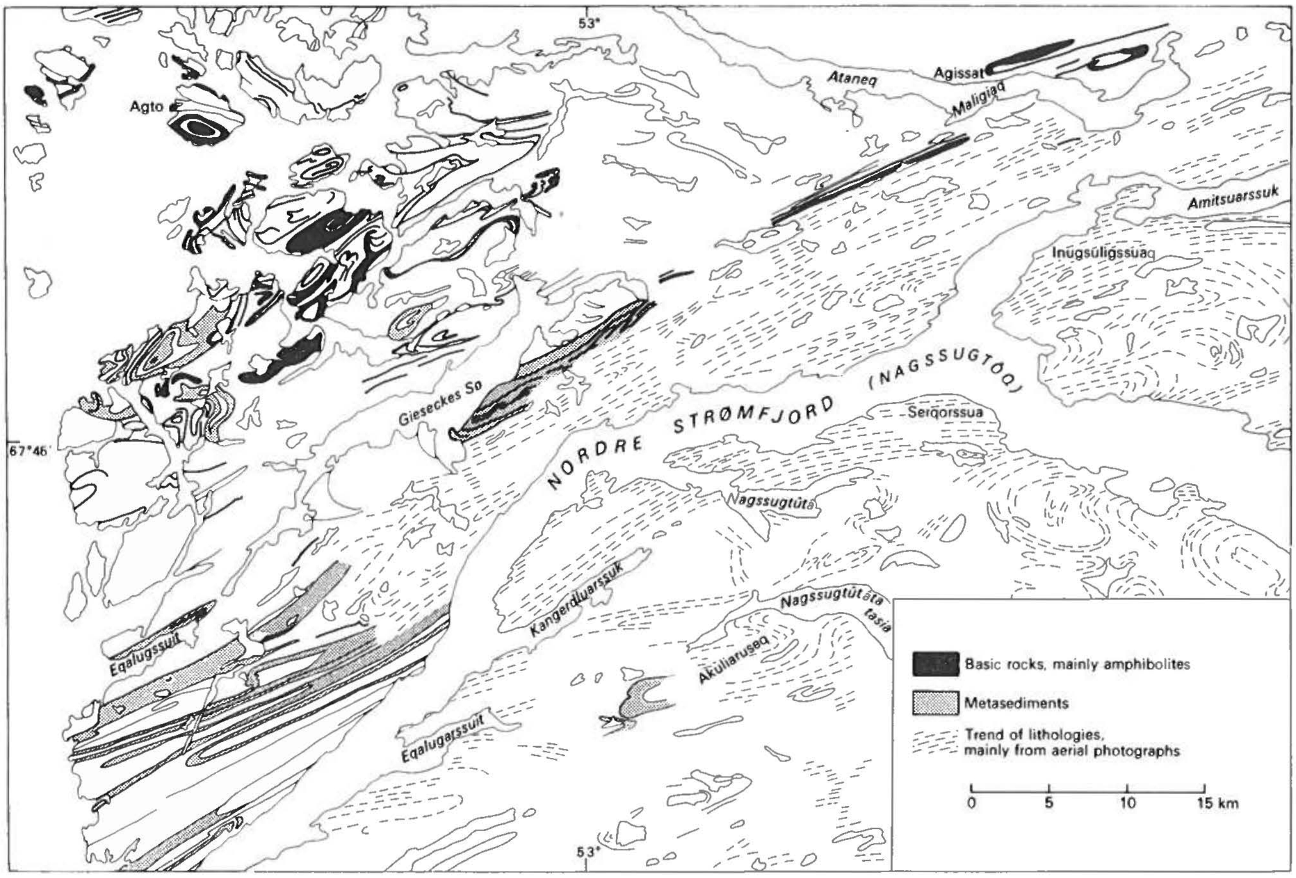


Fig. 72. Simplified geological map of the Agto and Nordre Strømfjord areas (from Bondesen, 1970 a).

pre-Nagssugtoqidian supracrustal rocks as defined under (b) are restricted to the central part of the belt, between Agto and the Ikertôq thrust zone (fig. 71). South of Ikertôq fjord supracrustals become very scarce.

Both supracrustal groups (a) and (b) show evidence of having been deformed and metamorphosed before the Nagssugtoqidian deformation. The presence of graphite and thick marble horizons in group (b) and their absence in group (a) may indicate that the latter group of supracrustals is older.

Granites, migmatites and pegmatites

No large granite or migmatite areas occur within the Nagssugtoqidian mobile belt in West Greenland. Only a few small granite occurrences associated with migmatites are known, mainly from the inner part of Nordre Strømfjord, Lersletten, the Agto region and the inner part of Søndre Strømfjord. They appear to be late kinematic with respect to the main Nagssugtoqidian deformation, and most occur in amphibolite facies areas. They are often foliated at the borders and can have porphyritic centres. The main minerals are: quartz, microcline, plagioclase, hornblende and biotite. The quantitative composition can vary from granodioritic to granitic or tonalitic.

In many parts of the belt, where the main deformation is less intense, the basement gneisses appear to have been derived from granites. This is the case in the areas between Holsteinsborg and Itivdleq and in the inner part of Søndre Strømfjord.

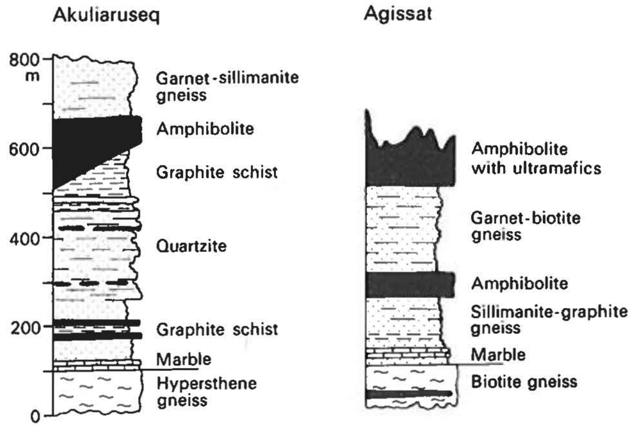


Fig. 73. Simplified stratigraphic sections across the supracrustal rocks at Akuliaruseq and Agissat (from Bondesen, 1970 b).

Pegmatites as late 'dykes', or as earlier veins and schlieren abound throughout the whole area, but are not evenly distributed. The late pegmatites in the Nordre Strømfjord and Egedesminde areas often contain allanite and occasionally beryl and tourmaline. The structure of the pegmatites varies considerably; some are zoned, usually with a quartz core, others show a relatively homogeneous mineral distribution, while still others are very coarse grained and develop good euhedral feldspars in quartz (Noe-Nygaard & Ramberg, 1961). Apart from the latest generations, the pegmatites in granulite facies terrain possess granulite facies assemblages, often with well developed hypersthene crystals.

Charnockites and syenites in the Archaean block

Directly south of the Nagssugtoqidian boundary, in the north-east part of the Archaean block, occurrences of charnockitic and syenitic rocks have been found (fig. 71). Their texture indicates that they were deep-seated magmatic rocks which have been slightly deformed in most places producing an indistinct foliation. The large crystals of the mafic minerals appear mostly undeformed, and were presumably recrystallised after the deformation, which was mainly of cataclastic type. At the same time aggregates of small crystals formed in cracks in pre-existing crystals.

The charnockitic rocks consist mostly of quartz, andesine antiperthite, K-feldspar perthite, hornblende and hypersthene. Accessory minerals include garnet, clinopyroxene, biotite and magnetite. The K-feldspars are often corroded by bulbous myrmekite forms. Zircon is locally present in large, slightly rounded crystals. The bulk of the quartz and feldspar is in large crystals and these show undulose extinction due to strain.

The syenitic rocks appear in the field as pink or white rocks. They consist mostly of K-feldspar, albite and aegirine-augite with some quartz. Small crystals of carbonate are present in the matrix of the pink syenites. Biotite and diopside are present in the white syenitic rocks. The structure and mineral content of the rocks is that of an alkali syenite. Locally an irregular banding of presumed igneous origin can be seen, mostly due to variations in pyroxene content.

Basic to intermediate intrusives

Most of the amphibolite layers and lenses in the southern part of the Nagssugtoqidian mobile belt are thought to represent reoriented and metamorphosed remnants of dolerite dykes belonging to the same dense swarms which intruded the Archaean gneisses south of the boundary. These pre-Nagssugtoqidian dolerite swarms can be divided into two main groups: (1) An older E–W swarm composed mostly of gabbronorite dykes containing orthopyroxene and locally olivine. (2) A younger NNE striking (Kangâmiut) dyke swarm composed of gabbro dykes normally without orthopyroxene and often containing garnet. In the central and northern parts of the belt, in the Agto and Egedesminde areas, only a few discordant metadolerites have been recognised by Henderson (1969) and K. Sørensen (1970). These show evidence of having also been deformed and metamorphosed by the Nagssugtoqidian main tectonic events and could be correlated with the southern metadolerites. Where supracrustal rocks and recognisable metadolerites occur together, the metadolerites always cut the supracrustal sequences. This is also the case with the youngest (Nagssugtoqidian) group of supracrustals, which was probably deposited during or just before the main episode of dyke intrusion.

A large folded quartz diorite body is found in the central part of the belt, at the head of Arfersiorfik fjord (Henderson, 1969). The main part of the body is homogeneous and contains hypersthene, hornblende and biotite. At the margins it passes into a dark biotite-garnet gneiss. It is considered to have been a thick, intrusive sheet of possibly early Nagssugtoqidian age which has undergone deformation and metamorphism.

Anorthosites, gabbro-anorthosites and ultrabasic intrusives

At the head of Itivdleq several ultrabasic bodies and a large mass of anorthosite are present (fig. 71). The anorthosite, in addition to calcic plagioclase, contains clinozoisite and muscovite (Ellitsgaard-Rasmussen & Mouritzen, 1954). Accessory minerals are hornblende, biotite, chlorite, scapolite, calcite and quartz. The age relations of the anorthosite are uncertain, but it is considerably deformed by Nagssugtoqidian movements and may well be of early or pre-Nagssugtoqidian age.

In several places, e. g. in the Agto and Ikertôq areas, thin lenses of gabbro-anorthosites and ultrabasic rocks are found, often in association with pre-Nagssugtoqidian supracrustals. The composition of the ultrabasites ranges from dunites, hypersthenites and pyroxene hornblendites to soapstones and serpentinites. While the outer zones of the lenses are always strongly sheared and metamorphosed, the central parts acted as competent bodies, retaining often their original texture and composition. The age of

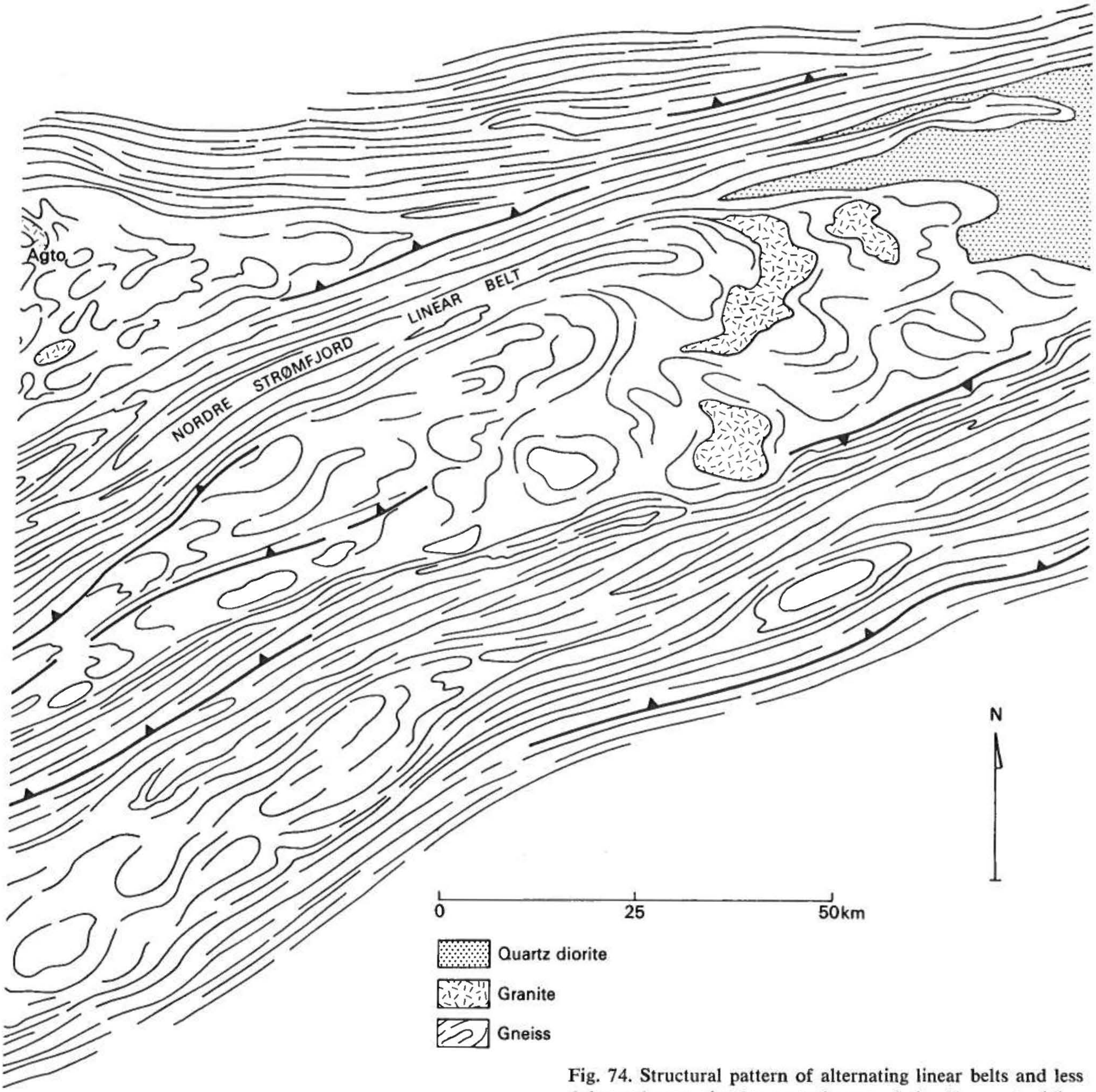


Fig. 74. Structural pattern of alternating linear belts and less deformed areas in the central part of the Nagssugtoqidian mobile belt.

these gabbro-anorthositic and ultrabasic lenses is probably pre-Nagssugtoqidian.

Structure

Regional structural pattern

As observed by Ramberg (1949) and Noe-Nygaard (1952) the Nagssugtoqidian complex is characterised in West Greenland by a predominant ENE trend of the main structural elements. In a general way it is possible to subdivide the complex into linear or straight belts where this regional fabric is well developed, and areas where a preferential direction is not so obvious (fig. 74). This typical alternating pattern resembles a large scale augen structure, the augen being represented by lens shaped 'islands' in which the original pre-Nagssugtoqidian structures and the dykes intruding them are still preserved. In the linear belts the older structures and dykes have, by contrast, been generally completely deformed and reoriented by the Nagssugtoqidian movements.

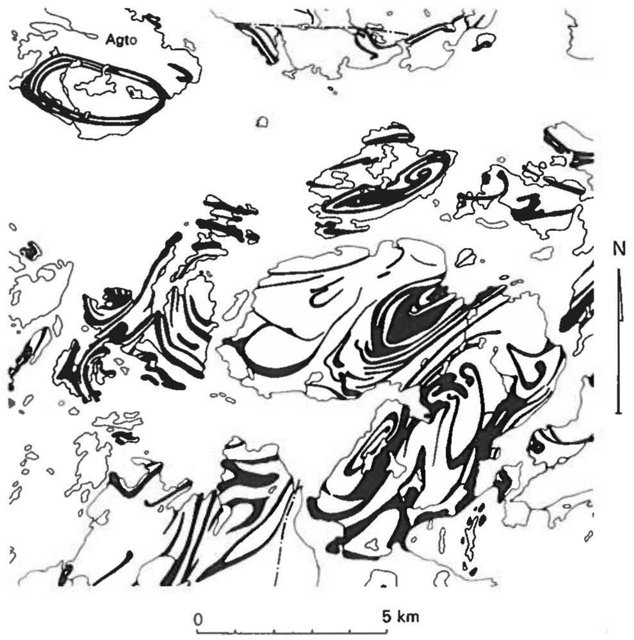


Fig. 75. Intricate dome and basin structures formed by superimposed folding in the Agto region (from Bondesen, 1970 a).

Pre-Nagssugtoqidian 'islands'

The islands, or lacunae, in which the pre-Nagssugtoqidian structures are best preserved vary in size from rounded inclusions of recognisable Archaean rocks (e. g. gabbro-anorthosite) preserving their original textures, to major mappable units tens or even hundreds of square kilometres in area. Detailed studies by K. Sørensen (1970) and Skjernaa (1973), in the Agto region show that the 'islands' possess intricate interference structures formed by superimposed similar-type folding (fig. 75). This resulted often in dome and basin structures of various shapes. K. Sørensen (1970) has described some of the types of interference patterns from the northern part of the Agto region. The dips and plunges of foliation, lineations and fold axes are all steep, mostly between 55° and 75°, and locally up to four deformation phases have been recognised pre-dating the Nagssugtoqidian ENE trending shear movements.

Structures similar to those described from the northern part of the Agto region are found in the very large 'lacunae' situated between Nordre Strømfjord and Nordre Isortoq (Noe-Nygaard & Berthelsen, 1953; K. Sørensen, 1970). Here the effects of later Nagssugtoqidian deformation are more obvious and are expressed in the ENE alignment of dome and basin structures.

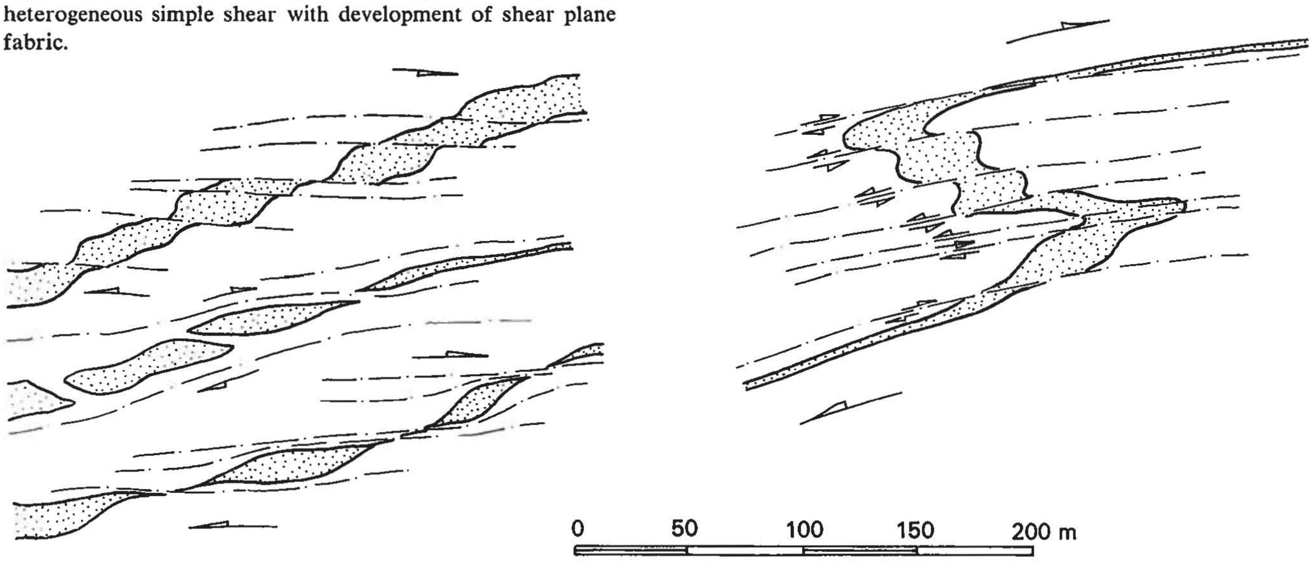
The structural pattern within the lacunae in which dominant strain directions are apparently lacking is very similar to that found in parts of the main Archaean block south of the Nagssugtoqidian boundary.

Nagssugtoqidian linear belts

In the linear, or straight belts, the formerly relatively open pre-Nagssugtoqidian structures have been tightened into isoclinal structures. Simultaneously they, together with the gneiss foliation and other pre-existing features, were reoriented approximately parallel to a plane striking ENE and dipping generally to the NNW. The dip varies from sub-horizontal near the southern Nagssugtoqidian boundary to moderately steep (50°–60°) in the central part of the mobile belt around Nordre Strømfjord.

In general the linear belts are thought to have originated through a simple shear strain (rotational

Fig. 76. Gleitbretter, folding, and disruption of dykes by heterogeneous simple shear with development of shear plane fabric.



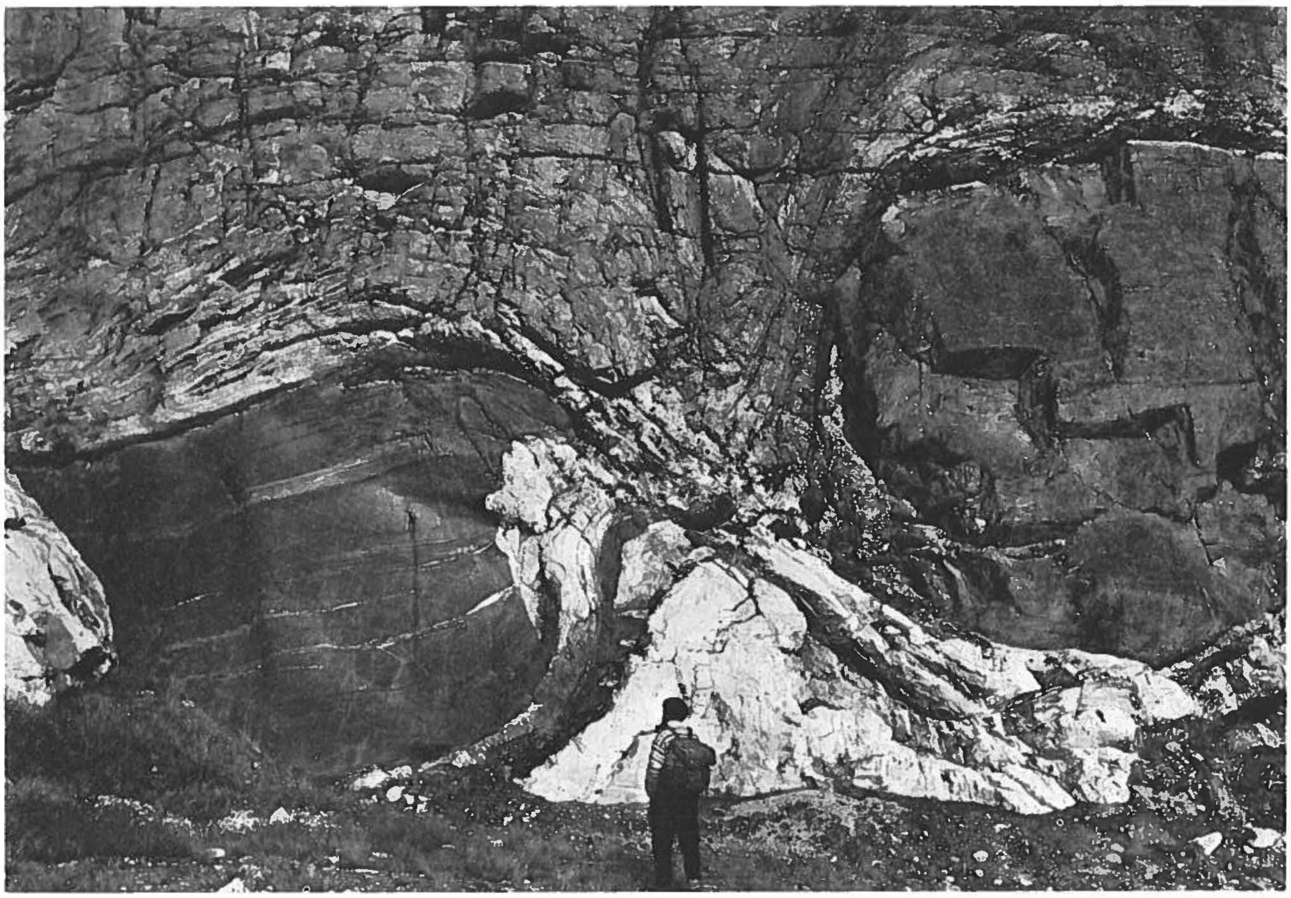


Fig. 77. Boudinage of a dyke near the head of Søndre Strømfjord.

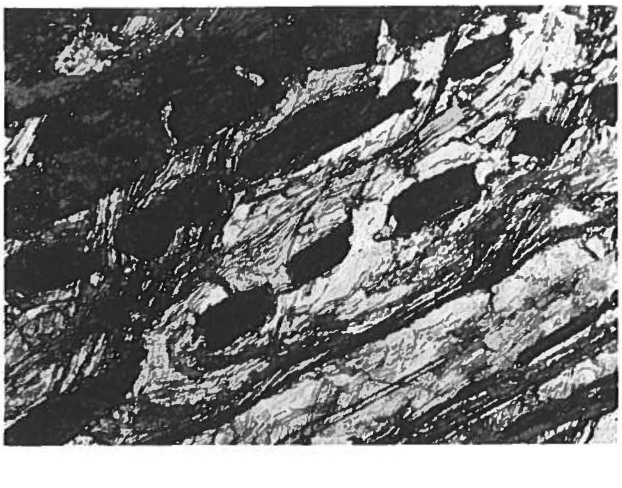
strain). Different movement patterns are inferred for the linear belts situated in the Agto region and those found south of Nordre Strømfjord, though the nature of transition from the one to the other pattern is not known.

Linear belts south of Nordre Strømfjord

The shear deformation has acted mainly as a ductile overthrusting from the north-north-west, approximately at right angles to the belt, along a sub-horizontal shear plane (Escher *et al.*, 1975; Bridgwater *et al.*, 1973). Locally the effects of oblique and horizontal movements parallel to the linear belts can also be observed. A characteristic of these belts is an often well developed, penetrative lineation or stretching direction contained within the foliation. This lineation is defined by individual minerals or by groups of minerals, which are thought to have recrystallised continuously during the deformation and probably in their present position outline the direction of maximum, finite elongation.

It is a typical feature that most of the fold axes are sub-parallel to the mineral lineation (Escher & Watterson, 1974). Other fold axes with strongly discordant relationship to the stretching direction refold clearly the mineral lineation and the foliation, and are usually attributed to a late Nagssugtoqidian drag-folding. Locally within the linear belts, discontinuities in the simple shear strain pattern produced folds and typical 'Gleitbretter' structures (fig. 76). Boudinage of more competent layers like amphibolites, ultra-

Fig. 78. Boudinage of dykes at Umîvît in the north-east part of Søndre Strømfjord. Width of the dykes *c.* 30 m.



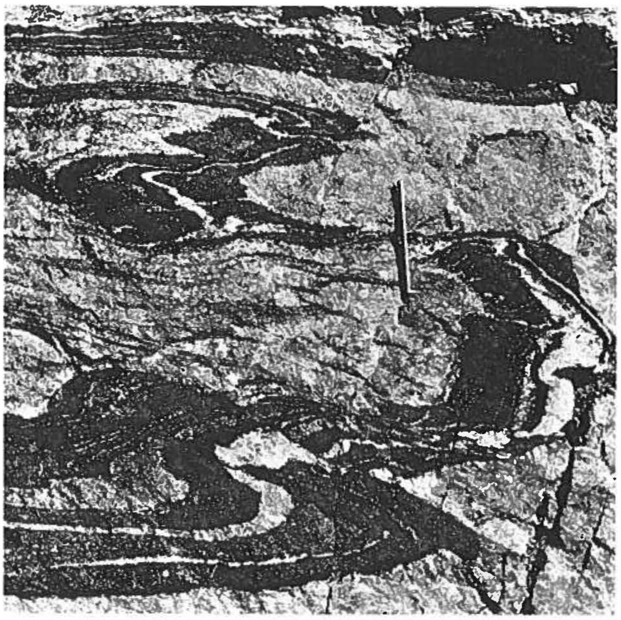


Fig. 79. Flow folding in migmatites near the head of Søndre Strømfjord.

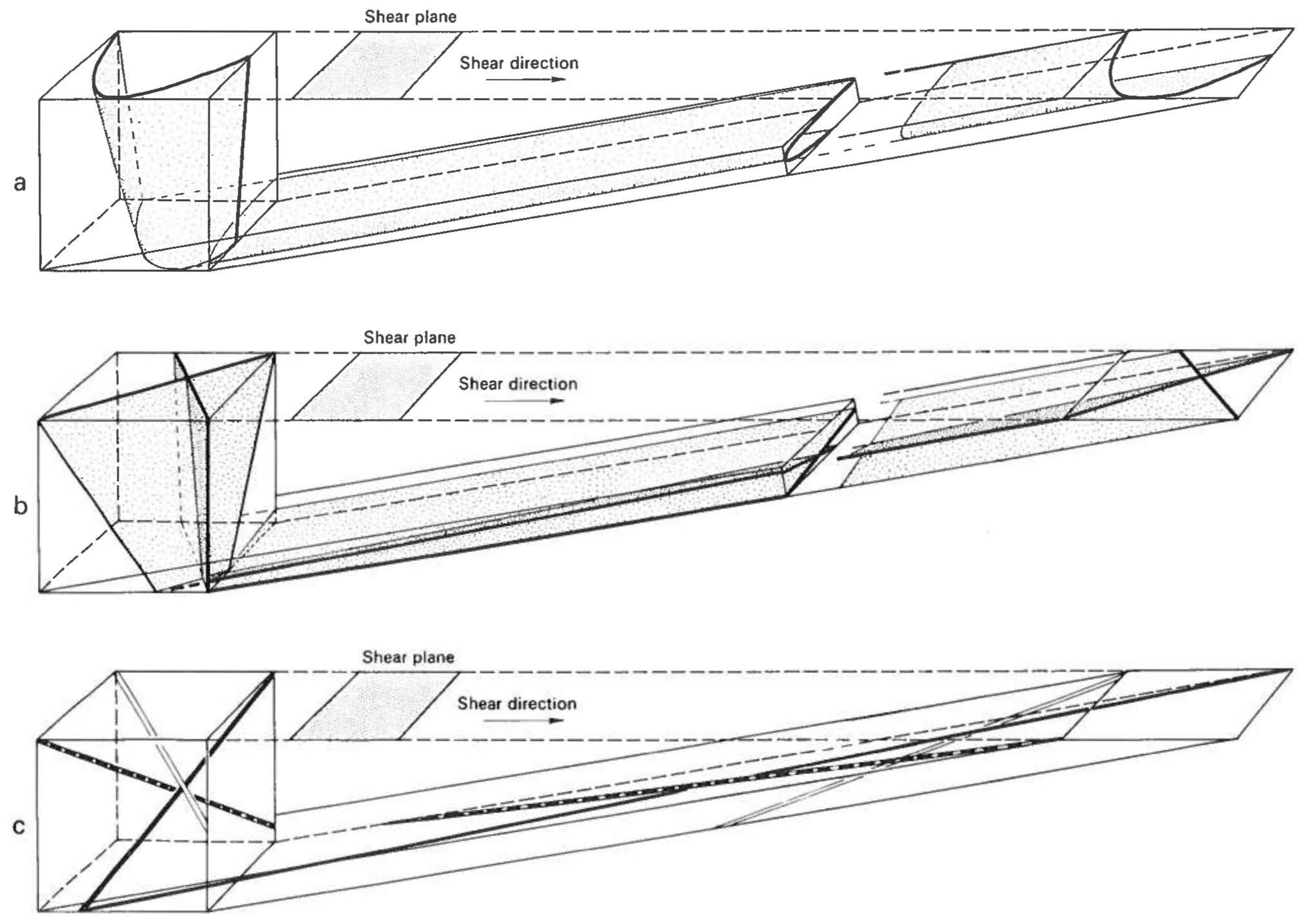
Fig. 81. Map of the deformed and undeformed dykes in the Søndre Strømfjord area. →

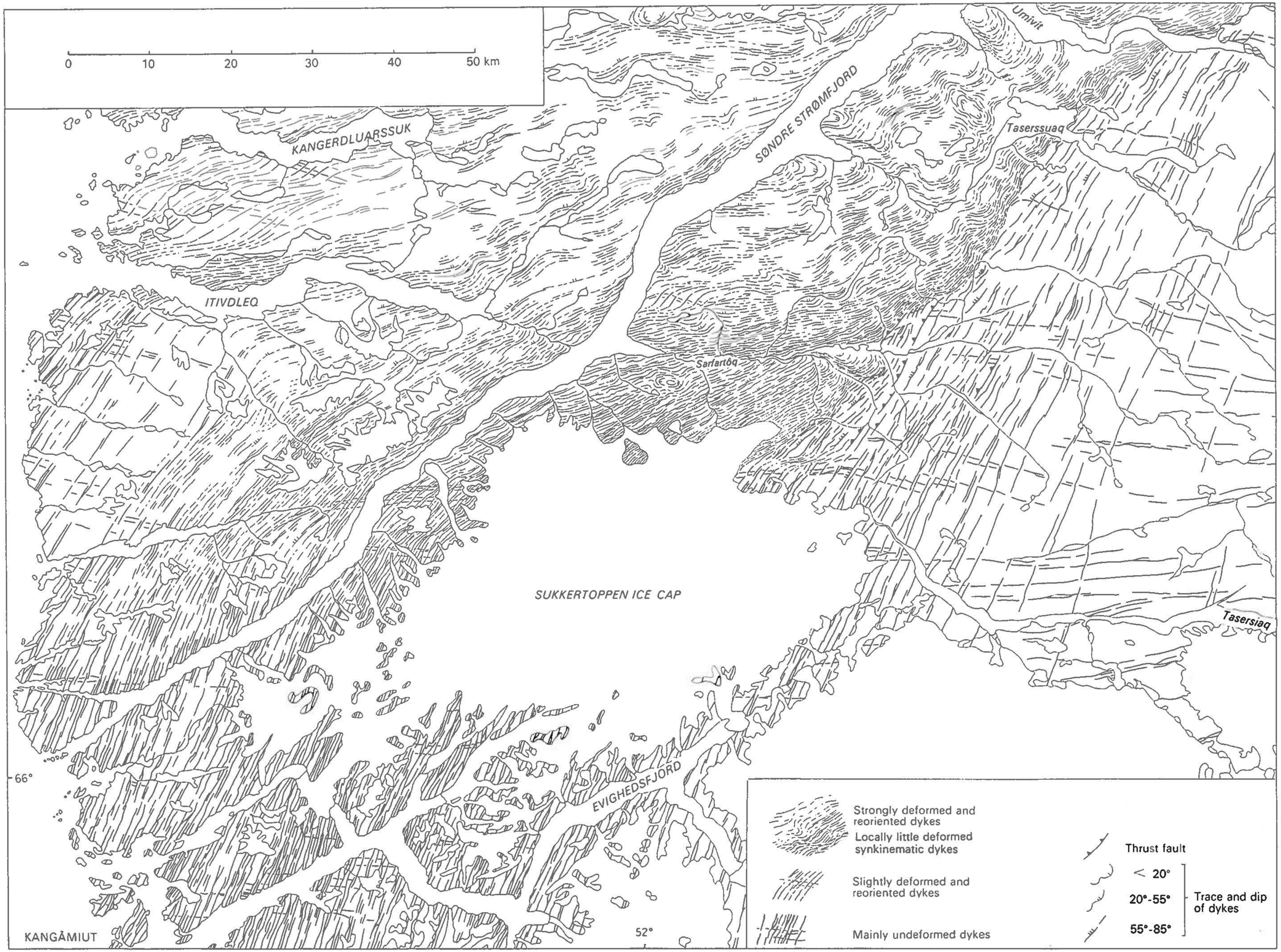
basics and pegmatites also occur locally, mainly following the simple shear strain stretching direction. Spectacular boudinage of Kangâmiut dykes can be seen in the linear belt following the north-east part of Søndre Strømfjord (figs 77, 78). Boudinage in two directions is very common here, indicating probably a pure shear strain or flattening acting during late Nagssugtoqidian ductile overthrusting.

In places where groups of rocks had strongly contrasting viscosities, combined simple and pure shear strain has resulted in the formation of very complex 'flow-fold' patterns, having no direct relation to the regional strain pattern. Examples of such structures can be seen in the small migmatite areas in the north-east part of the Søndre Strømfjord region (fig. 79).

In fig. 80 is shown a model which could explain by ductile overthrusting (simple shear) the following features, characteristic of linear belts: (a) the closing of pre-existing, open fold structures; (b) the parallelisation of fold limbs, axial planes, foliation planes, and originally discordant dykes; (c) the parallelisation of

Fig. 80. Simple shear strain model; for explanation see text.




0
10
20
30
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50 km
KANGERDLUARSSUK
SØNDRE STRØMFJORD
Umivit
Taserssuaq
ITIVDLEQ
Sarfartôq
SUKKERTOPPEN ICE CAP
Tasersiaq
66°
EVIGHEDSFJORD
KANGÂMIUT
52°
Strongly deformed and reoriented dykes
Locally little deformed synkinematic dykes
Slightly deformed and reoriented dykes
Mainly undeformed dykes
Thrust fault
< 20°
20°-55°
55°-85°
Trace and dip of dykes

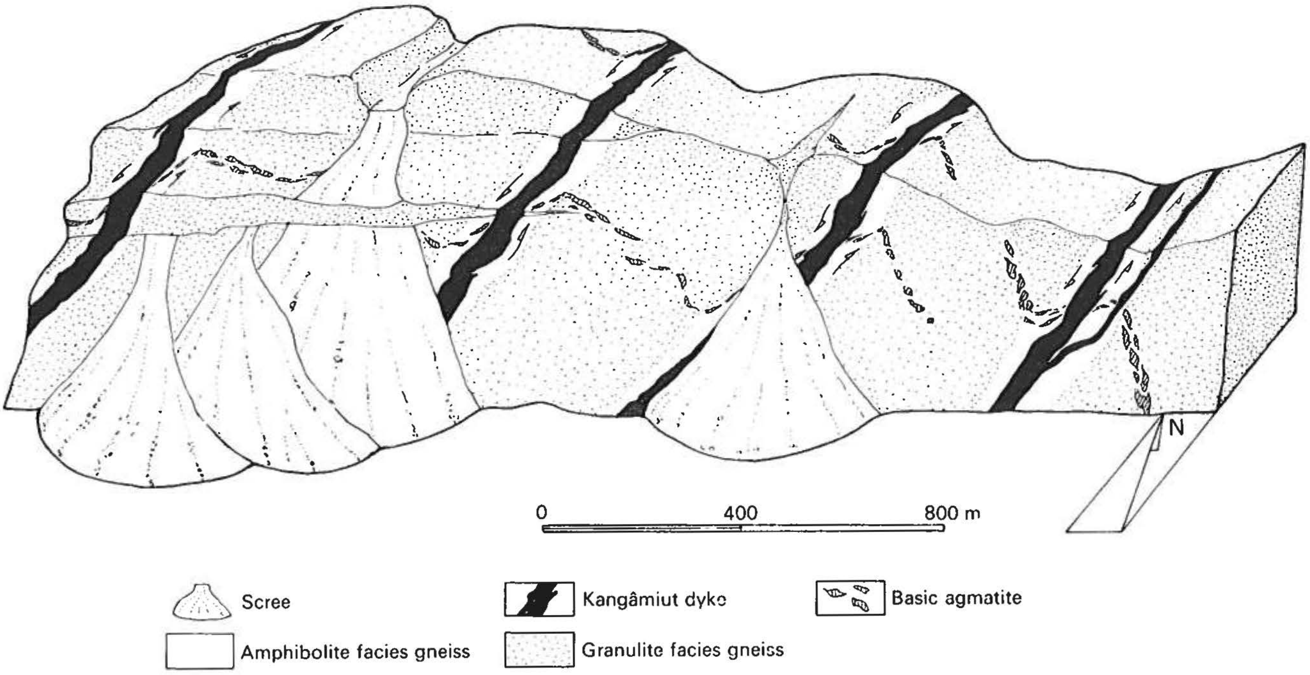


Fig. 82. Shear zones along dyke margins displacing agmatite horizons, east of lake Taserssuaq.

lineations (mineral lineation and stretched elements) and fold axes. Only fold axes lying exactly within the plane of simple shear would not be reoriented.

Linear belts in the Agto region

The Nordre Strømfjord linear belt (figs 69, 72) can be traced diagonally through the Agto area for about 70 km. The extension of the belt near the Inland Ice cuts and deforms the northern, marginal part of the quartz diorite body at the head of Arfersiorfik. In the outer part of Nordre Strømfjord the linear belt is approximately 15 km wide and cuts through areas with pronounced interference patterns.

The Nordre Strømfjord linear belt is characterised by the following features: (1) The linear belt makes a low angle with the axial planes of the latest folds in the surrounding 'island' areas and cuts these structures. (2) The rocks of the linear belt are mostly foliated biotite and hypersthene-bearing gneisses and metasediments of group (b), which generally show post-deformation recrystallisation. (3) Linear structures which outside the linear belt are oriented in various directions have a well developed horizontal point-concentration within the linear belt, while planar structures have been steepened and their strike rotated in an anticlockwise sense.

The boundary conditions of deformation (Ramsay & Graham, 1970) and the nature of the reorientation of planar and linear elements show that the linear belt developed by sinistral transcurrent simple shear, with a subvertical shear plane and horizontal shear direction. In contrast to the linear belts south of Nordre Strømfjord the newly formed mineral lineation is not well developed, but with this exception fig. 80 can also be taken to demonstrate the deformation of the Nordre Strømfjord linear belt with an appropriate 90 degrees shift towards the horizontal plane.

Throughout the Nagssugtoqidian linear belts the boundaries between more and less deformed areas may be progressive, due to ductile shear, or discordant, due to brittle thrusting or wrench faulting. In the Agto region and near the southern boundary, the zones of brittle movement are often accompanied by crush-breccias and pseudotachylites.

The southern Nagssugtoqidian boundary

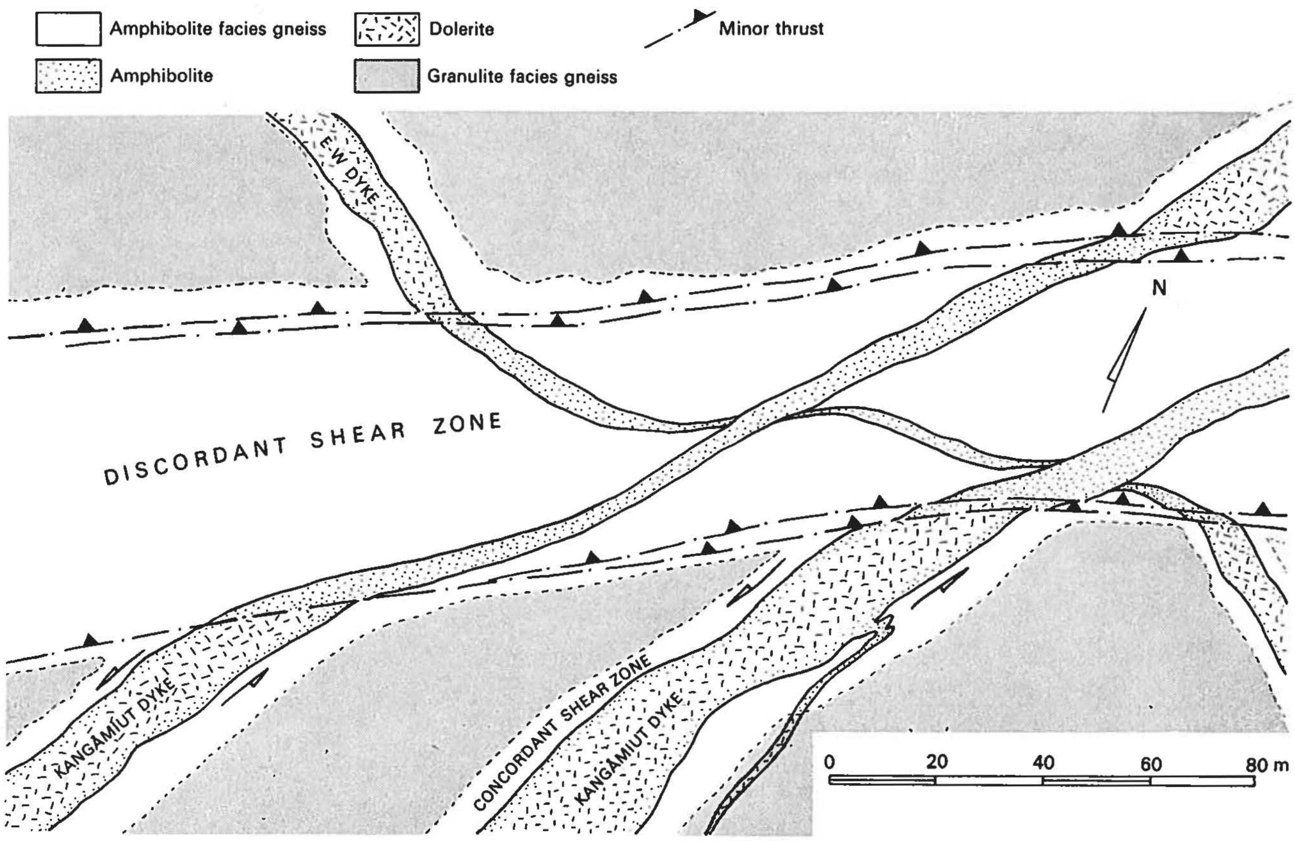
The southern Nagssugtoqidian boundary cuts across Søndre Strømfjord near the Sukkertoppen ice cap following roughly an east-north-east direction (figs 71, 81). South of this boundary, granulite facies gneisses are cut by two undeformed basic dyke swarms, with the dominant NNE striking (Kangâmiut) dyke swarm post-dating an E–W swarm. The Nagssugtoqidian boundary forms in this area a transition zone approximately 20 km wide in which the dykes, together with their country rocks, are progressively deformed and metamorphosed resulting in a reorientation and parallelisation of both dykes and country rock structures. These changes increase towards the NNW and may be either abrupt, or more gradual and brought about in a series of shear belts which partly follow the margins of wide dykes (figs 82, 83) and partly are parallel and similar to the Nagssugtoqidian linear belts (fig. 84).

Deformation in the boundary region has the following characteristics (Escher *et al.*, 1975): (a) continuity of dykes and gneiss lithologies is maintained across the boundaries separating deformed and undeformed rocks; (b) at the deformation boundaries changes in orientation of dykes are abrupt rather than gradual (figs 84, 85). These characteristics can be observed in both horizontal and vertical sections and can be assumed to characterise the three dimensional strain pattern. The only type of strain consistent with these characteristics is thought to be a mainly homogeneous rotational strain or simple shear strain.

In the horizontal plane the Kangâmiut dykes are reoriented in a clockwise direction while the E–W dykes are reoriented anticlockwise (fig. 81). This reorientation is accompanied by a considerable thinning of the dykes and their country rocks. In vertical sections perpendicular to the boundary all dykes and other structures in the gneisses are reoriented in the same direction, i. e. in accord with an overthrusting shear movement from the NNW along shear planes dipping between 10° and 30° to the NNW (fig. 85).

Fig. 83. Shear zones along the margins of a Kangâmiut dyke reorienting a thinner cross cutting E–W dyke. East of Umîvît.

Fig. 84. Shear zone parallel to Nagssugtoqidian linear belts, intersecting dykes of both swarms and post-dating shears along dyke margins. East of the head of Søndre Strømfjord.



Reorientation of the dykes resulted in a considerable change in the angle of intersection of the two dyke swarms, and in the angle between dykes and original gneiss structures (figs 85, 86).

In a general way the displacement at the southern Nagssugtoqidian boundary can be described as ductile overthrusting of the northern Nagssugtoqidian rocks over a stable pre-Nagssugtoqidian foreland to the south, with an effective horizontal shortening of at least 65 per cent. This deformation also produced a new foliation in originally often isotropic granites and gneisses. The new foliation has a strong linear component plunging down dip to the NNW and following the long axis (*X* axis) of the strain ellipsoid. Locally the overthrusting was brittle resulting in the formation of thrusts, crush-breccias, mylonites and pseudotachylites. In general the southern Nagssugtoqidian boundary has been formed by movements identical to those responsible for the formation of linear belts south of Nordre Strømfjord.

Recognisable deformed Kangâmiut dykes have not been observed north of Amerdloq fjord. However, the metadolerites seen by K. Sørensen (1970) and Henderson (1969) in the northern part of the Nagssugtoqidian mobile belt, may be in some way connected with the Kangâmiut swarm.

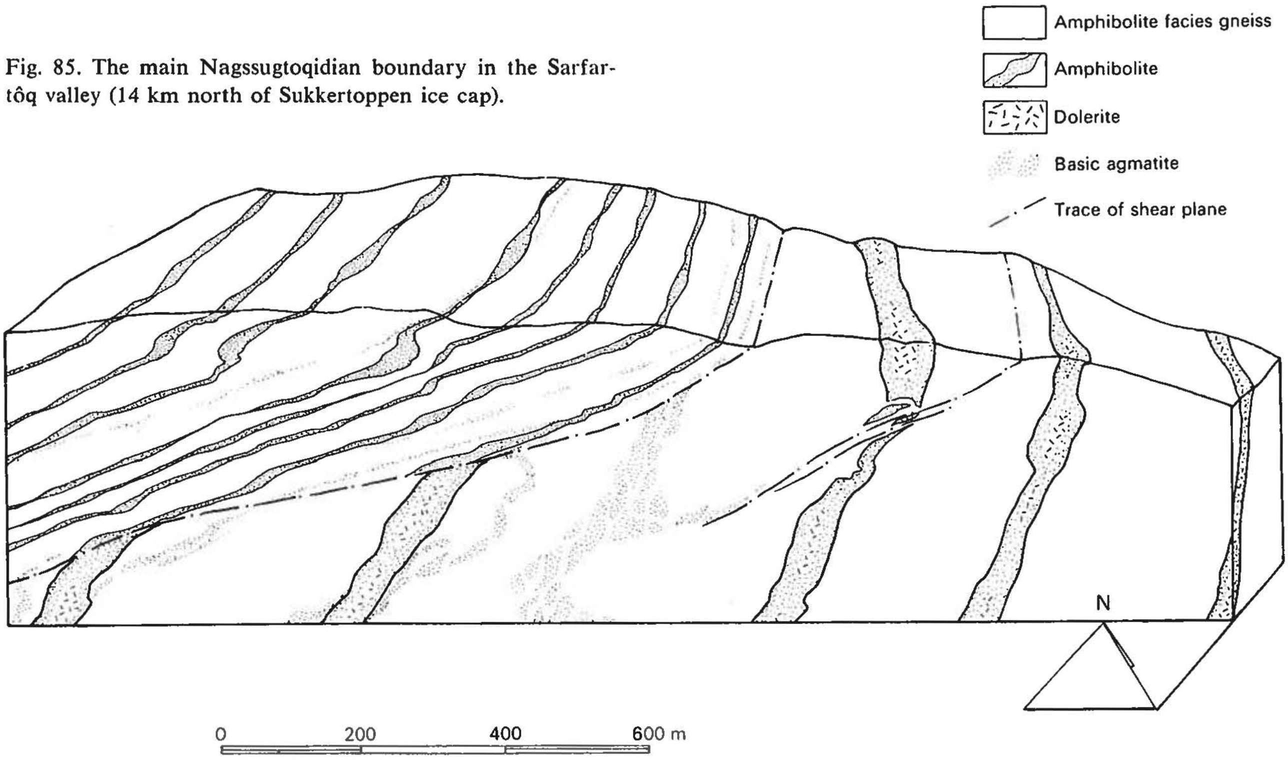
Relation between deformation and dyke intrusion at the southern Nagssugtoqidian boundary

Investigations on the southern Nagssugtoqidian boundary in the area between Sukkertoppen ice cap and Søndre Strømfjord (Escher *et al.,* 1975), and in the area between Holsteinsborg and Itivdleq (Bridgwater *et al.,* 1973), show that the Nagssugtoqidian shear-deformation does not everywhere post-date the intrusion of the Kangâmiut dykes. In several places, e. g. in the Itivdleq and Sarfartôq areas, Kangâmiut dykes clearly intrude along early Nagssugtoqidian ENE striking shear planes. Some of the dykes are unmetamorphosed and undeformed and others display typical synkinematic shapes and internal foliation (fig. 87). Often they occur as a network of relatively thin dykes following the Nagssugtoqidian shear planes and connected with each other by apophyses which cut the new foliation in the gneisses. In contrast to the Kangâmiut dykes, the E–W dykes appear to be everywhere deformed by the Nagssugtoqidian movements.

These observations lead to the following succession of deformational events in relation to the dykes:

(a) Intrusion of E–W dyke swarm.
(b) Early Nagssugtoqidian simple shear strain in limited zones.
(c) Intrusion of the main (Kangâmiut) dyke swarm, in places simultaneously with continuing simple shear.

Fig. 85. The main Nagssugtoqidian boundary in the Sarfartôq valley (14 km north of Sukkertoppen ice cap).



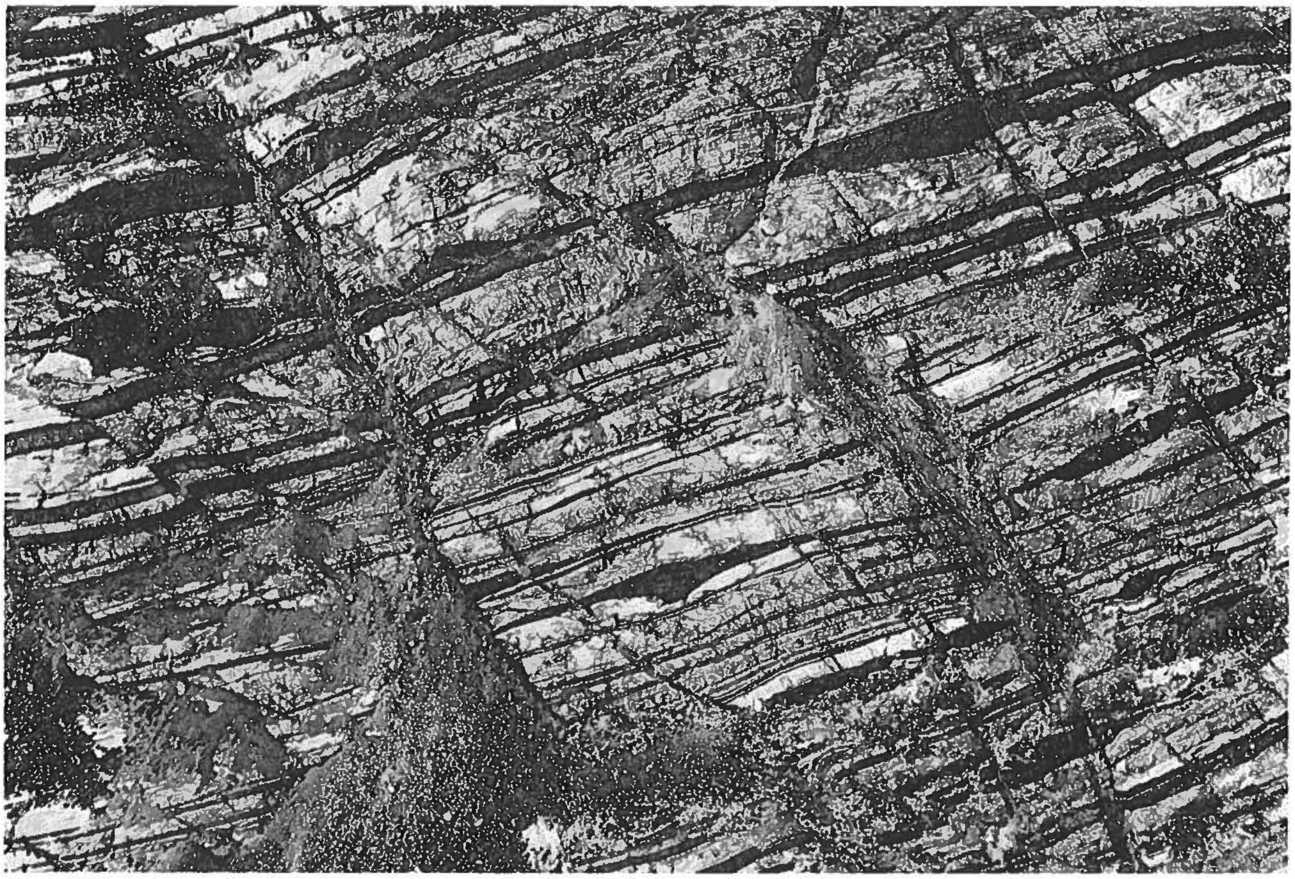
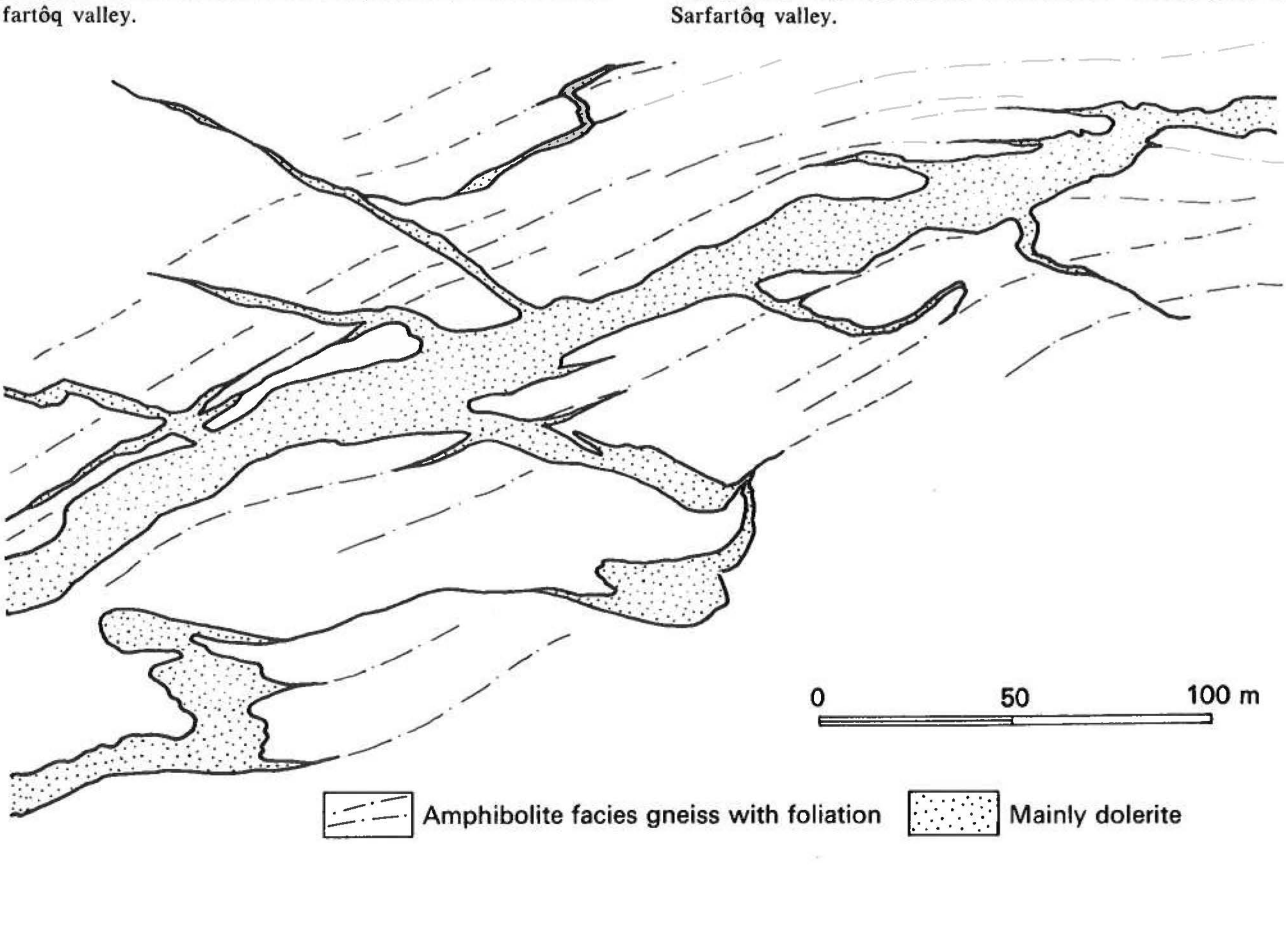


Fig. 86. Intersection at acute angle of two dykes (upper half of picture) in Nagssugtoqidian linear belt near the boundary, which were probably at right angles to one another before deformation. Height of section c. 500 m. North side of Sarfartôq valley.

Fig. 87. Irregular intrusion pattern of dykes syn- or post-dating early Nagssugtoqidian deformation. Western part of Sarfartôq valley.



(d) Continued simple shear mainly by ductile overthrusting in the same way and direction as the early Nagssugtoqidian movements. This event probably represents the main period of Nagssugtoqidian deformation.

The main difference between the eastern and the western part of the Nagssugtoqidian boundary is that in the east the main Nagssugtoqidian deformation considerably overlapped the southern limit of the early movements, while in the west it never reached the boundary of the early Nagssugtoqidian shear movements.

The northern Nagssugtoqidian boundary

North of Jakobshavn, in the southern part of the Atâ Sund, a major zone of transcurrent faulting and mylonitisation cuts the Nagssugtoqidian ENE trending structures (fig. 88). To the north of this wrench zone rocks belonging to the Rinkian mobile belt display a totally different structural style: the dips of foliation and lithology are here generally low, and the most obvious structures are large domes often surrounded by rim-synclines (Escher & Pulvertaft, this volume).

Reconnaissance mapping by Escher & Burri (1967) in the boundary regions has shown that the main movements along the transcurrent shear zone were sinistral. In many places they resulted in the formation of drag folds. The mylonites associated with the horizontal shear zones may be several hundred metres wide; they are completely recrystallised and form a compact rock in many places cemented and veined by quartzo-feldspathic material. Locally younger shear zones cut the mylonites and show that repeated movements took place along this boundary.

The gneisses on both sides of the wrench zone are generally augen gneisses with a well developed subhorizontal stretching direction of the augen.

Fig. 88. Simplified stereogram showing the major zone of transcurrent faulting between the Nagssugtoqidian and Rinkian mobile belts.

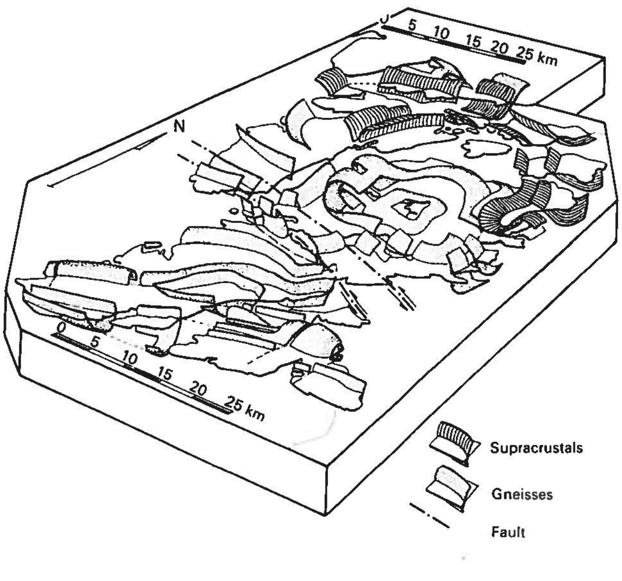


Fig. 89. Folding of previously boudinaged metadolerites, near the head of Søndre Strømfjord.

Late to post-Nagssugtoqidian movements

Throughout the Nagssugtoqidian mobile belt a weak deformation can be seen which locally refolds the typical Nagssugtoqidian ENE trending structures by concentric type buckling around NW trending axes. In the Egedesminde region (Henderson, 1969) and in the Ikertôq area (Escher, 1966), entire parts of linear belts are weakly refolded in this way. In the Søndre Strømfjord area the late buckling deformed previously boudinaged metadolerites (fig. 89). Brittle transcurrent or thrust-movements post-dating this deformation can locally be observed, and resulted often in the formation of mylonites and pseudotachylites. Pseudotachylites have been described by Henderson (1969) from the Arfersiorfik area, by Jensen (1968) from the Agto area and by Bridgwater *et al.*, (1973) from the Ikertôq area. At least three periods of Nagssugtoqidian pseudotachylite formation can be recognised.

Pre-Nagssugtoqidian deformation south of the boundary

Directly south of the Nagssugtoqidian boundary, in the north-east part of the Archaean block, the granulite facies gneisses show an indistinct NW striking foliation. This foliation, which is roughly perpendicular to the Nagssugtoqidian direction, seems to be mainly of cataclastic origin. Most of the gneisses are here probably derived from intrusive charnockites and syenites mainly by a brittle-shear-deformation.

To the south-east of lake Tasersiaq the granulite facies gneisses are retrogressed to amphibolite facies in persistent zones of intense shearing in which pseudotachylite breccias and veins post-date the main deformation. These events are all post-dated by both the Kangâmiut and the older E–W dykes.

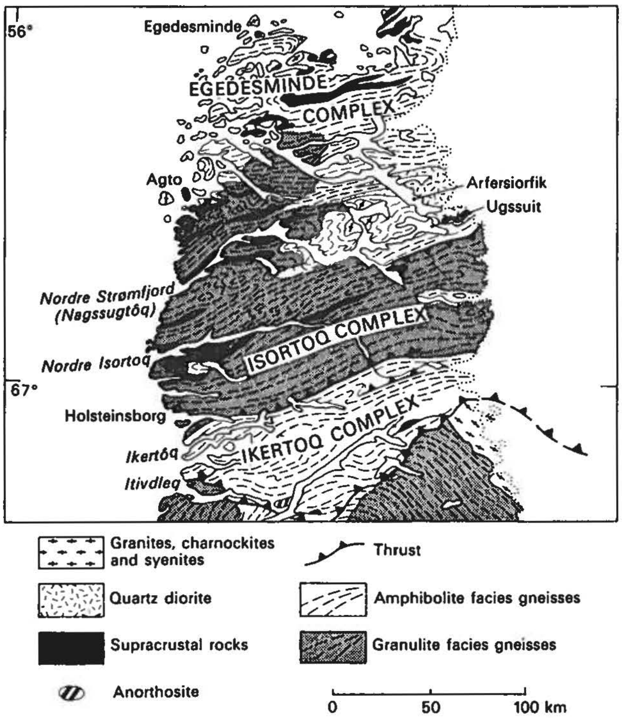


Fig. 90. Map of the main metamorphic complexes within the Nagssugtoqidian mobile belt.

Metamorphism

Ramberg (1949), on the basis of reconnaissance mapping, divided the rocks between Egedesminde and Søndre Strømfjord into three metamorphic complexes (fig. 90). The southernmost Ikertoq complex, and the northernmost Egedesminde complex are characterised by rocks belonging to the amphibolite facies, while the central Isortoq complex contains granulite facies rocks. Later work has confirmed the relevance of this division. Only locally has knowledge of the Nagssugtoqidian metamorphism been established in more detail.

In general the metamorphic events responsible for the highest grade parageneses outlasted the main Nagssugtoqidian periods of deformation. In the majority of rocks neither the textures nor the number of phases contradict the view that these parageneses represent an equilibrium.

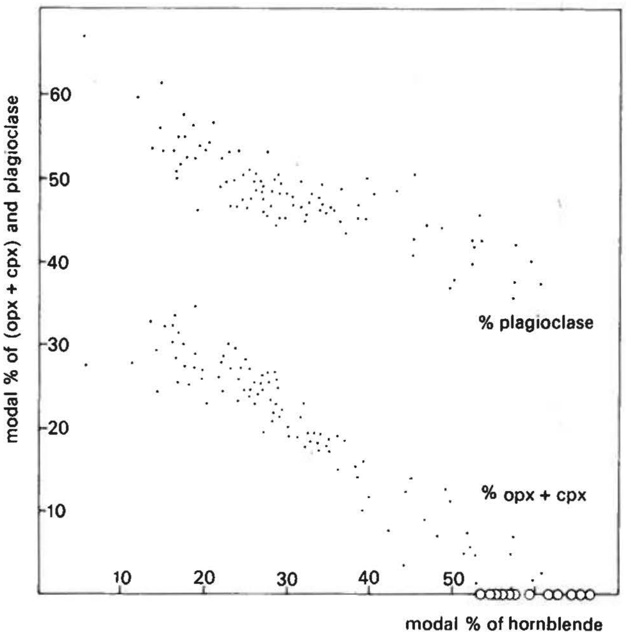
New data are available mainly from the Agto area and from the area of the southern Nagssugtoqidian boundary.

Metamorphism in the Agto area

The Agto area is situated marginally within the Isortoq complex. Apart from granulite facies parageneses it also includes some amphibolite facies rocks. A few metadolerite dykes here cut the pre-Nagssugtoqidian 'island' structures and are deformed by the Nagssugtoqidian linear belts.

The metadolerite dykes show the imprint of a metamorphic event of probable Nagssugtoqidian age, but the parageneses are mostly of the granulite facies; only a few are amphibolites, free of sphene, in contrast to the schistose Kangâmiut dyke amphibolites from within the deformation boundary. Most of the Agto metadolerites consist of hornblende, orthopyroxene, clinopyroxene and plagioclase, and occasionally garnet. There is a wide variation in the composition of plagioclase and hornblende.

Fig. 91. Variation in modal composition of the Agto metadolerites.



The modal percentage of hornblende varies between 5 and 65 per cent (fig. 91). As no regional variation in the hornblende content exists and as almost all of the variation can be found in single metadolerites from their margins to their centres, it is believed that the modal variation (i. e. the variation in metamorphic grade) is due not to gradients in temperature or pressure, but to differences in the activity of water. The mixing of amphibolite and granulite facies parageneses found in the Agto area may be explained without inferring gradients in physical parameters, and without inferring a "retrograde amphibolite facies metamorphism". This last point can be further discussed with reference to the Agto metadolerites.

Most metadolerite samples have granuloblastic textures but in others blastophitic textures, resembling those of the Kangâmiut dykes from outside the deformation boundary, are found. This indicates that the paragenesis of the metadolerites results from a retrogressive reaction. A second argument in favour of this is shown by the varying composition of the plagioclase during reaction. This variation is partly preserved in the zonation of the plagioclase, and the nature of this zonation shows that the metadolerites are in a 'frozen' state of hydration.

The Agto metadolerites have a significantly lower hornblende content than the metabasites concordantly interlayered in the surrounding gneisses. The plagioclase zonation in these metabasites is generally the reverse of that of the metadolerites, which indicates that the concordant metabasites (amphibolites and two-pyroxene amphibolites) are in a 'state' of prograde metamorphism. The two sets of metabasites can thus be envisaged as having converged towards identical metamorphic grade, without having reached identical final states.

The general character of metamorphism within the area as represented by that of the concordant metabasites should be one of prograde granulite and high grade amphibolite facies metamorphism.

The Agto area is situated within the boundary zone (fig. 90) between the Egedesminde and Isortoq complexes, and with reference to the above conclusions there are at present only arguments in favour of the granulite facies metamorphism of the central part of the Nagssugtoqidian mobile belt being prograde and of Nagssugtoqidian age.

Metamorphism at the southern Nagssugtoqidian boundary

The pre-Nagssugtoqidian metamorphism of basement and dykes

South of the Nagssugtoqidian boundary, in the northeastern part of the Archaean block, the rocks show the imprint of strong cataclastic deformation. The rocks affected by this brittle deformation seem to be derived mainly from charnockites, syenites and granites, with smaller amounts of quartzitic and aluminous rocks. During recrystallisation after the crushing, mineral parageneses were formed which belong to the granulite or amphibolite facies or a facies transitional between these two. Amphibolite facies rocks are locally also present in restricted zones within the Archaean rocks. The occurrence of an earlier cordierite-bearing paragenesis together with a younger kyanite-bearing one in an aluminous rock suggests, assuming that it is cogenetic with the surrounding rocks, that temperature decreased (or pressure increased) during the main pre-Nagssugtoqidian recrystallisation. The distribution of the hypersthene, and thus the distribution of the granulite facies rocks might very well be governed by the distribution of water at the time of the metamorphism.

The basic dykes belonging to the Kangâmiut and E–W dyke swarms, are mostly undeformed south of the Nagssugtoqidian boundary. They also cut the cataclastic structures of the country rock and therefore must post-date the brittle shear-deformation phase and related recrystallisation.

The magmatic mineral assemblages in the undeformed dykes comprise: olivine, augite, hypersthene, labradorite, opaque minerals, K-feldspar and quartz. In the rocks where olivine is present this mineral often has a radially textured reaction rim which consists of hypersthene at its inner side and of amphibole at its outer side. Hornblende forms rims at the clinopyroxene–plagioclase contact. The amphibole and the orthopyroxene probably formed at the subsolidus stage, perhaps involving a certain degree of metasomatism with addition of water to the dyke rock.

Other minerals formed by static recrystallisation in the solid state are: garnet, plagioclase, hornblende, sphene, opaques and biotite. The crystals of this group show typical recrystallisation textures often with mosaic textures. The recrystallisation without deformation within the basic dykes probably pre-dates the Nagssugtoqidian events. This is shown by the fact that the garnet in some dykes is not retained in the dyke rims of amphibolite which were formed by shearing and recrystallisation during the early Nagssugtoqidian events. Also, the degree of recrystallisation of the dykes does not decrease regionally away from the Nagssugtoqidian boundary.

The Nagssugtoqidian metamorphism

The Nagssugtoqidian boundary forms a transition zone in which the Kangâmiut and E–W dykes, together with their country rocks, are progressively deformed and metamorphosed. These changes increase towards the north-north-west and may be either abrupt, or more gradual and brought about in a series of shear belts which partly follow the margins of wide dykes (fig. 82); and partly are parallel and similar to the Nagssugtoqidian linear belts. The Nagssugtoqidian shear-deformation was accompanied by a strong recrystallisation in the amphibolite facies, the brownish hypersthene gneisses being 'retrogressed' to light grey biotite-hornblende gneisses. This Nagssugtoqidian metamorphism is characterised by the abundant formation of biotite, quartz and andesine in quartzo-feldspathic rocks, while in the basic rocks, hornblende, andesine, biotite and garnet were formed. The latter minerals are found in the sheared dykes, and are generally oriented to form a strong mineral foliation and lineation.

Both Archaean rocks and Nagssugtoqidian rocks exhibit a retrogressive overprint corresponding to the greenschist or a still lower facies. It is particularly developed in late fracture zones but is also present to a minor degree throughout the rocks. Typical assemblages are: sericite–albite–prehnite–epidote (*s. l.*)–carbonate–chlorite. It is possible that this overprint has a similar age throughout the area, i. e. late Nagssugtoqidian or younger. It is also possible that they are each attached as a low-temperature tale to the *T*-culmination responsible for the development of the high-grade parageneses.

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