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Report No. 57

Structural and lithological divisions of the western border of the East Greenland Caledonides in the Scoresby Sund region between 71° 00′ and 71° 22′N

by

Peter Homewood

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1 map in pocket

1973

Abstract

The area described lies on the western border of the East Greenland Caledonian fold belt in the Scoresby Sund region.

The lithological divisions distinguished during field-work comprise a probably autochthonous basement and cover sequence overlain by three thrust masses. Each thrust mass comprises supracrustal and infracrustal rocks.

Structural complexity and metamorphic grade increase upwards from the autochthon through the thrust masses. This is the result of thrusting of each allochthonous unit from a relatively more internal part of the fold belt; the highest thrust mass of the pile has the most internal origin.

Metamorphism and main deformation date from the Caledonian orogeny. Subsequent major normal faults have given the area a block structure, bringing different units into juxtaposition.

The rock types described may be divided into two cover sequences with associated infracrustal rocks in each case. It appears that both cover sequences may be representative of a single or several closely related sedimentary basins. The depositional age of these sediments is not known, but new age dates reported elsewhere suggest that some of them may have been metamorphosed before the Caledonian orogeny.

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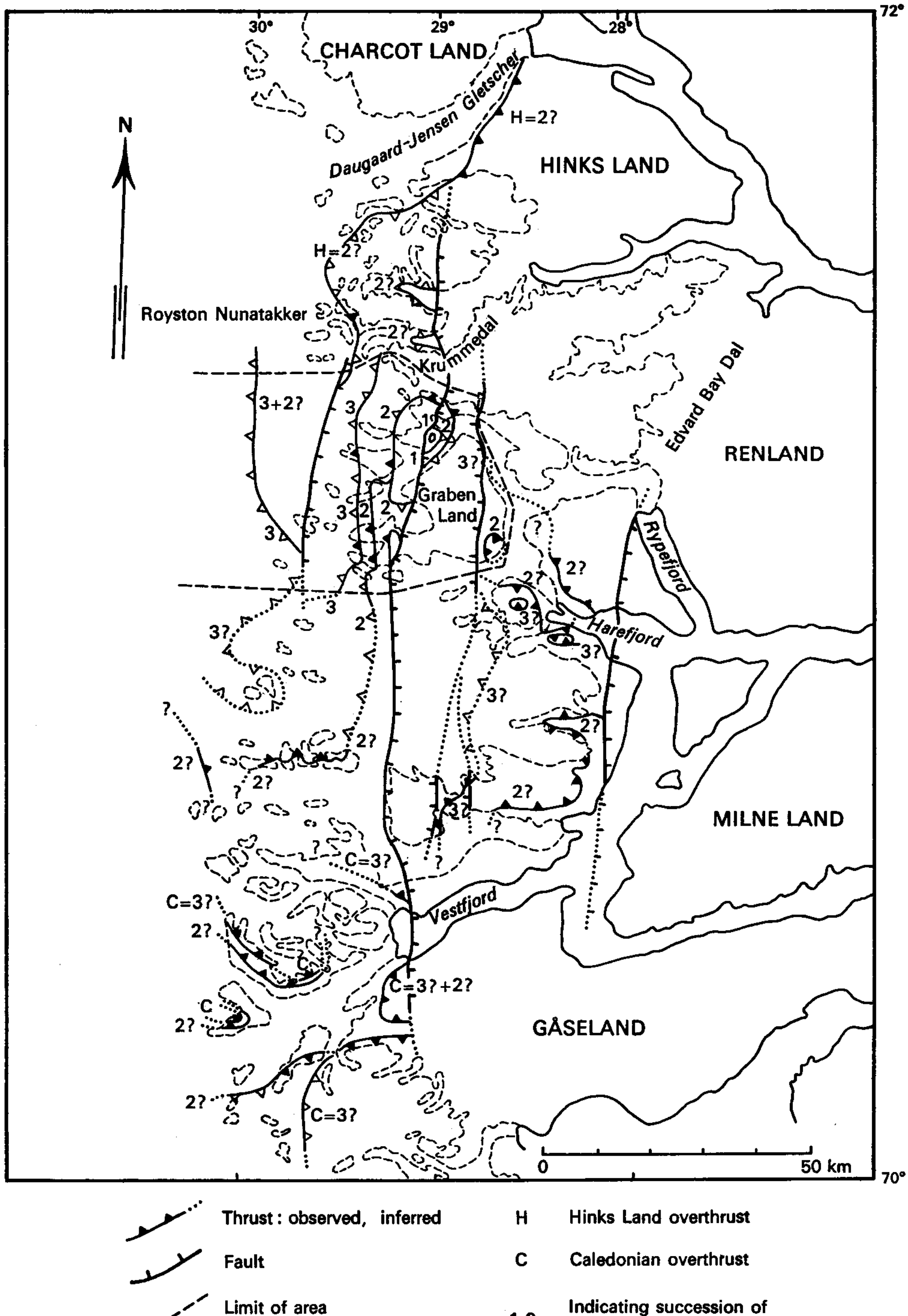

Fig. 1. Main structural lineaments of the western border of the Caledonian fold belt 70–72° N.

INTRODUCTION

Area and accessibility

The area described in this report, roughly covering 800 km^2, was mapped during July and August 1970 as part of the five year series of expeditions to the Scoresby Sund region of East Greenland carried out by the Geological Survey of Greenland (Henriksen & Higgins 1969, 1970, 1971).

The area is formed by a group of nunataks and lies WNW of Harefjord and Rypefjord, inner Scoresby Sund region, between 71° 00′ and 71° 22′ N and 28° 30′ and 30° 30′ W (fig. 1 and Plate 1).

The larger nunataks, to the east, are mountainous with moraine covered plains and small ice-caps. To the west, a number of small nunataks crop out from the ice. Altitude varies from 800 to 2500 m.

Access was mainly by foot on the larger nunataks; helicopter and skis were used to visit the small nunataks and the less accessible areas of the larger nunataks.

Lithological divisions

Field mapping has revealed the following principal lithological divisions mainly found in distinct thrust units:

1. Ferruginous quartzite series
2. Metavolcanics
3. Leucocratic gneiss, migmatite and augen granite
4. Chlorite schist series and serpentinite
5. Chlorite gneiss and chlorite granite: basement rocks associated with the chlorite schist series
6. Rusty mica schists
7. Siliceous chlorite gneiss associated with the rusty mica schists
8. Leucocratic gneiss associated with the rusty mica schists
9. Rusty brown gneiss
10. Leucocratic gneiss and amphibolite: basement rocks associated with the rusty brown gneises

These may be divided into two distinct cover sequences, the ferruginous quartzite series and the chlorite schist series forming the first, the rusty mica schists and the rusty brown gneiss forming the second. Each cover sequence is associated with infracrustal rocks.

The chlorite schist series, the rusty mica schists and the rusty brown gneiss, together with their associated infracrustal rocks, have been superposed by thrusting in a westerly direction and now overlie the ferruginous quartzite series, the metavolcanics and certain infracrustal rocks, which may well be autochthonous.

The higher metamorphic grade and greater structural complexity of the rusty brown gneiss compared to the rusty mica schists, and of both these compared to the chlorite schists suggests that each unit has been thrust from correspondingly more internal zones of the fold belt.

Important normal faults running north–south post-date the main orogenic events and divide the area blocks. The two easternmost faults outline a graben structure.

Dolerite dykes, which are undeformed and post-date regional metamorphism affecting the other rocks, are to be found throughout the area.

Previous work

Although the area described in this report had not been investigated prior to the 1970 GGU expedition, several workers have previously visited the general region. E. Bay (1895) was the first, during 1891–1892, followed by H. G. Backlund, K. Lupander and E. Wenk during the 1930's (Backlund, 1955). J. Haller made several reconnaissance flights over parts of the Scoresby Sund region in 1958 and the area figures in his *Geology of the East Greenland Caledonides* (Haller 1971).

The adjacent areas to the north of the investigated area were mapped by Vogt (1965) and Henriksen & Higgins (1969).

During the 1970 GGU expedition, J. D. Friderichsen, L. Jemelin and H. Rütishauser mapped the adjacent areas to the east and the south.

LITHOLOGICAL DIVISIONS

The lithological divisions are described in units reflecting the structural position in order of increasing metamorphic grade of the cover sequence involved in the unit. This also corresponds to the vertical order of the structural units, the lowest grade characterising the lowermost unit.

Structural unit A (probably autochthonous)

1. Ferruginous quartzite series

Occurrence

The exposure of this series is extremely limited, being restricted to a small outcrop on the south-east flank of Vindue Nunatak, on the edge of Vindue Gletscher. This series is truncated at the top by an important thrust, and the base of the sequence is not exposed.

Description

Some fifty metres of grey phyllites with thin quartz bands are overlain by quartzites of two types:

(a) Banded quartzites, reddish brown in colour, with thin pelitic layers rich in opaque minerals.

(b) Granular quartzites, extremely rich in stilpnomelane and magnetite.

These quartzites are interbanded with dark semipelites rich in opaque minerals.

Composition

The grey phyllites contain white mica and quartz as major minerals, accessories are tourmaline and zircon, chlorite is rare.

The banded quartzites comprise mainly quartz, accompanied by magnetite, stilpnomelane, chlorite, carbonate and apatite in variable quantities.

The granular quartzites have a high proportion of stilpnomelane and magnetite, accompanied by quartz and carbonate. Chlorite is rare.

2. Metavolcanics

Occurrence

The north-westernmost nunataks of the area, directly south of the Royston Nunatakker, are formed by a homogeneous fine-grained greenstone. Similar rocks on the Royston Nunatakker show pillow structures confirming their volcanic origin (Henriksen & Higgins 1969).

Composition

The metavolcanics comprise actinolite, albite and pistacite accompanied by chlorite, stilpnomelane and opaque minerals. Amygdale minerals are axinite, albite and calcite.

3. *Leucocratic gneiss, migmatite and augen granite*

Occurrence

Leucocratic gneisses associated with migmaties and an augen granite outcrop over a large part of the area east of the graben structure on Graben Land.

The gneiss is homogeneous to banded, and is intruded by at least two generations of metamorphosed basic sills and dykes. These may measure up to 50 m in width and are particularly well seen in the cliffs on the south-east corner of this nunatak. Pegmatitic granite bands with very few dark minerals occur conformably with foliation within the gneiss. The gneiss apparently grades up into siliceous gneiss or siliceous schists which contain the same basic intrustions.

Migmatites were observed at several localities. A generation of discordant amphibolites post-dating the interbanding of paleosome and neosome is penetrated by veins of neosome. This suggests several phases of migmatisation, or simultaneous migmatisation and intrusion.

On the south-eastern tip of Graben Land, peninsular 1120, a well-foliated to homogeneous augen granite is exposed. The leucocratic gneiss lies conformably with the foliation of the granite and apparently the passage of the one to the other is gradual. Elongated microcline augen form a progressively greater proportion of the rock; as the proportion of microcline increases, the foliation becomes less pronounced.

Composition

Leucocratic gneiss: principal minerals are quartz, microcline, white mica and plagioclase. The main dark mineral is biotite, both brown and green, frequently altered to chlorite. Epidote, both pistacite and clinozoisite, is ubiquitous. Accessories are sphene, apatite, zircon and opaque minerals.

The pegmatitic granite comprises quartz, microcline and plagioclase with small quantities of white mica, biotite more or less altered to chlorite, and epidote.

Amphibolites: green actinolite is the major constituent, with green and brown biotite more or less altered to chlorite. Quartz, plagioclase and epidote are less important; accessories are sphene, apatite, carbonate and opaque minerals. One amphibolite was formed solely by actinolite.

Migmatite: neosome is quartz and microcline.

Augen granite: microcline forms up to 60% of the rock; quartz, plagioclase and white mica are major constituents. Minor constituents are green biotite, green amphibole, chlorite, pistacite and clinozoisite. Accessories are sphene and apatite.

Structural unit B

4. Chlorite schist series and serpentinite

Occurrence

A fairly thick series of metasediments may be traced from Vindue Nunatak southwards across the eastern corner of Varde Nunatak, across the headland west of Stendal into the moraine covered plain to the south where there are a few scattered outcrops. West of Stendal a well exposed part of the sequence occurs consisting of:

lowest	white quartzite	1 m
	chlorite schists	several decimetres
	dolomitic marble	5–10 m
	chlorite schists	20 m
	quartzites, with layers rich in chlorite passing up into chlorite pelites	5 m
	dolomitic marble	several decimetres
highest	chlorite schists	several hundred metres

The white quartzite lies discordantly on a homogeneous chlorite granite.

The thickness of this series may have been considerably altered by deformation, and the figures given are those at the exposure described, not an average from the various exposures in the area.

The outcrops further south (south-western Graben Land) mainly expose chlorite schists with a fairly high proportion of carbonate matrix in places. Small flat lenses of serpentinite observed lying parallel to the foliation in this area are probably thin layers of metabasic material broken up by a strain-slip cleavage oblique to the foliation.

Two isolated outcrops of serpentinite also occur near the exposures of the chlorite schists on the moraine covered plain south-west of Stendal. The metasediments overlie a siliceous chlorite gneiss.

On Vindue Nunatak the series is exposed on both sides of the western major fault limiting the graben. West of the fault, chlorite schists overlie a chlorite gneiss. East of the fault, siliceous chlorite schists of possibly in part metavolcanic origin overlie a strongly sheared siliceous gneiss and are thrust over the ferruginous quartzite series.

Further north, on the north flank of Vaskedalen, chloritic schists of possibly largely metavolcanic origin begin with a layer of white quartzite and lie above a homogeneous chlorite gneiss. These schists have been intruded by dykes of basic and granitic material, and are truncated by an important thrust. The granitic intrusions are more recent that the basic.

In the south-western nunatak region, the nunataks 1970, 2130, 2160 and 2190 are formed by chlorite schists, siliceous schists and carbonate-rich chloritic schists similar to those exposed further east.

Composition

Dolomite marbles: principal minerals are carbonate, mainly dolomite; quartz and white mica are present in small quantities.

Chlorite schists: these contain quartz, albite, white mica, chlorite and biotite. Carbonate is of variable importance. Accessories are pistacite, tourmaline, apatite and zircon. Garnets, often with 'snowball' structure, are frequent.

Chlorite schists of possibly metavolcanic origin: principal minerals are quartz, plagioclase, green biotite, chlorite, white mica, and epidote. Accessory minerals are sphene and apatite. Carbonate is present in variable amounts. These schists have been intruded first by basic and then granitic rocks:

(a) Metabasics: principal mineral is actinolite. Accessory minerals are carbonate, white mica and epidote. Quartz is present in fractures.

(b) Granite: quartz, K-feldspar and plagioclase form the main part of the rock. Dark minerals are biotite and chlorite.

5. Chlorite gneiss and chlorite granite: basement rocks associated with the chlorite schist series

Occurrence

In the south of the area, the chlorite schists overlie greenish siliceous gneiss and siliceous schists. The latter may represent either sheared basement rocks or a lower member of the metasedimentary sequence.

West of Stendal the metasediments are separated by an unconformity from a homogeneous chlorite granite, which may be fairly well foliated in places.

Metamorphosed basic dykes and lenses are common, both in the gneiss and the granite.

On Vindue Nunatak the chlorite schists succeed a homogeneous chlorite gneiss as do the greenschists visible north of Vaskedalen. These gneisses also contain dykes and lenses of metabasites.

In the north of the area, metabasites occur therefore both in the chlorite schists and their associated basement rocks.

Composition

Chlorite gneiss: principal minerals are quartz, plagioclase, K-feldspar, chlorite and green biotite. The gneiss is often siliceous. Secondary minerals are white mica and pistacite, and accessories are sphene, apatite and ore.

Chlorite granite: microcline, plagioclase, quartz, green biotite, chlorite and white mica occur together with epidote. Accessories are sphene, apatite and zircon. The K-feldspar is perthitic and the plagioclase is zoned.

Metabasics: These are of two varieties: (a) medium-grained amphibolites with little plagioclase, and (b) fine-grained metavolcanics similar in composition to those described under 2 Metavolcanics.

Structural unit C

6. Rusty mica schists

Occurrence

These rocks crop out in the north, the central part and the south-east of the area, and consist of a fairly thick sequence of banded psammitic and pelitic metasediments. They are normally rusty brown in colour, but the psammitic layers may be grey in places.

The lithology is highly variable from one exposure to another, being mainly pelitic apart from the sequence on Varde Nunatak which is mainly psammitic.

Composition

Major constituents are quartz, biotite and white mica, accompanied by garnet, chlorite in places and occasionally plagioclase. Accessories are apatite, tourmaline and opaque minerals.

7. Siliceous chlorite gneiss: basement rocks associated with the rusty mica schists

In Vaskedalen, to the north of the area, the rusty mica schists overlie a sequence of siliceous chlorite gneiss with basic sills and dykes. These rocks are similar to the gneiss mentioned under 5 (Chlorite gneiss and chlorite granite).

8. Leucocratic gneiss: basement rocks associated with the rusty mica schists

Occurrence

To the south of Varde Nunatak, the rusty mica schists lie discordantly over a series of homogeneous to banded leucocratic gneiss and amphibolites. This discordance may be either stratigraphic or tectonic.

The leucocratic gneiss containing metabasic sills and dykes is exposed on the southern tip of Varde Nunatak, on Pukkelen, on both sides of the moraine covered plain to the south-west of Stendal, and on the nunataks south of there. The southern exposure of the chlorite schists is a structural window in the gneiss.

Composition

Principal minerals are quartz, microcline, plagioclase and biotite, accompanied by white mica and epidote. Accessories are sphene, apatite, and zircon.

Structural unit D

9. *Rusty brown gneiss*

Occurrence

Rusty brown gneisses crop out on Graben Land within the graben structure, and form the nunataks from the western extremity of Varde Nunatak to the south-western tip of Graben Land, point 2000. They also form the nunataks in the south-west of the area.

This gneiss is generally somewhat migmatised, locally very much so. Conformable bands of granitic material up to 30 m thick were observed as well as occasional pegmatite dykes. Neosome is formed both *in situ* and intrudes as discordant and conformable veins in the rock. These veins are often several centimetres thick.

In the south of the area the rusty brown gneiss encloses several large ultrabasic intrusions.

Lithology in the gneisses varies in a manner comparable to that of the rusty mica schists; the psammitic layers are less influenced than the pelitic layers by migmatisation.

Marble bands were not observed in the rusty brown gneisses, but some bands of massive siliceous rock show mineral assemblages probably derived from calcareous rocks.

On the south-east corner of Graben Land, west of peninsular 1120, a thrust plane separates the rusty brown gneiss and leucocratic gneiss and amphibolite from more highly migmatised gneisses of the same general types. Neosome of the same composition as that in the rusty brown gneiss forms a greater proportion of the rock and feldspar phenocrysts are abundant.

Mineral composition of these rocks is similar to that of the rusty brown gneiss and leucocratic gneiss and amphibolite (see below, section 10) but chlorite is more abundant, and kyanite is often rimmed with yellow minerals, products of alteration.

Composition

Garnet is ubiquitous in the rusty gneiss and frequent both in paleosome and in neosome; single crystals may attain 20 cm in diameter.

Rusty gneiss: principal minerals are quartz, plagioclase, biotite, garnet and white mica, accompanied occasionally by chlorite and K-feldspar. Accessories are apatite, zircon, sphene and opaque minerals. Kyanite is frequent and in several places was found in association with sillimanite.

Neosome: quartz, microcline, plagioclase, white mica, garnet and biotite are accompanied by apatite, zircon and opaque minerals.

Amphibolites: green hornblende and plagioclase are accompanied by quartz and garnet. Accessories are apatite, sphene and opaque minerals; chlorite is occasionally present.

Ultrabasic rocks: olivine, pyroxene (diallage), hornblende and biotite form the rock which has veins of quartzo-feldspathic material in places.

Carbonate rocks: on the southern bank of the easternmost lake of Stendal, a massive green and red siliceous rock contains quartz, garnet, clinozoisite, anorthite, actinolite and clinopyroxene, accompanied by a little carbonate, zircon and sphene.

10. Leucocratic gneiss and amphibolite: basement rocks associated with the rusty brown gneiss

Occurrence

Leucocratic gneiss and amphibolite occur as conformable units within the rusty brown gneiss and have been folded into large isoclinal structures with them. The frequent occurrence of thin layers of rusty brown gneiss in the leucocratic gneiss is also attributed to intense isoclinal folding.

Two distinct generations of amphibolites were observed; an earlier phase of deformation affected the gneiss and the first generation of amphibolites prior to the emplacement of the second generation. The conformable amphibolite bands are frequently boudinaged and isolated lenses with recrystallised rims were noted.

A single marble band, frequently boudinaged and measuring several centimetres to several metres in width, was found at two localities in amphibolite bands close to the contact with the rusty brown gneiss.

Composition

The leucocratic gneiss contains quartz, microcline, plagioclase and white mica as major constituents, accompanied by biotite and amphibole. Chlorite and epidote may be present. Accessories are sphene and apatite. Garnet may be present in amphibole rich layers.

Amphibolites: principal minerals are green amphibole and plagioclase, accompanied by biotite, chlorite, quartz and epidote. Acessories are apatite, sphene and opaque minerals. Microcline is occasionally present. Amphibole often replaces pyroxene, which is present as relicts and originally formed large poikilitic crystals.

Marbles: calcite and dolomite are accompanied in varying proportions by silicates. Talc, tremolite, pyroxene and olivine are present. Olivine is frequently replaced by antigorite.

Dolorite dykes

These are to be found throughout the area, measuring up to 50 m in width, and generally striking north–south. They have not been affected by the Caledonian orogeny and presumably are part of the scattered swarms of presumed Tertiary age found in the inner Scoresby Sund region (Wenk 1961, p. 44; Henriksen & Higgins 1971, p. 16).

STRUCTURAL GEOLOGY

Thrusting

The area is characterised by the thrusting of several units apparently in a westerly direction (Plate 1 and figs 1 & 2). Two major thrusts marked 1 and 2 on the map were observed and a third, marked 3 on the map, although not observed directly, was deduced from structural and petrological arguments. These thrusts superpose units comprising infracrustal and supracrustal rocks from different zones of the chain. Two minor thrusts were observed within the major units.

The lowermost thrust (marked 1 on the map) separates the chlorite schists and associated basement rocks from the ferruginous quartzite series below, and is visible on the south-east flank of Vindue Nunatak, on the edge of Vindue Gletscher. This thrust is apparently warped, dipping gently south-west, west or north-west.

The second thrust (marked 2 on the map) separates the rusty mica schists and associated infracrustal rocks from the chlorite schists. Although visible on the northern flank of Vaskedalen dipping gently north to north-west this thrust was not located on Varde Nunatak, where no infracrustal rocks were found between the rusty mica schists and the chlorite schists. Further south, on the south-western corner of Graben Land, the chlorite schists outcrop in isolated patches on a moraine covered plain. They are overlain to the west by leucocratic gneisses which lie discordantly under the rusty mica schists. No contact between the chlorite schists and the overlying gneisses was observed here.

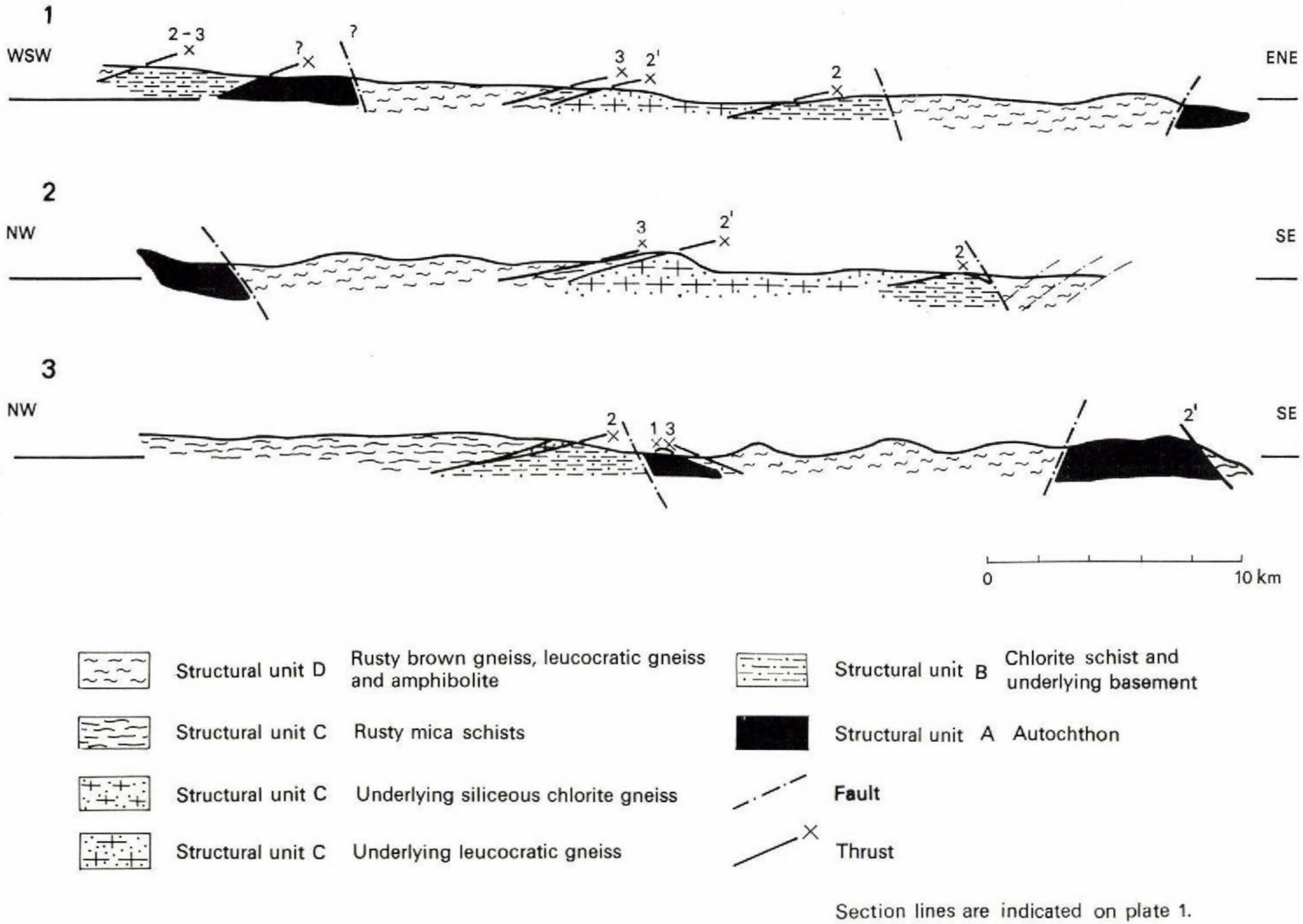

Fig. 2. Cross-sections of the area mapped; section lines are shown on plate 1.

The third major thrust (marked 3 on the map) separates the rusty mica schists from the overlying rusty brown and leucocratic gneisses. These form the topmost unit of the pile. The rusty brown and leucocratic gneisses overlie the rusty mica schists on Graben Land and in the west of the area with no apparent discordance, but differences in their respective structural and metamorphic histories indicate that they represent two different units.

Within the lower thrust unit, a probable minor thrust of unknown importance cuts through the gneiss underlying the chlorite schists below point 1500 on Vindue Nunatak. This thrust dips gently west to south-west.

The relationship of infracrustal and supracrustal rocks in the second thrust unit is not clear. In the northern part of the area the rusty mica schists lie apparently conformably on siliceous chlorite gneiss of possible infracrustal origin; on Varde Nunatak, in the central part of the area, the rusty mica schists are directly superposed to the chlorite schists and no infracrustal rocks were found between the two metasedimentary series. In the south of the area the rusty mica schists overlie infracrustal rocks of a different aspect to those in a similar position in the north, and are clearly discordant on Pukkelen and on the south-western tip of Graben Land. This boundary, marked 2′ on the map, could be either stratigraphic or tectonic (see p. 11).

On the south-east corner of Graben Land the rusty mica schists overlie the gneisses and migmatites. The two formations are apparently concordant, but the contact (marked 2′ on the map) was not visited, and thus could be structural or stratigraphic. Comparison of the rock types with those underlying the rusty mica schists in the north of the area led to the mapping of the contact as a thrust in the south-eastern and southern areas.

Within the topmost unit (the rusty brown and leucocratic gneisses) a minor thrust may be seen on the south-east corner of Graben Land, directly west of peninsular 1120. This thrust, visible for several hundred metres and dipping westwards, separates the rusty brown gneisses from similar rocks which are somewhat more migmatitic.

Folding

Structural unit A

The ferruginous quartzite series shows minor folds and kink-bands, but no major structures have been observed. No structures were observed in the metavolcanics exposed on nunataks 2452, 1990 and 1950.

The gneisses and migmatites cropping out on the eastern part of Graben Land were deformed after the emplacement of the first generation of basic intrusives and before the second. The second generation shows little evidence of major folding. Stereographic plots of poles to foliation in the gneisses are arranged about a more

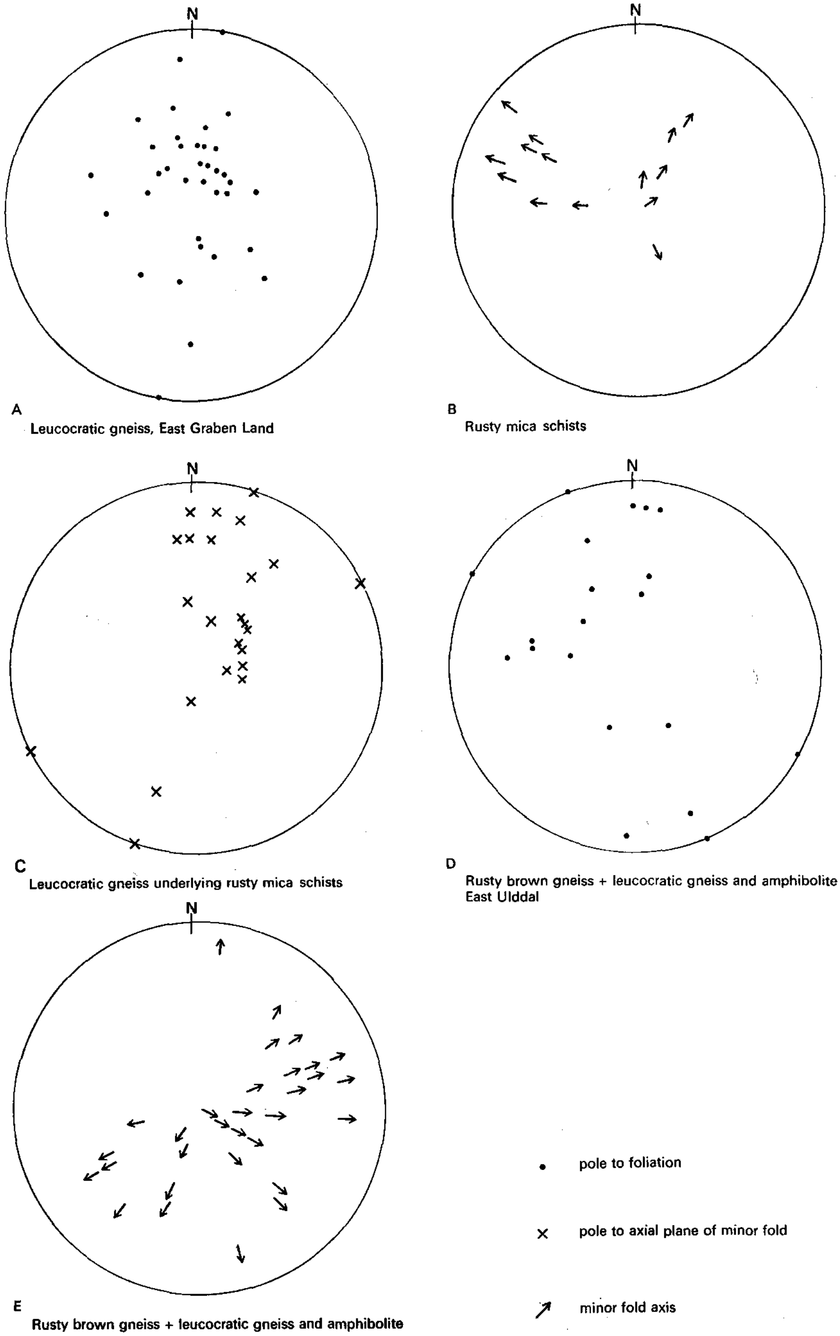

Fig. 3. Stereographic projections (lower hemisphere) of planar and linear elements.

or less horizontal east–west axis (fig. 3a). Structures in the augen granite are apparently similar to those in the gneisses which lie concordantly above.

Structural unit B

The chlorite schists are apparently fairly highly deformed, although no large scale folds were observed. Small isoclinal folds of several centimetres across are visible in the dolomite marbles, with axial planes sub-parallel to the bedding. In the south of the area the chlorite schists show a strain-slip cleavage oblique to the foliation which results in a microlithon structure. The chlorite schists dip generally south-west, being warped gently about axes plunging west or south-west. The serpentinites exposed in the moraine covered plain south-west of Stendal show no structures. Infracrustal rocks below the chlorite schists are highly sheared in places. Shear planes are generally parallel to the schistosity of the metasediments.

Structural unit C

The rusty mica schists show a strongly developed schistosity, usually parallel to the foliation. Minor folds are mainly visible in the siliceous layers, plunging WNW, SSE and NNE. The WNW and SSE directions apparently post-date the NNE folds, and the WNW plunges coincide with the direction of fairly open folds of mesoscopic scale (fig. 3b). No large scale structures were observed in these rocks. Foliation generally dips south-west in the outer zone, and south-east to the east of the major graben structure (east Graben Land).

Structures in the siliceous chlorite gneiss below the rusty mica schists in the north of the area were not studied in detail. Foliation in these gneisses is parallel to that in the rusty mica schists.

The leucocratic gneisses below the rusty mica schists to the south of the area show large scale fairly open folds with near vertical axial planes in the cliffs of Pukkelen. Stereogram plots of poles to axial planes of minor folds measured in these gneisses further south lie on a great circle; the computed axis plunges about 20° slightly north of west, coinciding with the apparent direction of the folds in the cliffs of Pukkelen (fig. 3c). The leucocratic gneiss and basic intrusions exposed in these cliffs may form a very large recumbent fold closing to the north and refolded by the open structures.

Structural unit D

The rusty brown gneiss and leucocratic gneiss and amphibolite which form the uppermost thrust unit show several large scale isoclinal folds with axial planes dipping steeply SSW on Graben Land. These may be seen in Stendal, Ulddal and in the cliffs below point 1855.

The computed axis of the antiformal structure mapped east of Ulddal plunges about 40° slightly north of east (fig. 3d). Minor fold axes show a complicated pattern, probably a result of interference, but none were measured plunging between north and west, whereas this was the most common direction in the rusty mica schists (fig. 3e).

Two open structures, an antiform and a synform, are visible in the cliffs above the ice-dammed lake 1030, south of the point 1860. Their axial planes are subvertical and apparently strike NE. A large ultrabasic intrusion occupies the core of the synform, which butts against the normal fault forming the limit of the graben. The relationship of these folds to the fault is not clear.

Schistosity in the rusty brown gneiss is more or less pronounced depending on the composition of the rock, and is most frequently parallel to the foliation. Minor folds are rarely visible in the schistose gneiss. Minor fold axes and poles to foliation show the same distribution for both the rusty brown and leucocratic gneisses.

The conformable interbanding of thin layers of rusty brown gneiss with leucocratic gneiss and amphibolite may well be explained by a phase of intense isoclinal folding pre-dating the major structures now visible. This phase would correspond to the formation of the present foliation of the rock.

Fractures

North–south trending major normal faults post-dating the main Caledonian structural and metamorphic events have given the area a block structure (fig. 1).

The easternmost of the normal faults shown on Plate 1 is visible in the cliffs on the north-east corner of Graben Land, and can be traced east of Ulddal between the two small ice-caps 1760 and 1530, and along the deep gulley which isolates the peninsular 1120 to the extreme south-east. The north-eastern exposure of this fault shows a complicated pattern of blocks resulting from minor faults and thrusts. The major fault dips westwards, usually between 40° and 70°. It was not possible to measure the throw, but this may be estimated as at least 500 m, and is probably a great deal more.

A spectacular normal fault may be traced from Gåseland in the south (fig. 1) through the centre of the mapped area, northwards through Krummedal and coincides with a flexure in the Hinks Land overthrust on the southern flank of the Daugaard-Jensen Gletscher to the north (Wenk, 1961; Steck, 1971). This fault dips eastwards, varying between 40° and vertical, and its throw may attain several thousand metres. This estimation is based on the displacement of the rusty brown gneisses.

These two faults outline a graben structure forming the main part of Graben Land.

In the south-western nunatak zone, on nunatak 2235–2060, basement rocks comprising gneiss and migmatites with large basic and granitic intrusions are brought into contact with rusty brown gneiss by a near vertical fault striking WSW–ENE. To the west, due south of the metavolcanics on nunataks 2452, 1990 and 1950, the chlorite schist series is exposed. This is a comparable situation to that of the fault zone running through the centre of the mapped area, where the rusty brown gneisses are brought into contact with the chlorite schist series and its basement. As the rusty brown gneiss has a constant dip westwards or south-westwards against the metavolcanics and the chlorite schists, there is probably an important normal fault dipping east hidden under the ice. The fault visible on nunatak 2235–2060 is possibly a related minor fault.

Faults of slight importance were observed striking north-west, north-east and east-west. Antithetic faults with throws of several hundred metres were seen on the nunatak south of the ice-dammed lake 1030 dipping westwards against the fault limiting the graben to the west (see profile 2, fig. 2).

METAMORPHIC GEOLOGY

Mineral associations and textures in the rocks of each unit previously described indicate different conditions in each case.

Structural unit A

The ferruginous quartzite series and the metavolcanics south of the Royston Nunatakker both have mineral associations containing stilpnomelane. In the case of the metavolcanics no deformation is apparant; stilpnomelane is clearly post-kinematic in the ferruginous quartzites. Sericite is syn-kinematic in the phyllites of the ferruginous quartzite series.

The gneisses, migmatites and augen granite east of the graben on Graben Land show epidote and chlorite as products of retrometamorphism occasionally accompanied by cataclasis. Green biotite may also be a product of retrometamorphism.

Structural unit B

The chlorite schists show syn-kinematic 'snowball' garnets. White mica is ante- to post-kinematic, while biotite and chlorite are syn- to post-kinematic.

The gneiss and granite underlying the chlorite schists show similar mineral assemblages with chlorite and epidote as products of retrometamorphism.

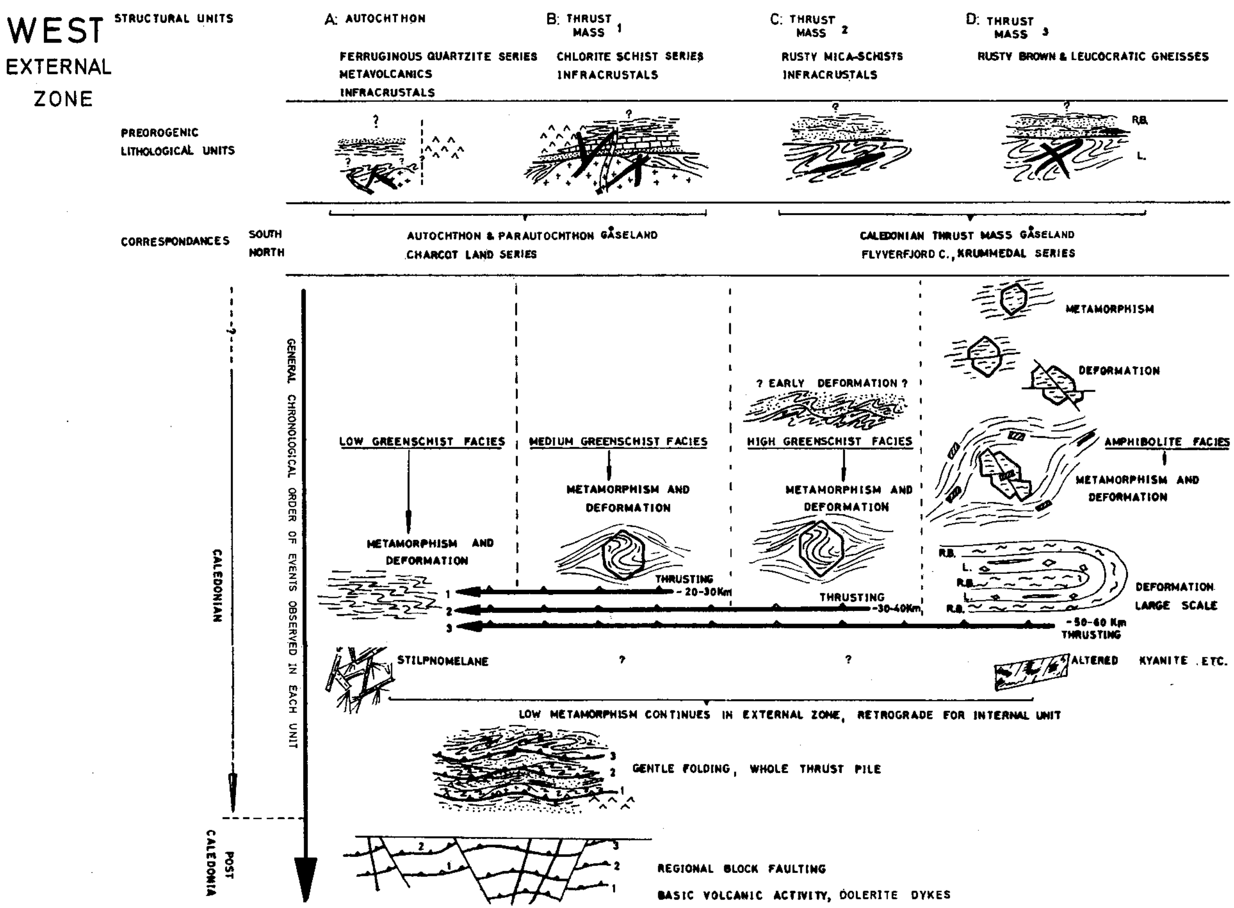

Fig. 4. Structural and metamorphic relationships within the various structural units.

Structural unit C

The rusty mica schists also show 'snowball' garnets with ante- to post-kinematic white mica and biotite. Chlorite is rare.

The leucocratic gneisses underlying the rusty mica schists in the southern part of the area show syn- to post-kinematic quartz, plagioclase, K-feldspar, biotite and epidote.

Structural unit D

The textures in the rusty brown gneisses indicate a complicated history of several metamorphic and structural events (fig. 4):

(a) Formation of garnets with inclusions parallel to S_1 (previous foliation?).

(b) Fracturing, firstly parallel and then oblique to S_1.

(c) Formation of the present foliation in the rusty brown gneisses and leucocratic gneisses and amphibolites. The previously formed garnets caused pressure shadows. This deformation may well correspond to a phase of intense isoclinal folding resulting in the present interbanding of the rusty brown gneiss with the leucocratic gneisses and amphibolites. Regional metamorphism acting simultaneously with this phase of deformation produced mineral assemblages such as:

Pelitic: quartz, plagioclase, biotite, white mica, kyanite and sillimanite.

Calcareous: clinozoisite, quartz, grossularite, anorthite, accompanied by amphibole, biotite and pistacite.

Dolomitic limestone: dolomite, calcite, tremolite, diopside, olivine (monticellite).

Migmatitic neosome was also formed during this phase, together with the intrusion of granitic sheets up to 50 m in width.

(d) The occasional presence of chlorite replacing biotite, haloes of alteration minerals around kyanite crystals and the replacement of olivine by serpentine in the marbles give evidence of subsequent retrometamorphism in the rusty brown gneisses.

CORRELATIONS AND CONCLUSIONS

Observations made during field-work and during study of the samples led to the division of the rock types in this area into four structural units; an autochthonous basement and cover sequence overlain by three thrust masses.

The ferruginous quartzite series, the metavolcanics and certain infracrustal rocks may well constitute an autochthon. The chlorite schist series and their associated infracrustal rocks form the first thrust mass, the rusty mica schists and associated infracrustal rocks the second, and the rusty brown gneiss and leucocratic gneiss and amphibilite the third and uppermost thrust unit. The leucocratic gneiss and amphibolite may well represent an older infracrustal sequence upon which the sediments now metamorphosed into the rusty brown gneiss were deposited.

The autochthon – structural unit A

The metavolcanics forming the nunataks 2452, 1990 and 1950 may be compared to those of the Royston Nunatakker (fig. 1) which are attributed to the autochthonous Charcot Land sequence (Henriksen & Higgins, 1969). These rocks show no sign of deformation and contain stilpnomelane as a significant metamorphic mineral.

The ferruginous quartzite series suffered low grade greenschist facies metamorphism during and after deformation, notably with the formation of stilpnomelane as in the metavolcanics.

The gneisses, migmatites and the augen granite on the eastern side of Graben Land contain chlorite and epidote as evidence of low greenschist facies retrograde metamorphism. Directly to the south of this area, Rutishauser (1970) found a psephitic rock overlying these gneisses, migmatites and augen granite; he compares this to the description of an autochthonous basement overlain by an apparent tillite in Gåseland (Wenk, 1961).

First thrust sheet – structural unit B

This consists of the chlorite schist series and associated infracrustal rocks.

The chlorite chist series comprises dolomitic limestones, carbonate rich chlorite schists, chlorite schists, quartzites with chloritic layers and chloritic schists of possible volcanic origin. These metasediments are discordant upon a chloritic granite or a chloritic siliceous gneiss.

These rocks have undergone medium greenschist facies metamorphism accompanied by deformation. Thrusting, apparently in a westerly direction, displaced this unit up to 20 or 30 km. The autochthon and the first thrust mass may be compared to the authochthon and Marble-Chlorite-Phyllite Series in Gåseland (Wenk 1961) and to the Charcot Land supracrustal sequence (Henriksen & Higgins 1969; Steck 1971).

Second thrust sheet – structural unit C

This is formed by the rusty mica schists and associated infracrustals.

Although substantial evidence was not gathered, these rocks may well have suffered an early phase of deformation before simultaneous high grade greenschist facies metamorphism and deformation. This unit was carried from 30 to 40 km westwards by thrusting, thus coming to rest upon the chlorite schist series and the autochthon.

The rusty mica schists may be compared with the Phyllite-Mica-Schist Series in Gåseland, considered as parautochthonous in that area by Wenk (1961).

The thrust plane (2) under the rusty mica schists or under the infracrustal rocks associated with these metasediments is equivalent to the Hinks Land overthrust observed in the region of Daugaard-Jensen Gletscher further north (Henriksen & Higgins 1969; Steck 1971).

Infracrustal rocks associated with the rusty mica schists cannot be correlated from the north to the south of this area and are lacking in the central part. They may form a separate unit in the south.

Third thrust sheet – structural unit D

This comprises the rusty brown and the leucocratic gneisses and amphibolites.

Several phases of metamorphism and deformation were recognised in the rusty brown gneisses: a first recrystallisation was followed by two events of fracturing. Subsequently a phase of intense deformation conferred the present foliation on the rock and may well have been a phase of intense isoclinal folding which has resulted in the interbanding of layers of rusty brown gneisses with the leucocratic gneisses and amphibolites. This deformation was accompanied by amphibolite facies metamorphism with temperatures of 600°C to 670°C and pressures of 5 to 7 kb, accompanied by migmatisation. A further phase of large scale deformation resulted in large scale isoclinal folds with fold axes plunging slightly north of east, and steeply inclined axial planes. Thrusting carried the rusty brown gneisses and leucocratic gneisses and amphibolites from 50 to 60 km westwards on to the lower thrust sheets. Low grade greenschist facies metamorphic conditions still prevailing in the external zone caused retrograde metamorphism in this uppermost unit.

The thrust plane (3) under this unit may be compared to the Caledonian overthrust described in Gåseland (Wenk, 1961).

Rocks similar to the rusty brown gneisses crop out in the eastern flank of Edvard Bay Dal (A. K. Higgins pers. comm. 1971). If the rusty brown gneisses may be correlated with these then the third thrust may have a displacement of up to 80 km (?).

The rusty mica schists and the rusty brown gneisses may be compared to the Krummedal supracrustal sequence (Henriksen & Higgins 1969, 1971). The infracrustals associated with the rusty mica schists in the north of the area may be compared with the so-called lower part of the Krummedal sequence (Henriksen & Higgins 1969) which Vogt (1965) described as basement.

All the units as well as the three thrust planes are deformed by gentle warping on east–west axes. Subsequently major north–south normal faults gave the area a block structure, and basic volcanic activity caused swarms of north–south trending dolerite dykes.

The autochthon and the first thrust sheet probably developed from the same sedimentary basin where volcanics, volcanoclastics, limestones, semipelites and pelites interfingered; a greater proportion of carbonates are found to the north and south of the mapped area; volcanics are more abundant in the northern part of the area and immediately beyond this to the north-west. These sediments and volcanics were intruded first by basic rocks, (probably in relation with the volcanism), and then by granitic rocks (Steck, 1971). The underlying basement was constituted by granite, gneisses and migmatites, enclosing at least two older generations of basic intrusions. No basal conglomerate was observed in this area but one apparently exists elsewhere (Wenk, 1961; Rutishauser, 1970). According to Wenk these metasediments are of Groenlandian age (Precambrian) and overlie a pre-Groenlandian basement. Wenk also describes them as the basal part of the Eleonore Bay Group.

The rusty mica schists and the rusty brown gneiss also may have developed within a single sedimentary basin. Psammites, semipelites and pelites together with occasional calcareous levels constitute a fairly thick sequence deposited on a crystalline basement. The gneisses now forming this reworked basement contain at least two generations of basic intrusions. In contrast to the rusty mica schists, the rusty brown gneisses contain occasional basic to ultrabasic intrusions apparently emplaced prior to the onset of the orogeny.

The rusty mica schists and the chlorite schists are lithologically analogous; their main difference is their colour, red in the first case and green in the second. This difference in colour could be explained by variation in metamorphic grade. Their similarity suggests that the first and second thrust masses may have developed from the same sedimentary basin. In this case each cover sequence would represent a different part of a single original sedimentary basin (or several closely related basins), of which the lithology gradually varied from east to west, being more constant from north to south.

There are strong lithological similarities between the sequence represented by the rusty brown schists and gneisses of the inner Scoresby Sund region and the lower part of the Caledonian geosynclinal sequence of the Kejser Franz Joseph Fjord and Alpefjord region. These similarities were recognised by the early workers in the region (Wenk, 1961; Vogt, 1965; Haller, 1971) and noted also by workers of the current expeditions (Henriksen & Higgins, 1969). The isotopic age dates so far obtained from the Scoresby Sund region do not entirely support the assumed correlation. While several K/Ar and Rb/Sr mineral ages confirm significant Caledonian orogenic activity (Hansen & Steiger, 1971; Hansen *et al.*, 1972, 1973a & b) a recent Rb/Sr isochron by Hansen *et al.* (1973) on three samples of the Krummedal sequence schists suggests a metamorphic event *c.* 1200 m.y. ago and contradicts any correlation with the late Precambrian Elonore Bay Group. Rb/Sr mineral ages of up to 1150 m.y. have also been obtained on plutonic rocks in the migmatite zone of the Scoresby Sund region.

Thus, while the main structural make-up of the region described and the principal metamorphic imprint is undoubtedly Caledonian, there is increasing evidence for the significance of pre-Caledonian elements.

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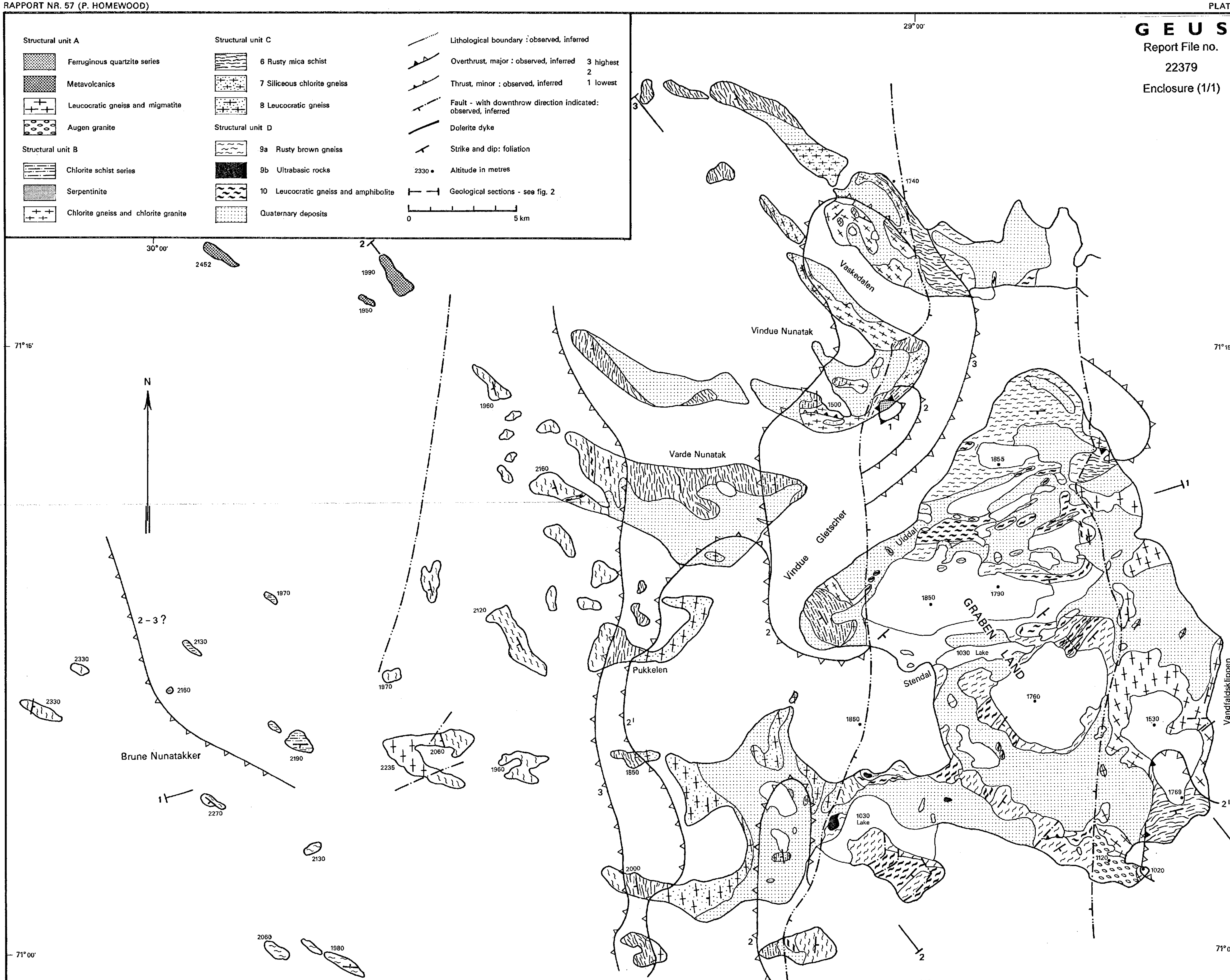
Structural unit A
Ferruginous quartzite series
Metavolcanics
Leucocratic gneiss and migmatite
Augen granite
Structural unit B
Chlorite schist series
Serpentinite
Chlorite gneiss and chlorite granite
Structural unit C
6 Rusty mica schist
7 Siliceous chlorite gneiss
8 Leucocratic gneiss
Structural unit D
9a Rusty brown gneiss
9b Ultrabasic rocks
10 Leucocratic gneiss and amphibolite
Quaternary deposits
Lithological boundary : observed, inferred
Overthrust, major : observed, inferred
3 highest
2
1 lowest
Thrust, minor : observed, inferred
Fault - with downthrow direction indicated: observed, inferred
Dolerite dyke
Strike and dip: foliation
Altitude in metres
Geological sections - see fig. 2
0
5 km
N
30° 00'
29° 00'
71° 15'
71° 00'
Vindue Nunatak
Vaskedalen
Varde Nunatak
Vindue Gletscher
Uddal
GRABEN LAND
Stendal
Pukkelen
Brune Nunatakker
Vandfaldsklippen
1030 Lake
2 – 3 ?
2452
1990
1950
1960
2160
2120
1970
2330
2130
2190
2270
2235
2060
1980
1740
1500
1855
1850
1790
1760
1530
1769
1120
1020
2000