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Report No. 67

The Krummedal supracrustal sequence around inner Nordvestfjord, Scoresby Sund, East Greenland

by

A. K. Higgins

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1 map in pocket

1974

Abstract

The Krummedal supracrustal sequence is a lower to middle Proterozoic sedimentary succession widely represented in the Caledonian fold belt of the Scoresby Sund region. Around inner Nordvestfjord laterally variable sequences of pelitic, semipelitic and psammitic rocks occur. The sequences of different areas ranging from 2500 m to more than 8000 m in thickness are described but no formal subdivision is attempted. High amphibolite facies metamorphism, migmatisation, emplacement of granite intrusions and several phases of deformation appear to relate to an orogenic episode giving dates in the range 900–1200 m.y. Caledonian orogenesis is represented by a relatively weak retrogressive metamorphic phase, westward displacements on major thrusts and emplacement of granite intrusions.

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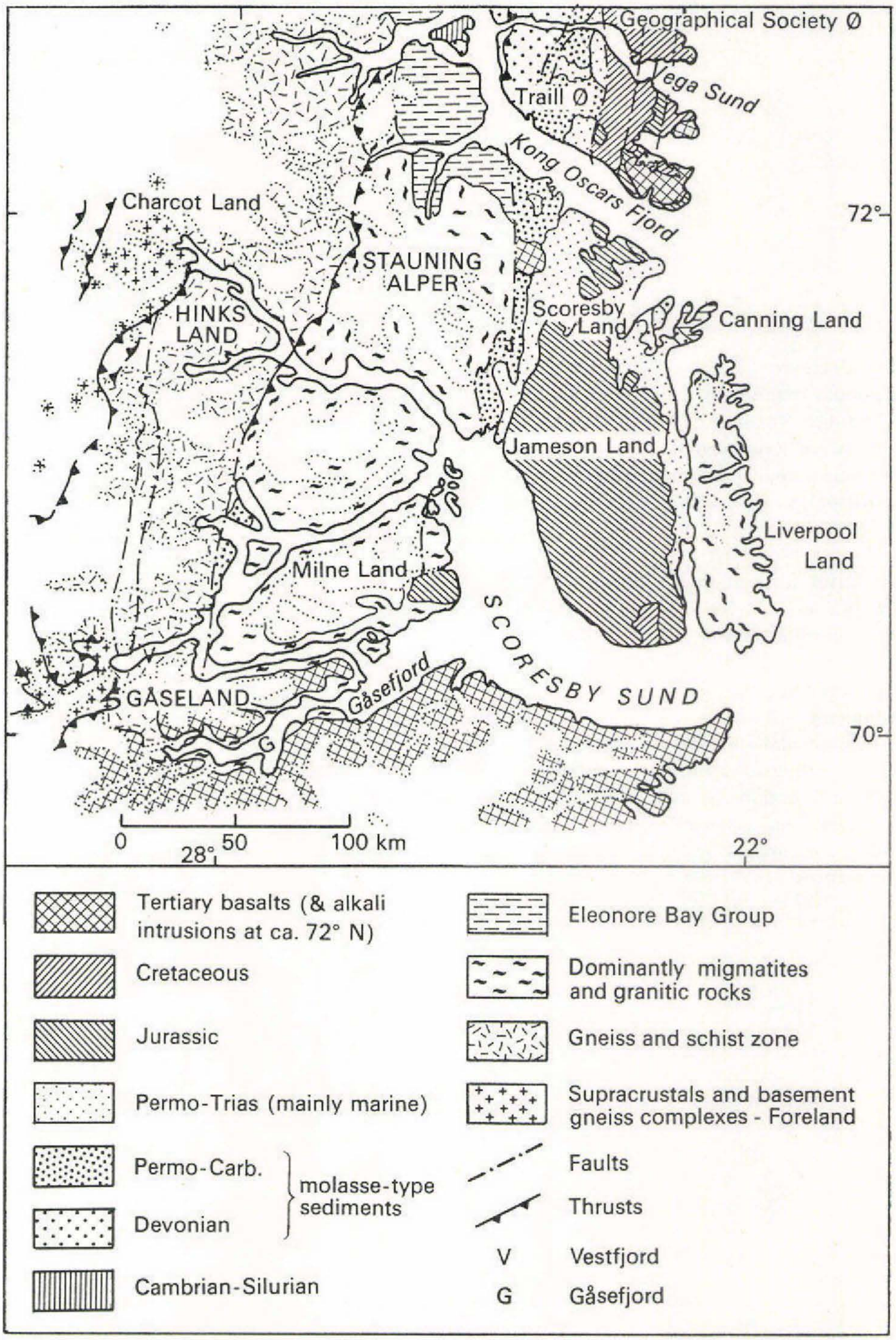

Fig. 1. Main geological divisions of the Scoresby Sund region.

INTRODUCTION

The East Greenland fold belt dominates the ice-free stretch of land between latitudes 70° and 82°N. A considerable proportion of this region comprises metamorphic crystalline complexes, whose characteristic features reflect partly pre-Caledonian orogenic events and partly Caledonian orogenic activity. Late Precambrian and Lower Palaeozoic geosynclinal accumulations show the influence of Caledonian deformation and metamorphism. Upper Palaeozoic continental molasse deposits and Mesozoic sediments border and partially conceal the fold belt in the outer fjord zone and coastal region. Tertiary basalts hide the continuation of the fold belt south of latitude 70°N. A comprehensive account of the East Greenland Caledonides is given by Haller (1971).

In the period 1968–1972 the Geological Survey of Greenland undertook systematic mapping in the southernmost section of the fold belt in the Scoresby Sund region (70°–72°N), prior to that time one of the least known parts of the fold belt. The investigations in the crystalline region of the inner fjord zone included a study of the stratigraphical, metamorphic and structural features of a widespread metasedimentary succession informally distinguished as the Krummedal supracrustal sequence. This report describes the Krummedal supractrustal sequence as represented in the region around inner Nordvestfjord which was mapped in 1968, although the interpretations presented draw widely from ideas developed in the later mapping of adjacent areas.

The main geological divisions of the Scoresby Sund region are shown in fig. 1. In the extreme west there are local tectonic windows of presumed foreland occurring beneath flat-lying westward directed Caledonian thrust sheets. The thrust sheets form part of a broad zone of gneisses and schists extending from south of Vestfjord to Hinks Land. A variably inclined major thrust forms the boundary between the gneiss and schist zone and a contrasting zone to the east dominated by migmatitic and granitic rocks. Late Palaeozoic and Mesozoic sediments occupy a broad basin separating the crystalline rocks of the inner fjord zone from a narrow strip of crystalline rocks in Liverpool Land, and an isolated development of late Precambrian and Lower Palaozoic sediments in Canning Land.

The main foreland windows occur in extreme western Gåseland and Charcot Land. In both areas supracrustal rocks are found overlying gneissic basement, and it was initially believed that the supracrustals in Gåseland represented the basal part of the Eleonore Bay Group (Wenk, 1961) and could also be correlated with the sequence in Charcot Land (Vogt, 1965). New regional mapping and isotopic age determinations have caused these views to be revised. According to Phillips *et al.* (1973) the Gåseland supracrustals may be Cambro-Ordovician, while the Charcot Land sequence (Steck, 1971) is veined by granites which have yielded age-dates of up to 1800 m. y. (Steiger & Henriksen, 1972; Hansen *et al.* 1973a). The basement gneisses in Gåseland have given mineral ages of up to 2290 m. y. (Haller & Kulp, 1962).

The Vestfjord–Hinks Land gneiss and schist zone comprises two principal lithological units, the Flyverfjord infracrustal complex and the Krummedal supracrustal sequence. The former consists of gneisses, granitic rocks, amphibolites and discordant amphibolitic dykes, with a complex history extending well back into the Archaean (2980 m. y.: Rex & Gledhill, 1974; 2525 m. y.: Hansen *et al.*, 1973 a; 2345 m. y.: Steiger & Henriksen, 1972). The Krummedal supracrustal sequence comprises dominantly mica schists and quartzites whose age of deposition is now presumed to be at least middle Proterozoic; a Rb/Sr whole rock isochron age by Hansen *et al.* (1974) dates a main metamorphic event at 1162 m. y.

The Flyverfjord infracrustal complex and Krummedal supracrustal sequence have been metamorphosed and deformed together, the intensity of deformation being greatest towards the south of the zone. The early workers in the region compared and correlated these supracrustals with the late Precambrian Lower Eleonore Bay Group (Wenk, 1961; Vogt, 1965; Haller, 1971), and the various tectonic and metamorphic events post-dating its deposition were thus viewed as Caledonian. The main metamorphism and much deformation is now by some workers attributed to a 950–1200 m. y. orogenic event, and Caledonian activity is considered responsible for development of the major thrusts, but relatively limited plutonism and a weak metamorphic episode.

The broad zone of dominantly migmatitic and granitic rocks extends from south of Gåsefjord to the Stauning Alper. The paleosome element in the migmatites is largely quartzitic or siliceous gneiss of sedimentary origin, while marbles occur as larger lenses or strips traceable discontinouously throughout the zone. Locally thick relatively non-migmatitic developments are preserved especially at the west margin of the zone around T-sø and Martin Karlsen Bugt (map 1); the lithological development resembles that of the Krummedal supracrustal sequence in many respects and a correlation is usually assumed. Only locally within the migmatite zone are areas characterised by amphibolitic lenses and bands encountered; such areas may represent migmatised equivalents of a basement infracrustal complex.

At an early kinematic stage granite sheets were emplaced in the migmatites of the migmatite zone and during subsequent deformation were isoclinally folded in structures of nappe dimensions. A major diorite sheet was emplaced between two phases of migmatite development. Late and post-kinematic granitic plutons and sheets are widespread, but concentrated in the eastern parts of the migmatite zone (Henriksen & Higgins, 1970, 1973; Chadwick, 1971, in press). A variety of age-dates in the range 365–1154 m. y. suggest major orogenic events in the middle Proterozoic, as well as evidence for Caledonian granite emplacement and metamorphism (Hansen & Steiger, 1971; Hansen *et al.*, 1972, 1973 b; Steiger & Henriksen, 1972; Oberli & Steiger, 1973). Late-Caledonian movements on the faults bounding both sides of the migmatite zone were associated with the Carboniferous–Permian continental deposition (Collinson, 1972).

The region described in this report, about 120 km by 60 km, spans the entire width of the northern part of the gneiss and schist zone and an adjacent western strip of the migmatite zone (map 1). The stratigraphical variations of the Krummedal supracrustal sequence, and the patterns of structural and metamorphic events which influence it are described.

REGIONAL DESCRIPTIONS

The main areas of occurrence of the Krummedal supracrustal sequence in the region around inner Nordvestfjord are shown in map 1. In the gneiss and schist zone supracrustals are found in the Alfabet Nunatakker, in an extensive area running from Hinks Land southwards through to Krummedal – subdivided for descriptive purposes here, and in a narrow strip west of the thrust running through Kiledal. East of this thrust, in the migmatite zone, an area of supracrustals outcrops in a broad strip running through Edvard Bay Dal to the T-sø–Nordbugt area, and extends to a small area west of the head of Sydgletscher.

The main features of the area between Hinks Land and Krummedal were outlined by Vogt (1965) based on his own and E. Wenk's investigations. Vogt's 'Hüllserie', which corresponds to the Krummedal supracrustal sequence, was presumed equivalent to part of the lower Eleonore Bay Group by Vogt and by Wenk (1961).

At the start of the new regional mapping in 1968 a new neutral name was thought desirable for the widespread supracrustal rocks, the spectacular sections in the deeply incised valley of Krummedal leading to establishment of the Krummedal supracrustal sequence (Henriksen & Higgins, 1969). Initially a division of the sequence into two parts was suggested, but new work in adjacent areas suggested the assumed lower division of siliceous gneisses represented reworked basement gneisses. The Krummedal sequence does resemble the late Precambrian lower Eleonore Bay Group in its lithological development as observed by the early workers, and also as recorded in many recent papers. The new age-date of 1162 m. y. by Hansen *et al.* (1974) for the main metamorphic event makes the assumed correlation untenable and lower to middle Proterozoic deposition of the Krummedal supracrustal sequence is now presumed (see also Phillips *et al.*, 1973; Henriksen

& Higgins, 1973). The Krummedal supracrustal sequence as a name, though widely used in Survey reports, is employed informally; no stratigraphical division has yet been proposed.

Alfabet Nunatakker

Description

The western nunataks of Charcot Land known as the Alfabet Nunatakker form part of a major thrust sheet comprising Krummedal sequence rocks which has been displaced westwards by at least 40 km over and beyond the foreland window of the main Charcot Land massif. A gently westward dipping thrust plane outcrops on Beta Nunatak and the adjacent nunatak to the north, cutting obliquely through shales and marbles of the low grade Charcot Land supracrustal sequence below (Steck, 1971). Above the thrust the higher grade metasediments of the Krummedal supracrustal sequence dip generally westwards with an apparent thickness of about 3000 m. The lower part of the sequence has a red-brown colouration and is conspicuously banded, while the upper part is a grey-black more homogenous development but with granitic and migmatitic features becoming more prominent upwards. Major recumbent folds have been noted in both divisions, so quoted thicknesses include at least local duplication of the succession. Only parts of the sequence have been traversed on foot as the entire nunatak group was mapped in a single day by two geologists using two helicopters.

Mylonitic developments occur at the base of the sequence associated with the thrust zone. These include finely banded gneissic rocks with thin amphibolite layers and thin leucocratic cherty blastomylonite. These give way rapidly upwards through sheared mica schists to the normal red-brown banded division of the supracrustal sequence.

The lower red-brown division is about 1500 m thick and comprises a conspicuous alternation of quartzite and mica schist layers, each from 5–10 cm to several metres in thickness. At a well-defined level traceable through several nunataks there is a rapid transition upwards into the grey-black division.

The grey-black division begins with a sequence of semipelitic to siliceous, sometimes schistose, gneisses. Some pure white quartzite bands and mafic gneisses occur, and locally mafic and leucocratic gneiss units several tens of metres thick alternate (fig. 2). The notable feature of the division is an apparent upwards increase in development of granitisation phenomena. At the lower levels there are frequent layers in which the growth of small feldspars has produced a gritty texture (fig. 3), and in several localities porphyroblastic feldspar developments produce a coarse augen gneiss with a rather mafic matrix. Upwards in the sequence augen gneiss bands and thin leucocratic veins, layers and sheets of muscovite-biotite gra-

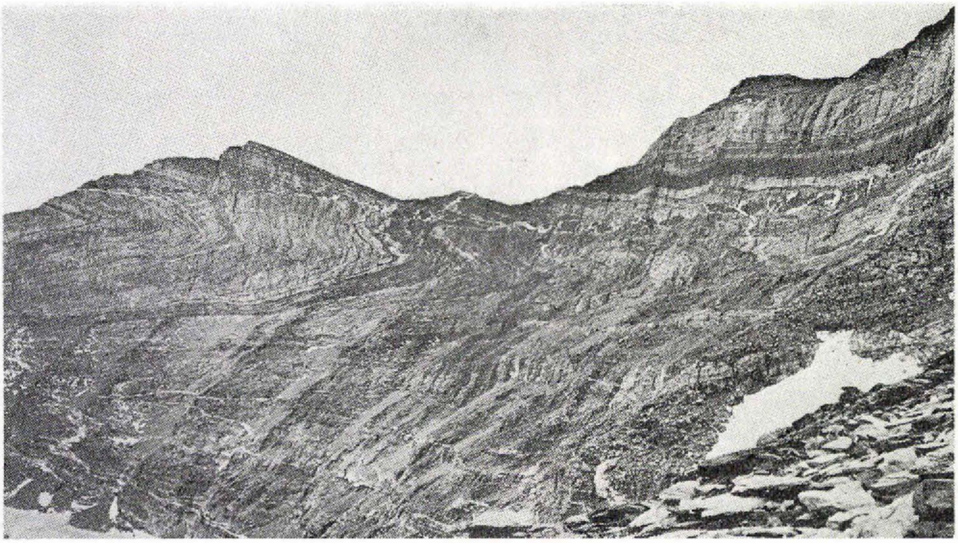

Fig. 2. Large scale folding in the grey-black weathering part of the Krummedal sequence – a semipelitic facies. The fold is cut by a basic dyke, now transformed to amphibolite and with conspicuous irregular veining. Section *c.* 300 m high is located in one of the northern Alfabet Nunatakker. Photo: Niels Henriksen.

nite become conspicuous; most developed or were emplaced concordantly with the general foliation.

In the westernmost nunataks, apparently at a higher level, though they are isolated from the sequences already described, foliated granitic sheets exceeding 100 m in thickness and containing large angular inclusions are developed. Major parts of these nunataks appear to comprise migmatitic gneisses very similar to parts of the migmatite zone more than 100 km away to the east. There is some uncertainty as the whether these rock types represent simply part of the upward and westward increase in granitisation phenomena, or represent a separate thrust sheet displaced from a more internal part of the fold belt (cf. Homewood, 1973; Phillips *et al.*, 1973).

In one of the nunataks a major recumbent fold structure is cut by a dyke 1–5 m thick emplaced roughly parallel to the fold axial plane. Subsequent to intrusion the dyke has been transformed to amphibolite and dissected irregularly by biotite pegmatite veins (fig. 2).

Composition

The mylonitised rock types from the thrust zone exhibit generally fine-grained cataclastic textures with in some samples small feldspar grains surviving as relics, or

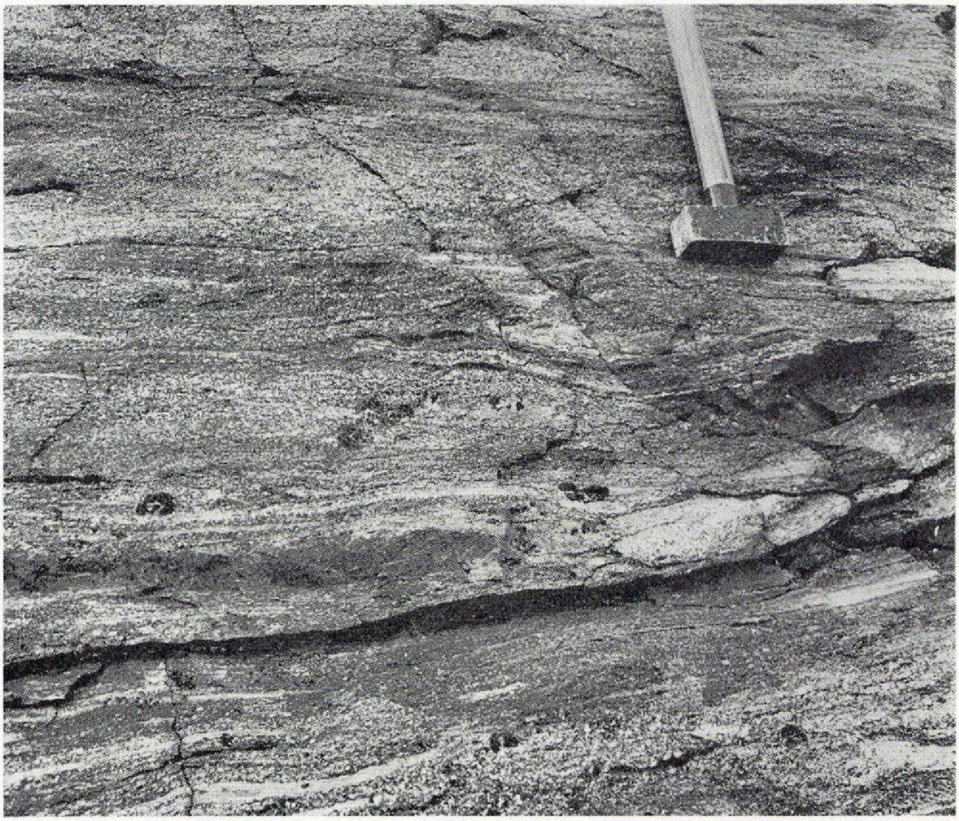

Fig. 3. Development of small feldspar porphyroblasts in semipelitic facies of the grey-black division of the Krummedal sequence. Alfabet Nunatakker. Photo: Niels Henriksen.

representing new growths with relic cores; epidote and muscovite overprint the mylonitic textures. In a sheared mica schist a fine-grained texture preserving relic, rounded, rolled garnets is partially masked by laths of new muscovite, and new, small euhedral garnets occur; the new growths clearly represent a post-kinematic metamorphic episode.

Assemblages in rock types of the red-brown banded division comprise variable proportions of garnet + muscovite + biotite + quartz, and also here in some cases late coarser-grained muscovite developments. Textures are generally fresh, occasionally showing slight strain.

In the metasedimentary rocks of the upper division assemblages comprise garnet + biotite + muscovite + quartz + plagioclase (An 30–38) in variable proportions, with carbonate often present in the siliceous bands, and a little hornblende in some mafic gneisses. Textures are generally fresh, with the feldspars tending to segregate in coarser augen or sweats, a feature reaching an extreme development in coarse augen gneisses. Sillimanite has been recorded in two samples. The granite layers comprise usually biotite + muscovite + quartz + feldspar (microcline + plagioclase). The amphibolite dyke is composed of a medium-grained aggregate of hornblende, with minor amounts of sphene, plagioclase and quartz.

Western Krummedal – Rencontre Sø

Description .

There are widespread and spectacular exposures of the Krummedal sequence in the western end of Krummedal, in western Rencontre Dal in which Rencontre Sø is situated, and in the nunataks to the north and west. These outcrops occupy a structurally defined unit between the arcuate trace of an eastward dipping thrust (the Hinks Land thrust) in the west, and a N–S trending fault which cuts across the centre of Krummedal and northwards apparently links up with the trace of the Hinks Land thrust (map 1). The cross-section of the Charcot Land area (fig. 11 section a-b) shows how the Hinks Land thrust is believed to arch over Charcot Land to link up with the thrust in the Alfabet Nunatakker. The fault continues southwards for more than 100 km, and in the area described by Homewood (1973) makes up the west fault of a graben structure.

The lithological divisions encountered within this area correspond closely with those of the Alfabet Nunatakker. A red-brown weathering banded division is succeeded by a grey-black division, both having a regional westward dip, and upwards and westwards migmatitic rocks are found. These are all considered to form part of the Krummedal supracrustal sequence, here with an apparent thickness of about 3000 m.

The red-brown division overlies a homogeneous, pale grey, up to 1000 m thick, group of siliceous gneisses with numerous thin amphibolite bands, well exposed in fault bounded inliers in Krummedal and east of Rencontre Sø. These siliceous gneisses were at one time regarded as a lower quartzitic division of the Krummedal sequence (Henriksen & Higgins, 1969), a view now discredited. The gneisses are fine-grained, faintly foliated and in thin-section exhibit blastomylonitic textures and low grade mineral assemblages. The amphibolites locally preserve intrusive features such as apophyses and xenoliths implying they were originally sills and dykes, but in thin section comprise fine-grained aggregates of pale amphibole (actinolite), plagioclase, epidote, quartz, chlorite and biotite. At a similar structural level in areas to the south comparable rock types have been described by Homewood (1973) and Phillips *et al.* (1973). There is much to support their viewpoint that such rocks represent reworked basement gneisses and mylonites, which subsequently were recrystallised under moderate greenschist facies metamorphism.

A conspicuous red-brown colouration and characteristic alternation of quartzite

Fig. 4. Mesoscopically folded Krummedal sequence. In this banded development the quartzite bands dominate, the mica schists forming very thin layers. South-east of Freuchen Gletscher. Photo: A. K. H.

and mica schist bands marks the lower part of the Krummedal supracrustal sequence. The red-brown division is 2000 m or more in thickness with conformable contacts above and below. At some localities the basal few hundred metres is somewhat massive quartzite with little mica schist, but at other localities mica schists are exclusively developed. The bulk of the division has a regular banding, and brown-grey quartzite layers 20–50 cm thick alternate with generally thinner mica schist layers (fig. 4). Brown carbonate-bearing lenses are often seen in the quartzites. West of Rencontre Sø and north of Freuchen Gletscher feldspathic augen are conspicuously developed in local horizons, and there are several concordant granitic sheets with augen-like feldspar clasts.

The grey-black division, comprising semipelitic and siliceous schists, is found west of Rencontre Sø and north of Freuchen Gletscher in the nunatak region. Upwards there appears to be a rapid transition into gneissic rocks, and migmatitic developments in which the paleosome is a siliceous gneiss. Some highly siliceous units seem to have escaped migmatitic effects. As outcrop is discontinuous it is again uncertain, as in the Alfabet Nunatakker, whether there is an original upwards transition, or a distinct thrust unit of migmatites.

Composition

In the lower red-brown division, parageneses in the mica schists usually comprise garnet + biotite + muscovite + plagioclase (An 30–37) + quartz; kyanite in association with staurolite occurs in one specimen from a locality near Rencontre Sø. The quartzitic bands consist of plagioclase + quartz + muscovite ± garnet ± carbonate ± amphibole. Textures are generally fresh, the garnet representing early porphyroblastic growth and the two micas forming polygonal arches outlining microscopic folds. In some thin-sections muscovite also occurs in late, patchy coarse developments parallel to the schistosity. Specimens from the northern part of the zone exhibit more marked late retrogression than elsewhere, chlorite is common in patches and seams and garnet sometimes deeply chloritised, but this may represent a concentration of sampling in the vicinity of the underlying reworked gneisses and nearby thrust.

Quartzitic rock types from the grey-black to migmatitic upper division comprise in thin-section coarse-grained aggregates of quartz, often with only little biotite and muscovite. In the gneissic rocks grain size is also notably coarse, and they comprise fresh textures of microcline + oligoclase + biotite + muscovite ± garnet. Retrogression is insignificant. Sillimanite has not been recorded in the migmatitic rocks, though this may be due to the restricted sampling.

Hinks Land – eastern Rencontre Dal

Description

The Krummedal supracrustal sequence outcrops in a broad strip running from Hinks Land southwards to eastern Rencontre Dal and the mouth of Krummedal. A N–S trending fault forms part of the west margin with the western Krummedal–Rencontre Sø area, but for the most part there is a tectonically modified contact with the original basement – the gneisses and amphibolites of the Flyverfjord infracrustal complex.

Deformation intensity is variable, as will be discussed later, and whereas in much

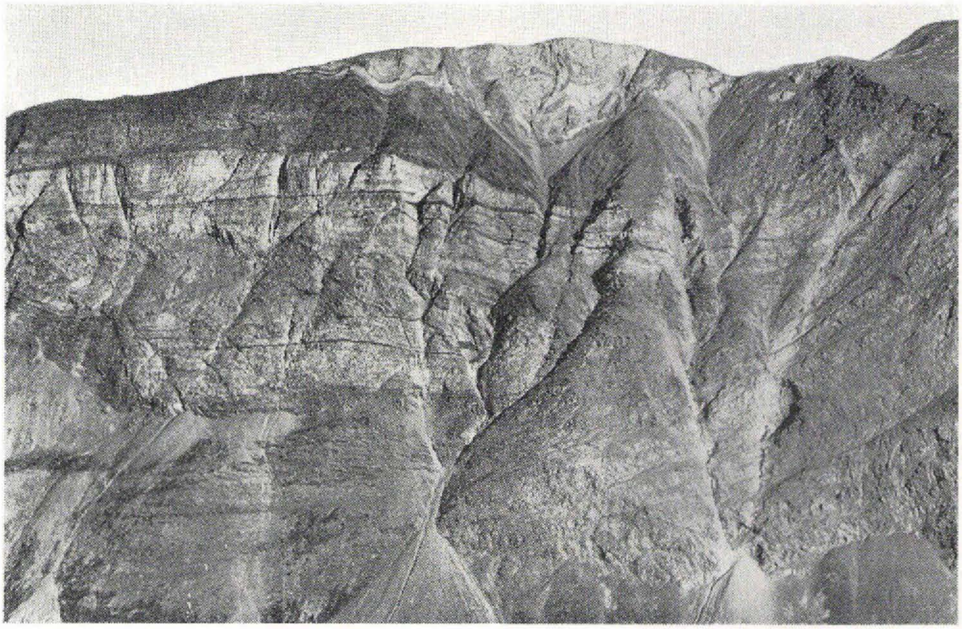

Fig. 5. Isoclinal folding of a pelitic facies of the Krummedal sequence (dark zones) and gneisses and amphibolites of the Flyverfjord infracrustal complex (leucocratic zones). East wall of Rencontre Dal. Height of section *c.* 600 m. Photo: Niels Henriksen.

of Hinks Land the red-brown weathering supracrustals form a relatively simple capping to the plateau, in Carraradal and parts of Rencontre Dal there is intense isoclinal interfolding of the basement gneisses and the supracrustals (fig. 5). At an early stage in the investigations a strip of siliceous gneisses adjacent to the supracrustals was considered to be a lower division of the Krummedal sequence, as in the area described just to the west, but they are now viewed as reworked basement gneisses, an interpretation supported by studies of their chemistry (J. D. Friderichsen & E. Kirsbo, pers. comm. 1973).

In Rencontre Dal there is a concordant and sharp contact between the reworked gneisses and the Krummedal sequence. Thin marble lenses may be present as the lowest unit of the Krummedal sequence, and a 50–75 m development of marble and amphibolite high up on the east wall of Krummedal may represent the same level on the reverse limb of a major fold. Red-brown mica schists, often lacking banding, generally form the next few hundred metres of the sequence. They are succeeded by the typical banded alternation of quartzites and mica schists, which outlines spectacular folding in the mouth of Krummedal and eastern Rencontre Dal (fig. 6). The quartzite bands are 1–5 m thick, and frequently they contain calcareous layers or lenses of brownish colouration. About 2000 m of the sequence

Fig. 6. The characteristic banded development of the lower levels of the Krummedal sequence, with regular alternations of quartzite and mica schist bands. Folding is of variable intensity developed on axial planes moderately inclined and dipping into the wall. Locality east of the mouth of Krummedal and height of section *c.* 500 m. Photo: Niels Henriksen.

is represented in the Rencontre Dal area, though thickness estimates are a little speculative. Locally the uppermost levels represented appear to be more siliceous.

In Hinks Land new mapping by the Survey has added detail to the original descriptions by Vogt (1965). A report by A. Steck is in preparation for north-west Hinks Land. There are similarities and differences compared to the Rencontre Dal area. At the base of the Krummedal sequence there is often a marble and amphibolite association seen usually as a series of lenses or discontinuous layers, but locally as in Carraradal the intensely folded marbles are more than 100 m thick. Grey or red-brown mica schists succeed the marble, in some areas a generally pelitic succession, in other areas with occasional quartzite bands. At a level about 700–800 m above the base the lithology changes and quartzites in 20–50 m units with some mica schists are developed; the quartzite proportion increases upwards.

Composition

Thin-section studies of rocks from the Rencontre Dal area show parageneses in the mica schists of: garnet + biotite + quartz + plagioclase ± staurolite ± muscovite ± chlorite. Textures are generally fresh with micas developed in polygonal arches about minor folds. Garnets are very often rounded and may preserve inclusions, in a few cases sinuous trails indicating syntectonic growth. Occasional augen formation about the garnet porphyroblasts indicates post-crystallisation deformation. Sometimes two phases of garnet growth are evident. Chlorite has been observed rarely as rims about the garnets, but more usually is present as late patchy fibrous aggregates in various parts of the sections. The quartzitic rocks vary from orthoquartzites to schistose quartzites comprising assemblages of quartz + biotite + muscovite ± feldspar ± garnet ± amphibole.

The rocks of Hinks Land exhibit generally a coarser grain and higher grade than the equivalent rocks of the Rencontre Dal area. Porphyroblastic kyanite and garnet are conspicuous, and quartzo-feldspathic sweats are common. In thin-section mica schist parageneses comprise generally kyanite + garnet + quartz + feldspar + biotite + muscovite. The kyanite and garnet often show indications of strain subsequent to growth but textures are generally fresh; chlorite is notably scarce. Quartzitic rocks comprise aggregates of quartz ± feldspar ± biotite ± muscovite.

Kiledal

Description

A strip of Krummedal sequence rocks occurs on the west side of Kiledal, continuing southwards along part of the north-west flank of Edvard Bay Dal. These outcrops are situated at the extreme east margin of the Hinks Land – Vestfjord gneiss and schist zone, and are separated by a prominent thrust from higher grade supracrustal rocks in Edvard Bay Dal.

The supracrustal sequence overlies concordantly quartzitic gneisses and hornblende gneisses of the Flyverfjord infracrustal complex, but any original discordance has been obscured by interfolding and interleaving of gneisses and supracrustals. Discordant amphibolitic dykes and ultrabasic rocks, a characteristic feature of the basement complex, become conspicuous a short distance below the contact.

The few hundred metre sequence which is preserved has a general eastward dip towards the thrust. Locally the lowest developments are pale grey siliceous to semipelitic massively bedded rocks with conspicuously large garnets up to 10 cm in diameter. Most of the succession comprises, however, medium- to coarse-grained, dark coloured, schistose gneisses with frequent quartzo-feldspathic schlieren and lenses. Kyanite porphyroblastic aggregates exceed 5 cm in length.

Composition

The siliceous and semipelitic rock types comprise in thin section assemblages of garnet + biotite + quartz + feldspar (K-feldspar and andesine) ± kyanite ± muscovite. Pelitic rock types comprise kyanite + garnet + biotite + muscovite + quartz + feldspar. Textures are largely fresh, retrogression is not marked, and only quartz and occasional kyanite prisms show indications of strain. Kyanite prisms are locally enveloped by muscovite aggregates.

Sydgletscher

Description

Supracrustal rocks assumed to represent parts of the Krummedal sequence are widespread along the west margin of the migmatite zone, the northernmost outcrops within the region with which this report deals being found around the head of Sydgletscher (map 1).

The Sydgletscher area outcrops are difficult of access, occurring mainly in scattered nunataks emerging from the high-level plateau ice cap. Rusty strips of schistose gneisses interbanded with presumed basement gneisses at the east side of Sydgletscher (cf. Zweifel, 1959) seem also to form part of the Krummedal sequence. Information on these outcrops is limited, as they were visited for only short periods during helicopter traverses.

Where examined, the rusty-red weathering and alternation of quartzitic and mica schist bands is strongly reminiscent of the most typical Krummedal sequence developments. The general appearence is non-migmatitic, but grain size is fairly coarse and the schists might be described as gneissose. Thin quartzo-feldspathic veins and semiconformable granite sheets also occur. The non-migmatitic sequence represented totals several hundred metres, but east of Sydgletscher there is a rapid transition into great thicknesses of migmatites in which the paleosome proportion is very similar to Krummedal sequence rock types.

Composition

The gneissose pelitic schists comprise aggregates of sillimanite + garnet + microcline + plagioclase (oligoclase) + biotite + quartz. Biotite and sillimanite (fibrolite) form a pronounced laminar fabric, sillimanite being abundant in some thin-sections (up to 10 %). Primary muscovite is absent, but secondary sericite is developed after sillimanite and plagioclase. Siliceous rock types consist of assemblages with quartz + microcline + plagioclase + biotite ± garnet ± sillimanite. The anorthite content of the plagioclase is notably high and may reach 50 %. Textures are generally fresh and stable, with only locally alteration of biotite to chlorite, and slight sericitisation. Strain features are common in quartz, and sometimes also in biotite and sillimanite.

T-sø – Nordbugt

Description

Between T-sø and Nordbugt, on the north side of Nordvestfjord, there are widespread outcrops of a thick supracrustal sequence. The sequence has a general easterly dip and an apparent thickness totalling at least 8000 m. There are a number of tectonic complications, major folds are clearly visibly on the north wall of Nordvestfjord, and parts of the sequence are intruded by granite sheets and influenced by migmatisation. East of Nordbugt massive granite bodies and intense migmatitic developments obscure the continuation of the sequence. The following details have been summarised from F. Keller's unpublished reports and maps, with supplementary petrographical observations made largely by Claus Andersen (pers. comm., 1974).

The west limit of the sequence is a prominent thrust running north–south across T-sø, which dips eastwards roughly parallel to the sedimentary bedding. There are several shear zones and extensive mylonitic developments in a zone up to 300 m wide. Immediately east of the thrust at T-sø the lowest recognisable level of the supracrustal sequence is a wedge of grey to brown weathered quartzitic biotite gneiss up to 500 m thick. The rock is fine- to medium-grained, contains sillimanite, kyanite and biotite, and represents presumably an original siliceous to semipelitic sediment. Since the lower contact of this zone is tectonic the true base of the supracrustal sequence is unknown.

The next major division, in many areas the lowest division, comprises about 3000 m of high grade pelitic to semipelitic schistose gneisses in which garnet and sillimanite are often conspicuous. The lower part may be very schistose and locally includes thin calc-silicate bands, while the upper part is more homogeneous and characterised by numerous garnet-feldspar leucocratic schlieren and lenses.

A red or yellow weathering banded sequence 1200–1500 m thick follows, the colour contrasting with the darker more schistose division below. Quartzo-feldspathic gneiss bands alternate on a 10 cm to 10 m scale with thin mica schist layers. There are occasional marble bands, and at the top a mappable quartzite unit is often present.

The succeeding 3000 m division of semipelitic to siliceous garnet-biotite gneisses is characterised by the occurrence of a number of sheets and bodies of leucocratic garnetiferous augen gneisses. The augen gneiss sheets are coarse-grained, with

K-feldspar augen often up to 3–4 cm across, and they were emplaced as intrusions. Generally the semipelitic gneisses are often slightly migmatitic and contain discordant veins and lenses of leucocratic garnet-bearing, granitic neosome.

The next division of leucocratic, banded quartzitic gneisses, at least 2000 m thick, is exposed mainly just west of Nordbugt. There are some pure quartzite bands, but in most gneisses the quartz proportion is less than 70 %.

These local stratigraphical divisions are traceable throughout the region from T-sø to Nordbugt, but only certain units continue further south, notably the uppermost banded quartzitic gneisses.

Composition

Thin section studies show much the same assemblages in the pelitic and semipelitic rock types, most commonly: sillimanite ± kyanite + garnet + biotite + plagioclase (An 25–32) + quartz. Kyanite has been found alone in two samples just above the thrust, and in association with sillimanite in four samples; where they occur in the same slide the sillimanite is fibrolite and kyanite is found in larger prisms and it is not certain that they are cogenetic. Sillimanite is widespread, and also is present in the augen gneiss sheets.

Studies of a number of marble specimens (Claus Andersen, pers. comm. 1974) show a progressive increase in grade eastwards across the sequence. Parageneses of calcite + tremolite + diopside are replaced successively by calcite + diopside + quartz, calcite + diopside + forsterite, and calcite + dolomite + forsterite.

Retrogression is common and often conspicuous. Sillimanite and kyanite are frequently partially replaced by sericite. Biotite often appears intergrown in parallel orientation with muscovite, but this may be a secondary feature; alteration of biotite to sericite and chlorite, and often prehnite, is widespread. Plagioclase may show sericitisation to varying degrees, and garnet may be seen with a corona of chlorite. In the marbles tremolite may be late in relation to the main parageneses, and can form a rim about forsterite.

Martin Karlsen Bugt – Edvard Bay Dal

Description

Supracrustal rocks are extensively exposed around Martin Karlsen Bugt, in the walls of Edvard Bay Dal, and on the ridge between Martin Karlsen Dal and Edvard Bay Dal. Eastwards along the coastal region of Renland there are extensive outcrops of siliceous gneisses, but here there are complications due to extensive migmatisation of variable intensity. The west boundary to this supracrustal unit is

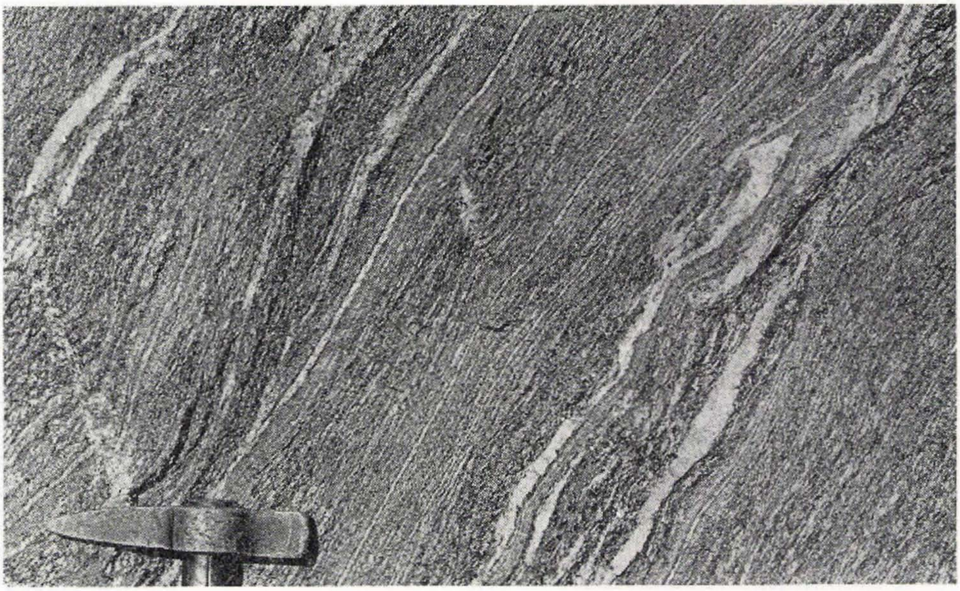

Fig. 7. Grey gneissose pelitic schist showing initial development of veins and sweats of quartzo-feldspathic material. Locality in east wall of Martin Karlsen Dal. Photo: A. K. H.

the thrust traceable through Kiledal. The region has been mapped somewhat inhomogeneously from widely scattered camps, coastal traverses and helicopter reconnaissence, and the section described is a composite one of limited reliability. There are a number of major structures which clearly duplicate parts of the succession, but an apparent thickness of the order of 8000 m seems to be indicated.

As in the T-sø–Nordbugt region the dip is generally eastwards, such that the assumed lowest part of the sequence overlies the thrust. Again the true base of the succession is unknown.

The lowest division of the sequence is best seen east of Kiledal where it comprises about 1500 m of rather monotonous coarse, granular schistose gneisses, with occasional siliceous layers and scattered calc-silicate horizons. A 3 m thick white marble is found locally close to the thrust contact. The dominant rock type was probably derived from a semipelitic sediment.

A broad zone comprising a conspicuous alternation of rusty red and grey coloured bands follows, notably prominent in the northern walls of Martin Karlsen Bugt and the east wall of Martin Karlsen Dal. The coloured bands are 20 to 200 m thick and generally schistose, though the grey bands weather more readily. There are occasional siliceous bands and a few basic layers. Sillimanite is commonly conspicuous in hand specimens, and thin veins and lenses of leucocratic granitic material are characteristic (fig. 7). This dominantly pelitic zone is about 2000 m thick.

It is succeeded by a sequence of massive brown semipelitic gneisses (1000 m +) somewhat similar to the lowest part of the succession already described.

In the southern east wall of Edvard Bay Dal a varied sequence is encountered probably equivalent to part of that described above. Grey and orange coloured mica schist bands are locally conspicuous, but siliceous units are better represented and include a 300 m massive, well-bedded highly siliceous division. A 50 m marble and amphibolite unit is found locally and comprises layers of marble or sandy marble 10–250 cm thick alternating with basic layers 10–300 cm thick. Above this varied sequence massive brown or red, coarse-grained garnet-biotite gneisses occur, developing eastwards and upwards a progressively coarser grain and more prominent feldspathic augen-like leucocratic sweats. The total sequence here is perhaps 2000 m, of which the upper half comprises the massive semipelitic garnet-biotite gneisses.

Higher stratigraphic levels are exposed east of Martin Karlsen Bugt where details are obscured by variable migmatitic developments. There are obvious similarities with the T-Sø–Nordbugt region in that part of the sequence is characterised by massive augen granite sheets, and further east a development of at least 2000 m of homogeneous siliceous gneisses occurs in the cliffs of northern Renland. The latter form a monotonous well banded succession in steep walls exhibiting a number of major flat-lying folds. The rocks are biotite-garnet bearing siliceous gneisses for the most part, sometimes with a rusty colouration, and in many areas permeated by granitic neosome veins and schlieren.

Composition

Metamorphic mineral assemblages are closely similar to these of the T-sø–Nordbugt region, as might be expected in view of the close proximity of the two regions. In pelitic rock types parageneses comprise: sillimanite ± kyanite + garnet + K-feldspar + plagioclase (An 25–37) + quartz. Sillimanite is very common, though often partially altered to muscovite. Sillimanite and kyanite occur together in several thin sections, though need not have developed simultaneously. Semipelitic and siliceous rock types comprise: garnet + feldspar + quartz in varying proportion, occasionally also kyanite or sillimanite. Basic rock types consist of hornblende + garnet + sphene + opaques + quartz + epidote, the garnet often very abundant. Textures in all rock types are generally fresh, and retrogression features are only prominent in a very few slides. A few samples show extensive chloritisation of biotite and sericitisation of plagioclase, and in a single case garnet porphyroblasts have suffered disruption at a late stage.

LITHOFACIES

The lithological variations of the Krummedal supracrustal sequence in the region around inner Nordvestfjord are summarised in map 1 and the columnar sections of fig. 8. Distinction is made between developments which are generally pelitic, semipelitic or psammitic, banded pelitic/psammitic units and the presence of marbles and the rare amphibolites. In most areas the base of the exposed sequence is a tectonic contact, such that the relative stratigraphical succession in different areas cannot be equated with any certainty. There are local facies variations within a limited range of rock types and in general no reliability can be placed on lithology as indicative of a specific stratigraphic level. The total thicknesses recorded seem to be in excess of 8 km, with much greater thicknesses probable.

In Hinks Land the lowest levels of the Krummedal sequence, perhaps the true base, comprise marbles and amphibolites but they are not continuously developed.

Pelitic rocks form thick sequences, notably in the Hinks Land, the T-sø–Nordbugt and Martin Karlsen Bugt–Edvard Bay Dal areas, while in other regions a banded pelitic/psammitic succession is most characteristic.

Psammitic developments, in some cases rather pure quartzites, are important especially at a high stratigraphic level on both sides of Nordvestfjord. Further east in the generally migmatitic region siliceous gneisses are abundant in the paleosome.

In attempting to summarise the depositional environment for the Krummedal sequence within the region described it is to be remembered that the initial relative positions of the structural units in which the outcrops are now preserved is not yet resolved. However, the apparent thicknesses are always considerable, 2500 m in the gneiss and schist zone and more than 8000 m at the western edge of the migmatite zone, and there is a certain uniformity and monotony in the general development. The thicknesses are of geosynclinal proportions and it may be envisaged that the sequence accumulated under fairly stable conditions over a considerable time period in an extensive trough, or perhaps a steadily subsiding near-shore shelf environment. Lateral lithological variations, though of a minor nature, suggest some dependance on local supply sources. The repetitive banding over wide areas suggests rhythmic accumulation, which may be seasonal. As noted already the highest levels appear to be dominantly siliceous, though whether this is a significant change of regional significance is uncertain.

In the other parts of the gneiss and schist zone extending from the region described southwards to western Gåseland (fig. 1) the Krummedal supracrustal sequence may be traced continuously. In general terms its features throughout the zone are very similar, a rusty brown colouration is characteristic, and pelitic, psammitic and banded variations are described though monotonous pelitic mica schist sequences seem to dominate (Henriksen & Higgins, 1971; Homewood, 1973; Phillips *et al.,* 1973). Migmatitisation has also been encountered at several locations as the sequence was traced upwards. Phillips *et al.* note near the base of

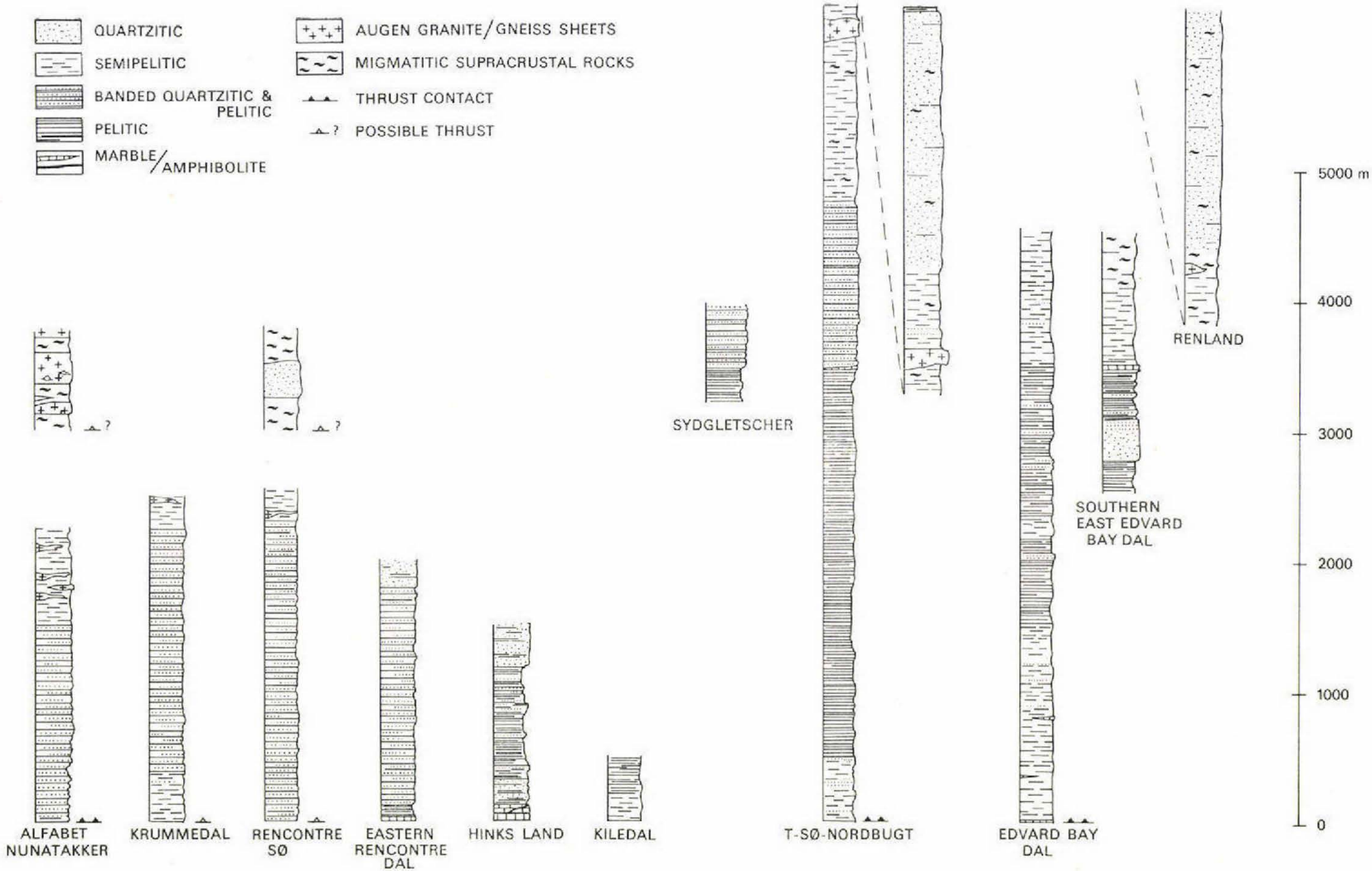

Fig. 8. Apparent lithostratigraphical successions at various locations.

the sequence in the southern part of the zone local developments of amphibolites, breccias and agglomerates which they suggest represent a volcanic episode.

Projecting the gneiss and schist zone northwards beyond the 72nd parallel into the so-called central metamorphic complex, areas of red-brown weathering banded supracrustal sequences interfolded with gneissic and granitic rocks are again encountered. Aerial reconnaissence by Niels Henriksen and the writer indicated widespread outcrops with a very similar lithological development and style of folding to that known in the Krummedal sequence, though pending new field investigations conclusions are premature. Similar depositional environments over a zone 350 km or more in a north–south direction are a speculative but interesting possibility.

No formal subdivision of the Krummedal supracrustal sequence has yet been attempted and there appear to be few diagnostic features which can be used on a regional basis. Structural complexities and high grade metamorphism with related migmatitic phenomena are further hinderances to interpretation.

METAMORPHIC FACIES

It will be apparent from the regional descriptions already presented that the Krummedal supracrustal sequence has undergone everywhere regional metamorphism appropriate to various pressure–temperature conditions of the amphibolite facies. Subsequently an episode of retrogressive metamorphism has left a widespread but variable impression on the higher grade assemblages.

The distribution of the principal index minerals within the region as determined from thin-section analyses is presented in fig. 9. The pattern reflects the high grade main phase of metamorphism, through representation suffers from the inhomogeneous nature of the mapping and sample collection. The main metamorhpic phase is clearly post-dated by the various thrusts, most clearly surrounding the Charcot Land tectonic window, but there is also a significant contrast across the line of the thrust through T-sø and Kiledal.

At the western edge of the migmatite zone the entire metasedimentary zone is characterised by the presence of sillimanite and garnet, often also kyanite, and notably lacking muscovite except as a secondary product. Sillimanite has been recorded also in two samples from one locality in the northern Alfabet Nunatakker where migmatitic rocks are also prominent, though it has not been found in the migmatites west of Rencontre Sø in the few samples collected.

Kyanite is widespread in pelitic rocks from Hinks Land and the strip of metasediments west of the thrust through Kiledal, in stable assemblages with garnet, muscovite and biotite.

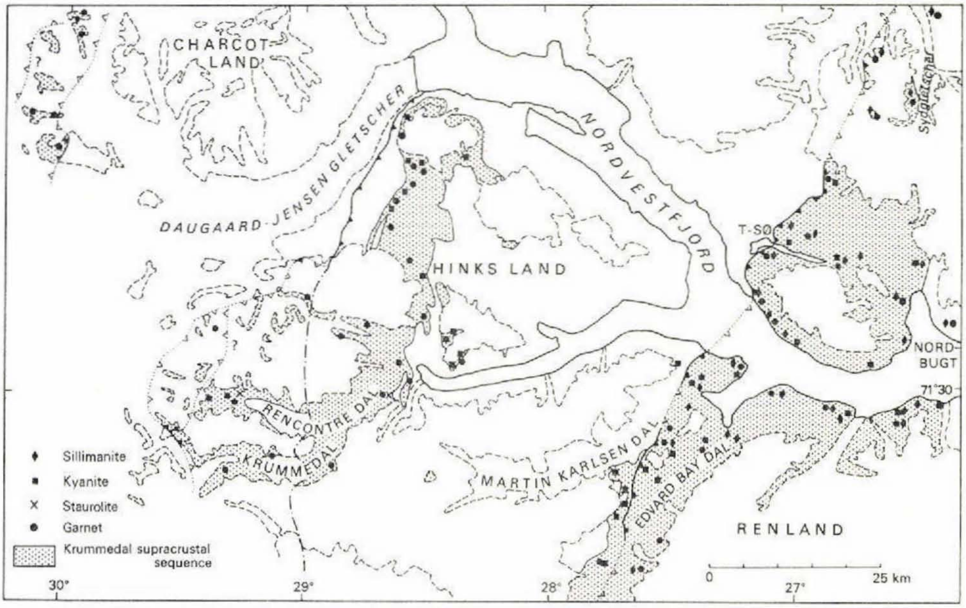

Fig. 9. Distribution of metamorphic index minerals.

In the Krummedal and Rencontre Dal region there appears to be a scarcity of index minerals and the general field appearence is indicative of a lower grade than other regions. Kyanite together with staurolite has been noted from one locality. Staurolite has been noted also south-west of the head of Flyverfjord. The presence of staurolite in this general region may be indicative of a slightly lower metamorphic grade.

Samples from the thrust and fault zones confirm that dislocation movements post-dated the main metamorphism. Fine-grained blastomylonitic textures are common, with occasional relic porphyroclasts of feldspar and garnet surviving, the latter often disrupted and rolled. These fine-grained textures are overprinted by a low grade new metamorphic phase most commonly represented by sporadic coarse muscovite, and occasionally new, small, euhedral garnets, which correspond to the widespread though variously developed retrogressive metamorphic phase.

Retrogressive metamorphic features, the partial break-down of the high grade mineral parageneses in response to a late low grade metamorphic episode, are common. Most usually chlorite, muscovite (sericite) and prehnite are the alteration products, though muscovite may also occur as new, late, large prismatic laths cutting across the foliation. Retrogression was notably not markedly developed in the samples examined from the Alfabet Nunatakker.

Somewhat similar metamorphic parageneses are encountered in the Krummedal supracrustals of other parts of the gneiss and schist zone in the inner Scoresby Sund region. Homewood (1973) in discussing the area just to the south of that described here places all the observed events within the Caledonian orogeny, in line with the original working hypotheses. Phillips *et al.* (1973) for the Gåseland–Paul Stern Land region have established a detailed succession of metamorphic and tectonic events, and on the basis of isotopic work by Hansen *et al.* (1973) refer the main metamorphic phase to a *c.* 1200 m. y. orogenic event, while the thrusting, associated folding and late retrogressive episode are regarded as Caledonian.

STRUCTURES

The traces of the principal folds, thrusts and faults affecting the Krummedal supracrustal sequence are shown in fig. 10, and cross-sections of parts of the region make up fig. 11. A treatment of the structures of part of north-west Hinks Land, together with Charcot Land, is to be presented separately by A. Steck.

Few details are available for the Alfabet Nunatakker, except that several major tight or isoclinal structures are recorded with axial planes parallel to the regional bedding and dipping gently westwards. One of the major structures is cut by a

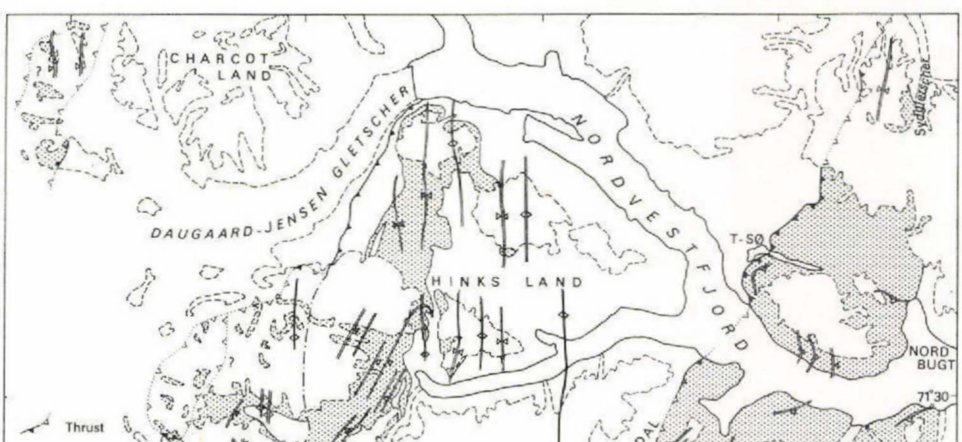

Fig. 10. Trace of thrusts, faults and axial planes of principal folds.

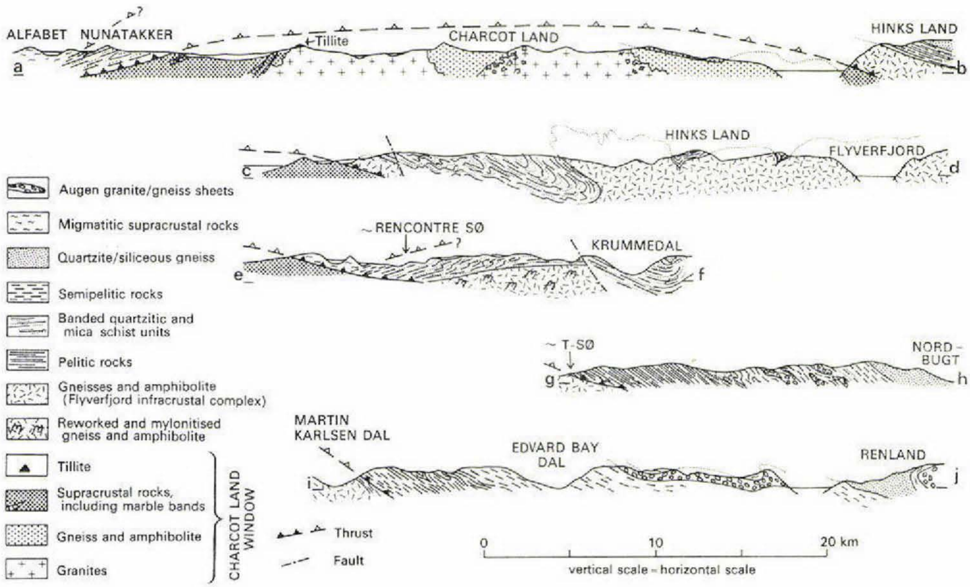

Fig. 11. Cross-sections. See map 1 for section lines.

basic dyke which has been transformed to amphibolite presumably during the main metamorphic phase (fig. 2).

In the west Krummedal–Rencontre Sø area there is an apparent simplicity of structures with a regional westward dip. Mesoscopic folds are locally conspicuous on axial planes roughly parallel to the general bedding, and with fold axes north or south plunging at low angles. The areas of siliceous gneisses, believed to be tectonically reworked basement, occupy inliers in the deep parts of the valleys with a general domal structure truncated to the east by the north–south trending fault. The doming may be a late feature post-dating the cataclastic developments in the siliceous gneisses.

In the Hinks Land–east Rencontre Dal area there are two quite distinct fold trends. An earlier set of tight, sometimes isoclinal, folds is developed on axial planes dipping south-east at moderate angles and with a north-east strike; fold axes plunge gently to the south or north. They are particularly intensely developed in Rencontre Dal and eastern Krummedal (fig. 6), and locally basement gneisses are found occupying the cores of isoclinal anticlines (fig. 5). Locally there are indications of two phases of early isoclinal structures. The later N–S trending fold set is represented by a number of major structures in Hinks Land. They have near-vertical axial planes and gently plunging fold axes, two major synclinal structures occurring in the north wall of Flyverfjord with tightly pinched cores of Krummedal sequence schists. Local detailed studies of mesoscopic interference of the two sets revealed a predictable spread of the orientation of earlier phase axial planes, but a fairly tight concentration of fold axes of both phases plunging at low angles to the north or south.

The Sydgletscher–T-sø–Edvard Bay Dal zone of metasediments preserves evidence for at least two major phases of folding, prominent examples being seen on the north wall of Nordvestfjord west of Nordbugt. Early isoclinal or tight folds have eastward dipping axial planes parallel to the regional strike. A later phase of open to tight more upright structures has NE–SW to N–S trends. No detailed structural studies have been made, but the great majority of measured fold axes and associated linear features plunge eastwards at low to moderate angles, a feature in marked contrast to the dominant N–S trends of the fold axes in the gneiss and schist zone to the west.

Throughout the region the main fold structures are developed on all scales down to that of the hand specimen. Thin-section analysis of numerous samples reveals that, except in the obvious zones of dislocation such as faults and thrusts, crystallisation related to the main high grade metamorphism overprints the deformation pattern. The major thrusting post-dates the main fold pattern in the region described, as well as the metamorphic zonation.

The most interesting of the thrusts are those outlining the Charcot Land window, dipping gently east and west on either side and presumably once continuous (fig. 11 section a-b). A westward sense of displacement of at least 40 km is implied for this structure, which if the view that the Charcot Land area represents an intact foreland block is valid then represents the Caledonian marginal thrust.

Mylonites and blastomylonites are developed in all the thrust zones and are up to 300 m thick. The reworked siliceous gneisses occurring in Rencontre Dal and Krummedal as faulted inliers may represent much thicker mylonitic and tectonised basement gneiss developments perhaps related to the same thrust (cf. fig. 11, section e-f), which would imply that the low grade greenschist metamorphism is Caledonian. This interpretation would fit in well with the reports of such developments at identical structural levels in the areas immediately to the south by Homewood (1973) and Phillips *et al.* (1973).

The thrust running from west of Sydgletscher southwards through T-sø to Kiledal and along Edvard Bay Dal is a fundamental structure. Throughout the Scoresby Sund region it separates the migmatitic zone to the east from the rather different gneiss and schist zone to the west. The main movement evidently post-dates the main metamorphic episode and related migmatisation, as well as the fold pattern. In that it brings into contact two contrasting zones of the fold belt the thrust may well be as important as the Caledonian marginal thrust, though the amount of displacement the structure represents is not known.

Migmatitic rocks are encountered in two areas of the gneiss and schist zone, in the westernmost Alfabet Nunatakker and in the nunataks west of Rencontre Sø. In both cases they are encountered at a high level of the Krummedal sequence, though it remains uncertain whether there is an upward increase in metamorphism and migmatisation, or whether the migmatitic division represents a distinct upper thrust sheet. Evidence within the region described, and elsewhere in the gneiss and schist zone, supports both viewpoints.

If the migmatitic developments do represent a thrust level then interesting speculations as to its provenance may be made. In comparing such rocks with those of the migmatite zone Homewood (1973) suggested a displacement of 80 km for part of an area just south of that described here. The same argument for the farthest migmatitic outcrops of the Alfabet Nunatakker would imply displacement of at least 110 km if they were considered derived from the nearest localities of the migmatite zone.

The fault pattern is relatively simple, north–south trending structures occurring throughout the gneiss and schist zone (fig. 1), and in some cases following the lines of weakness of the thrusts. The latest fault movements are known to have influenced the deposition of the Carboniferous–Lower Permian (?) Røde Ø Conglomerate (Collinson, 1972).

THE ISOTOPIC EVIDENCE

Prior to the Survey's regional mapping in the Scoresby Sund region the East Greenland fold belt from 70°–82°N was considered essentially a product of Caledonian orogenesis. Widespread late Precambrian and lower Palaeozoic sedimentation of geosynclinal proportions was thought to have been succeeded by Caledonian regional metamorphism, migmatisation and granite emplacement during the main phase of the Caledonian orogeny. Later phases of Caledonian deformation influenced accumulation of Devonian and Carboniferous continental deposits. This view is most comprehensively presented by Haller (1971). The few age dates then available supported the general thesis (Haller & Kulp, 1962).

The results of the Survey mapping were at first interpreted, without great difficulty, in line with the traditional viewpoint of Caledonian orogenesis (Henriksen & Higgins, 1969, 1970, 1971). The variety of pre-Caledonian Rb/Sr mineral age dates (up to 1154 m. y.) on supposed Caledonian plutons in the migmatite zone (Hansen *et al.* 1971, 1972) first cast doubts on this interpretation, and subsequently further zircon and monazite ages (Steiger & Henriksen, 1972; Oberli & Steiger, 1973) have supported a greatly modified interpretation that the migmatite zone has a composite origin; Caledonian orogenesis is considered as overprinting and partially reworking an early orogenic complex which now gives dates between 445 and 1650 m. y. in the Scoresby Sund region.

The geological field evidence suggests that the Krummedal supracrustal sequence is widely represented as paleosome throughout the migmatite zone. The isotopic ages from the adjacent gneiss and schist zone indicate a main metamorphic event at *c.* 1200 m. y. (see below) in the Krummedal sequence, that probably corresponds to the orogenic episode which caused the high grade metamorphism, deformation and migmatisation in the migmatite zone. A zircon age on one of the syn-migmatitic augen granite sheets indicates a time of intrusion or last major recrystallisation about 950 m. y. ago (Steiger & Henriksen, 1972). There remains, however, a diversity of opinion among those who have mapped the migmatite zone as to the relative importance of the pre-Caledonian and Caledonian orogenic phases in different parts of the zone (Henriksen & Higgins, 1973).

Relatively few age dates have been made on the Krummedal supracrustal sequence in the gneiss and schist zone. A whole rock Rb/Sr isochron on 3 samples by Hansen *et al.* (1973) gave an age of 1194 m. y., which additional data has subsequently revised to give a 7 point isochron of 1162 m. y. (Hansen *et al.,* 1974). This age is confidently interpreted as the time of an early metamorphism of the Krummedal supracrustals, presumably the high grade regional metamorphism, together with the associated main fold pattern.

Larsen (1969) obtained K/Ar mineral ages on Krummedal sequence schists and gneisses of 406, 426 and 616 m. y., and Hansen *et al.* (1973b, 1974) Rb/Sr ages of 442 and 445 m. y. These younger ages, and some intermediate ages, are considered to be a response to a weaker Caledonian overprint, presumably the low grade retrogressive metamorphism. Phillips *et al.* (1973) have used this age data as a basis for a detailed succession of structural and metamorphic events in the southern part of the gneiss and schist zone.

These results indicate deposition of the Krummedal supracrustal sequence fairly early in the Proterozoic, in which case the similarity in development with the lower part of the Eleonore Bay Group is no more than coincidental.

SUMMARY

Krummedal supracrustal sequence

The thick sequence of pelitic, semipelitic and psammitic rocks which makes up the Krummedal supracrustal sequence was deposited in a trough or subsiding shelf environment of great extent. About 2500 m of the sequence is represented in the schist and gneiss zone and probably > 8000 m at the west margin of the migmatite zone. Within the limited range of rock types which it comprises there are local lateral and marked vertical facies variations, though no attempt has been made at a formal subdivision. At one time assumed equivalent to the lower Eleonore Bay

Group (late Precambrian), it is now apparent that deposition must have taken place earlier in the Proterozoic, subsequent to the main events recorded in the Archaean basement (Flyverfjord infracrustal complex: 2345–2980 m. y.) on which it rests, and prior to the main metamorphic phase dated at 1162 m. y.

It is expected that future field work will demonstrate that the Krummedal sequence is widely represented between latitudes 70°–74°N in central East Greenland. However, it must be stated that there are still uncertainties within the Scoresby Sund region as to the relationships between the Krummedal supracrustal sequence and other supracrustal sequences of probable lower Proterozoic age; these include the mainly low grade Charcot Land sequence of the foreland (> 2000 m), a high grade metasedimentary sequence in eastern Milne Land at the east edge of the migmatite zone (> 4000 m), and a very thick partly migmatitic sequence in northern Liverpool Land (8–11 km?). Future isotopic work is aimed at resolving some of these problems.

Comparisons in general development within Greenland might be made with the 6000 m sequence of psammitic and semipelitic strata which make up Haller's (1971) 'Thule Group' in northern East Greenland, which was laid down prior to the Carolinidian event (*c.* 1000 m. y.: Henriksen & Jepsen, 1970). In northern West Greenland an up to 8000 m sequence of well-preserved quartzites and greywackes, the Karrat Group, is extremely widespread (Henderson & Pulvertaft, 1967); they give, however, consistent K/Ar ages of 1650–1800 m. y. and perhaps are of greater antiquity than the Krummedal sequence. The Ketilidian successions of South-West Greenland (> 5000 m) comprise largely volcanics and have more features in common with the Charcot Land sequence than the Krummedal sequence.

Comparisons of a speculative nature might also be made between the Krummedal sequence and metasedimentary successions of possible similar age within the British and Scandinavian Caledonides, but these lie outside the scope of this report.

The Proterozoic orogenic episode at *c.* 1200 m. y.

The main metamorphic episode in the Krummedal sequence, dated at 1162 m. y. ago, seems to have accompanied the several main phases of folding in the gneiss and schist zone. The emplacement of a suite of plutonic rocks in the migmatite zone, associated with and post-dating perhaps two migmatitic and several deformation phases, and giving many age dates in the range 950–1150 m. y. seems likely to relate to the same orogenic episode.

There is now a good deal of evidence pointing to a significant orogenic episode in the Scoresby Sund region corresponding to the well established Grenville – Sveco-Norwegian event (900–1200 m. y.) of North America and northern Europe. It is uncertain at present to what extent this orogenic episode affected other parts of central East Greenland, though it is relevant to note that the Carolinidian disturbances in northern East Greenland may have taken place about 1000 m. y. ago (Henriksen & Jepsen, 1970).

Late Precambrian and lower Palaeozoic sediments

Metamorphosed equivalents of the Eleonore Bay Group were once considered to be widespread in the inner part of the Scoresby Sund region, but under current interpretations are not represented. There is a possibility that the tillites and associated rocks preserved beneath the thrusts in the Gåseland and Charcot Land windows may be latest Precambrian to Cambrian (Phillips *et al.,* 1973), and a search is being made for microfossils in the material collected. If this possible age can be verified, then it will follow that the age of the thrust movements will also be Caledonian.

Caledonian orogenic events

Numerous Caledonian isotopic ages are known from the inner Scoresby Sund region, mostly K/Ar or Rb/Sr mineral ages, so there is no doubt that Caledonian thermal events have affected the region, the question remains only to their intensity. Much evidence suggests that the weak metamorphic retrogressive phase, the displacement of the thrusts with associated cataclasis and some of the plutons in the migmatite zone are referable to the Caledonian orogeny. Several important phases of Caledonian folding are recognised by Phillips *et al.* (1973) in southern parts of the Vestfjord–Hinks Land gneiss and schist zone. The very important Caledonian thrusts caused apparently a structural rearrangement of an existing pre-Caledonian orogenic complex, such that remnants of a thrust sheet containing migmatitic rock types may be seen overlying high grade metasediments, which in turn were thrust over an autochthonous foreland including some very low grade sedimentary rocks. However, there remains a certain diversity of opinion as to the significance of Caledonian orogenesis in the migmatite region.

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This report owes a great deal to other workers. Five geologists other than the writer were involved in the original field mapping, and ideas developed during the subsequent mapping of adjacent regions have contributed to the interpretations presented. The importance of the isotopic work carried out at the Eigd. Technische Hochschule in Zürich is self-evident. Niels Henriksen together with the writer jointly carried out a good proportion of the field mapping of the region described, but Henriksen deserves also special acknowledgement for his organisation and direction of the Scoresby Sund expeditions. Claus Andersen has been engaged in regional studies of samples collected by Franz Keller, Niels Henriksen and the writer, and has contributed many valuable petrographic observations.

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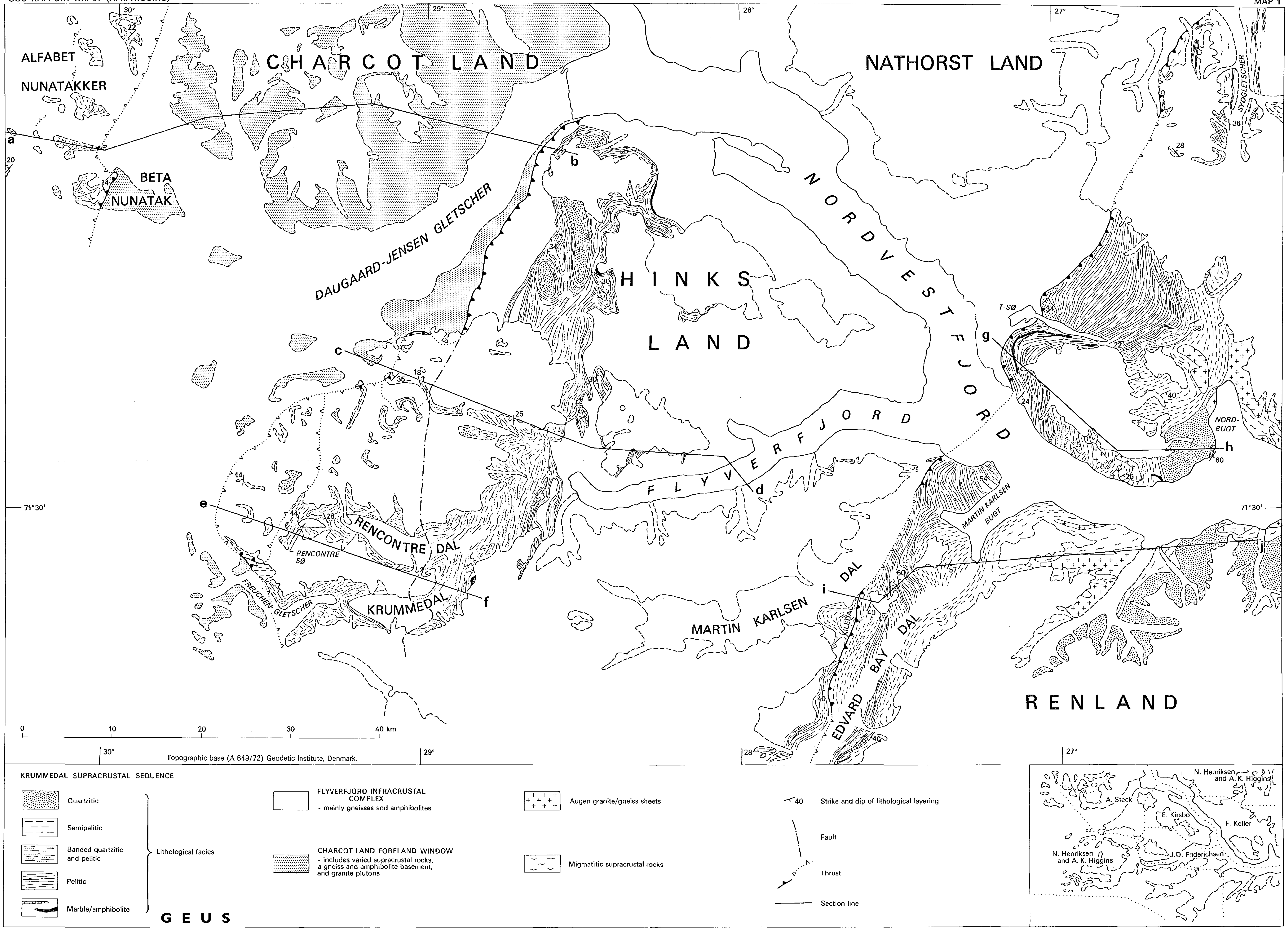
GRØNLANDS GEOLOGISKE UNDERSØGELSE

THE GEOLOGICAL SURVEY OF GREENLAND

GGU RAPPORT NR. 67 (A. K. HIGGINS)

MAP 1



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