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Geological reconnaissance of the Greenland Shield in Melville Bugt, North-West Greenland

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Geological reconnaissance mapping of the Thule – Melville Bugt region (75°15′N to 78°15′N) was completed in summer 1980 with the extension of the field work along the Lauge Koch Kyst in central and southern Melville Bugt (fig. 5). The work was concentrated in the region east of Kap Edvard Holm southwards down to Steenstrup Gletscher, the southern boundary of the 1:500 000 map sheet. The mapping was a continuation of the 1978 field work during which the area between Kap York and Fisher Øer was covered (Dawes, 1979).

Melville Bugt is characterised by an extremely narrow and broken ice-free coast, being for the most part composed of nunataks, islands and small peninsulas. The Inland Ice reaches the coast in many broad glacier fronts, often with floating tongues, and in summer the coast usually has a high concentration of ice. Parts of the nunatak terrain approach 1000 m altitude, with the snow-covered Haffner Bjerg as the highest summit at 1462 m.

The geological mapping was accomplished by combining a fixed-wing aerial survey with ground observations made from ship and helicopter. The whole coast, particularly the inner nunatak terrain, was overflown during two 5-hour flights from Thule Air Base using a Twin Otter aircraft. The ship-borne phase, based on the GGU motor cutter *K. J. V. Steenstrup,* was delayed until the end of August because of unfavourable ice conditions. Eventually a 12-day ship reconnaissance down to Steenstrup Gletscher was achieved although new ice in

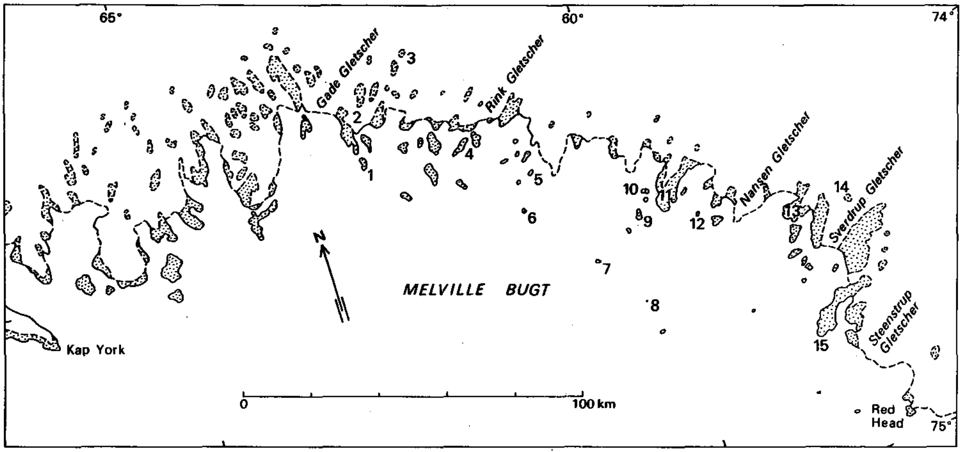

Fig. 5. Map of the Lauge Koch Kyst between Kap York and Red Head showing localities mentioned in the text. 1: Kap Edvard Holm; 2: Morell Gletscher; 3: Haffner Bjerg; 4: Fisher Øer; 5: Kløftø; 6: Bryant Ø; 7: Thom Ø; 8: Ajakos Skær; 9: Welhaven Øer; 10: Kivioq Havn; 11: Nûgssuaq; 12: Melville Monument; 13: Astrup Kystland; 14: Mylius Erichsens Monument; 15: Kap Seddon.

September prevented penetration of some areas of the inner coast and many areas have been only cursorily examined. The mapping was supported by 8 hours flying with a 206 Long Ranger helicopter chartered from Thule Air Base.

Previous work

Previous geological investigations in Melville Bugt have been few. Apart from cursory observations made during early exploration (e.g. Ross, 1819; Astrup, 1898) the first regional reconnaissance was carried out by Lauge Koch in 1916 (Koch, 1920). Some observations, e.g. on ironstone (Bøggild, 1953), were made in 1952 by a GGU party led by A. Rosenkrantz on board *K. J. V. Steenstrup* en route to the Thule district. In 1969 a commercial organisation, Greenarctic Consortium, carried out a ship-borne reconnaissance of parts of the coast, but no results have been published.

Regional geology

The whole Melville Bugt coast is composed of Precambrian Shield rocks sporadically overlain by Quaternary deposits. A small outcrop of Proterozoic Thule Group sandstones in the western end of the bay to the east of Kap York is the only outcrop of consolidated rocks overlying the Shield.

The Precambrian Shield between Kap Edvard Holm and Steenstrup Gletscher is composed predominantly of a high-grade gneissic complex containing areas of granite and amphibolite in which rusty-weathering metasedimentary units, commonly containing ironstone, form discrete but thin units. This complex has been intruded by a suite of basic rocks that are in many places strongly deformed and metamorphosed, although igneous textures and discordant relationships to the host gneisses have been preserved.

Cross-cutting unmetamorphosed dolerite dykes are the youngest Precambrian rocks recognised in the 1980 study area.

Gneisses

A suite of mainly granodioritic multiphase gneisses forms by far the largest part of the Melville Bugt region. The gneisses vary from rather homogeneous leucocratic granitic gneiss to veined and banded varieties. Gradations between the gneiss types are transitional but the scale of the work did not allow a meaningful distinction to be mapped. In many places the latest phase of the gneisses is a leucocratic, quartz-rich granite that forms subconcordant veins in an otherwise rather homogeneous gneiss. The gneisses are typically pale grey in colour with locally reddish weathering. They contain both biotite and hornblende in varying proportion. Garnet may occur, especially in gneisses in close proximity to metasedimentary rocks (see below).

The gneisses form both a high and rugged topography with some spectacular steep-walled islands, e.g. Melville Monument, as well as the low-lying coastal terrain. One region of particularly steep-cliffed terrain at Astrup Kystland between Sverdrup Gletscher and Nansen Gletscher is composed of a homogeneous leucocratic granitic gneiss in which compositional banding and other gneissic structure are not readily apparent.

Augen granite and gneiss

Several areas of augen gneiss and granite can be distinguished. Rock types vary from a gneiss in which small feldspar augen are orientated within the main planar fabric of the gneiss, to granites in which the augen feldspars reach several centimetres in length and make up a major part of the rock. On Welhaven Øer the passage between veined biotite gneiss and augen gneiss is transitional over only a few centimetres. A rather massive-weathering, pink, biotite-bearing, augen granite forms the whole of the nunatak Mylius Erichsens Monument.

Amphibolites

Two main groups of amphibolites based on metamorphic and structural relationship to the gneiss complex can be recognised in the study area.

Group 1 amphibolites are all metamorphosed and highly deformed rocks that have concordant relationships with the enclosing gneiss. Two main types can be distinguished:

(a) Large parts of the gneiss complex contain inclusions of dark, rather homogeneous amphibolite and schist as thin layers, boudins and agmatites in various stages of migmatisation. The extensive and clean exposures on some of the steep-cliffed nunataks and islands, e.g. Morell Gletscher, Kløftø, indicate that such amphibolites originally formed continuous bodies that are now intensely folded and broken up; they may have originated as early intrusions into the gneiss.

(b) On some nunataks and peninsulas, e.g. around Rink Gletscher and on Nûgssuaq, amphibolites form relatively thick, concordant units folded and interlayered with the gneisses. These amphibolite units display colour variation and compositional banding. Ultramafic rocks are local associates. Many of these amphibolites are garnetiferous. In some places the units are also associated with metasedimentary gneiss and schist sequences. These amphibolites are considered to represent metavolcanics.

Group 2 amphibolites are generally less metamorphosed and deformed than those of group 1, and discordant relationships to gneisses are preserved in many places. They are younger than group 1 amphibolites and cross-cutting relationships demonstrating this have been observed. The basic rocks of this group vary from amphibolite to metadolerite.

The rocks occur in somewhat irregular bodies within the gneisses, either concordant and subconcordant sheets and masses tens of metres thick, or discordant amphibolites that vary from several metres thick to dykes less than 10 cm across (fig. 6).

Amphibolites of this type are widespread in Melville Bugt but are particularly conspicuous in the south on the peninsulas on either side of Sverdrup Gletscher, where they form substantial bodies capping mountains built of gneiss, as well as sheets and dykes. In the thicker bodies, transitions from amphibolite and basic schists to metadolerite with well-preserved igneous textures, commonly in the centre of bodies, are common, although igneous textures may occur even at the margins.

Ultramafics

In addition to the ultramafic rocks associated with group 1 amphibolites, small isolated metamorphosed ultramafic pods and boudins occur sporadically in the gneisses. Olivine-bearing ultramafics, hornblendites and biotite-rich rocks are the main types and several outcrops of these rocks were observed in the Nûgssuaq area.

Metasedimentary rocks

Metasediments occur throughout Melville Bugt as relatively thin units within the gneisses. These units have been deformed with the gneisses, and contacts are consistently concordant. Due to the physiography and abundant ice cover, metasedimentary units cannot be traced over large distances and little structural correlation can be made between different areas.

All the metasedimentary tracts have rusty-weathering pelitic or semi-pelitic gneiss and schists as important rock types and these may be sillimanite- and/or garnet-bearing. Some units contain ironstones and a variety of other rocks, concordant amphibolites of group 1 above, quartzites and leucogneisses. Several units lacking ironstones are composed entirely of garnet- and/or sillimanite-bearing pelitic gneisses and schists.

The ironstones are mainly quartz-iron oxide (mainly magnetite) rocks that form concordant layers in the gneiss and in which millimetre magnetite-quartz banding can be well developed. All gradations in iron grade occur between low-grade magnetite-bearing gneiss, to magnetite-rich quartzite, through banded ironstone to monomineralic magnetite rock. The layers vary in thickness from about 15 cm to several metres. On Thom Ø classical banded ironstone in discrete layers up to 5 m thick occur within a succession of garnetiferous quartz-rich gneiss and schistose rocks.

At Kap Seddon, metasedimentary gneisses and schists contain folded but discordant amphibolite dykes of group 2.

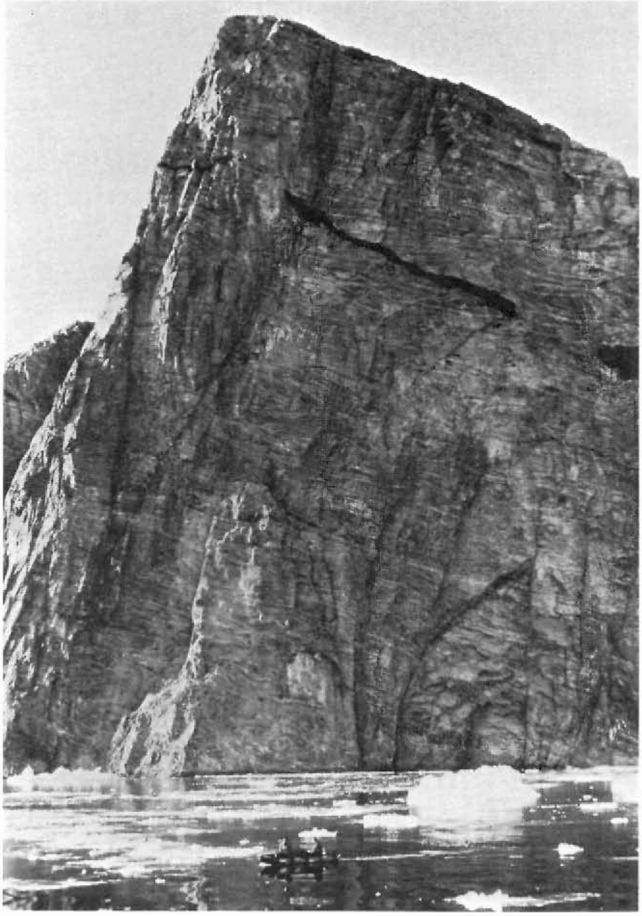

Fig. 6. The vertical eastern wall of Melville Monument showing a thin, broken up discordant amphibolite within grey banded gneisses. The height of the summit is about 335 m.

Cross-cutting dolerite dykes

Several generations of relatively straight, cross-cutting basic dykes with chilled margins traverse the region. The largest dykes form a WNW- to NW-trending swarm that can be traced through Melville Bugt and to the north in the Thule region up to 78°N. Dykes vary from thin centimetre bodies to major dykes up to 200 m in width; all varieties may contain large feldspars, commonly concentrated at one or both margins. Large resistant dykes of this swarm occur on, or form, some of the small outer islands and skerries, e.g. Thom Ø, Bryant Ø, Ajakos Skær.

Younger(?) NE-trending non-porphyritic dolerite dykes, several metres wide, occur sporadically through the region. Other dyke trends have also been noted. At Kivioq Havn a dyke chronology based on cross-cutting relations and relations to faults was determined.

This is from oldest to youngest: greenish weathering, slightly sheared NNE-trending dolerite, dark brown weathering, NW-trending dolerite and brown weathering, WNW-trending porphyritic dolerite of the main regional swarm.

Metamorphic and structural history

The metamorphic and structural chronology of the Melville Bugt region is complex but by means of amphibolites of group 2, a distinction can be made between major metamorphic and tectonic periods.

The gneisses and supracrustal rocks are all intensely deformed and have mineral assemblages indicative of amphibolite facies metamorphism. The precise age relationship between the supracrustal rocks (both metasediments and ? metavolcanics) and the gneisses is not readily apparent, although comparison with the Red Head – Upernavik region to the south, where gneisses and supracrustal rocks are preserved in a basement–cover relationship (Escher & Stecher, 1978), suggests a similar relationship for at least some of the gneiss-supracrustal rock associations in Melville Bugt. Deformation in Melville Bugt has been intense and contacts between gneiss and metasediments are all strongly deformed with gneiss and metasediments mixed and interlayered.

The oldest major structures recognised are long-limbed isoclinal folds that are revealed by the outcrop pattern of some group 1 amphibolite units. These are refolded by more open structures. Amphibolites of group 2 clearly post-date these early structures in the gneisses. In addition, in the Kap Seddon area, these younger amphibolites are also seen to cut structures in the rusty-weathering metasedimentary rocks. These amphibolites have been also affected by strong deformation and in the most transformed parts the rocks contain amphibolite-facies mineral assemblages. In many places transitional contacts with the gneisses also indicate an important period of remobilisation and gneissification following the basic intrusive period.

Age and correlation

The geology of the 1980 study area shows many similarities to the regions to the north and west (Dawes, 1979) and to the south (Escher & Stecher, 1978, 1980) although important differences are apparent (Table 1). The high-grade intensely folded gneisses containing amphibolite layers and inclusions extend into the region south of Melville Bugt, where, in the Upernavik area, they have been dated as Archaean (F. Kalsbeek, *in* Escher & Stecher, 1980).

The widespread group 2 amphibolites and metadolerites are considered to be the same age as the Kap York meta-igneous complex for which an Archaean age has been suggested (Kalsbeek & Dawes, 1980). In 1978, rocks of the Kap York complex were traced as relicts within the gneisses from Kap York eastwards to the Fisher Øer and it was concluded that large areas of the gneiss complex in western Melville Bugt were derived from such igneous rocks (Dawes, 1979). The 1980 field work has shown that these meta-igneous rocks also extend east of the Fisher Øer into southern Melville Bugt where they clearly intrude and

Table 1. Main ages of gneiss, supracrustal and igneous rocks in the region between Kap York and Upernavik

	Kap York region - western Melville Bugt (Dawes, 1979)	Central and southern Melville Bugt (this paper)	Red Head - Upernavik region (Escher & Stecher, 1978, 1980)
PROTEROZOIC	Dolerite dykes	Dolerite dykes	Dolerite dykes
	Thule Group, sediments volcanics, intrusions		
	Hudsonian orogeny and mixed gneiss complex	Hudsonian orogeny	Hudsonian orogeny
	?Metasediments, pelites quartzite	Metasediments, pelitic gneiss and schist	Metasediments (Karrat Group), pelitic ans semi-pelitic gneiss and schist, marble, quartzite, amphibolite
ARCHAEAN	Kap York meta-igneous Complex, acid to basic	Basic meta-igneous rocks, metadolerite, amphibolite (group 2)	Discordant amphibolite dykes
	Basement gneiss complex with amphibolites, meta-sediments, ironstone units	Basement gneiss complex with amphibolites (group 1), ultramafics, metasediments, ironstone units	Basement gneiss complex with amphibolites, ultra-afics, leucogabbro anorthosite

post-date the gneisses and early amphibolites (group 1), and at least some of the rusty-weathering supracrustal rocks.

South of Melville Bugt between Red Head (75°15′N) and Upernavik (72°50′N) the Archaean gneisses are overlain by a thick and very extensive rusty-weathering metasedimentary cover sequence correlatable with the Karrat Group of the Umanak region (Escher & Stecher, 1978; Escher, in press). Escher & Stecher (1980) recognise a division into an upper, thick unit of metagreywacke gneiss (interlayered semi-pelitic and pelitic rocks) and a much thinner, basal unit of carbonate, pelite, quartzite and amphibolite. These units are referable to the Nukavsak Formation and the Qeqertarssuaq Formation respectively (Escher, in press). The metasediments, seen by us in 1980 in Melville Bugt as relatively thin units complexly folded within the gneisses, contain lithologies that are similar to some of those described by Escher & Stecher (1980).

However, one notable difference is that the Melville Bugt metasedimentary sequences often contain ironstone as an important rock type; in contrast, no ironstone has been reported from the entire Red Head – Upernavik region. The most southerly ironstone outcrops seen by us in 1980 occur in the metasediments of the Kap Seddon district on the southern extremity of the study area, just north of Red Head. This distribution of ironstone-bearing supracrustals may indicate a fundamental difference in the ages of supracrustal rocks north and south of 75°N.

It is important to stress that in Melville Bugt not all supracrustal units contain ironstone and in the Kap Seddon district alone a field distinction was made into ironstone-bearing metasedimentary units and those composed almost entirely of pelitic and semi-pelitic schists. Furthermore, the ironstone-bearing supracrustal units at Kap Seddon are cut by discordant amphibolites (group 2) that are interpreted as part of the Archaean meta-igneous suite (see above). If this age designation is correct then these supracrustals are of Archaean age. In contrast no amphibolite dykes and discordant meta-igneous rocks occur in the metasediments between Red Head and Upernavik (Escher & Stecher, 1978) and isotopic dating of those metasediments suggests a Proterozoic age (F. Kalsbeek, *in* Escher & Stecher, 1980).

Thus there is evidence that the Greenland Shield in this region contains both Archaean and Proterozoic supracrustal suites. Escher & Stecher (1980) observed that the Karrat Group diminishes northwards so that between 73°N and 74°30′N the metasediments form as much as 80 per cent of the exposed rocks, while to the north they only form a few isolated outcrops within the Archaean gneisses such as on Red Head. This change in the outcrop ratio of basement gneiss to metasediment cover is particularly noteworthy and it must reflect the deeper level of crustal exposure towards the north; thus in southern Melville Bugt mainly Archaean basement with ironstone-bearing supracrustals is exposed. The eventual discovery of ironstone within supracrustal relicts in the gneisses south of 75°N would provide evidence to support the model put forward here.

The youngest episodes of regional deformation, metamorphism and remobilisation that affected Melville Bugt and regions to the north and south are referred to the Proterozoic (Hudsonian) orogeny (Table 1). This produced amphibolite-facies mineral assemblages and the present disposition of the supracrustal units.

Acknowledgements. We thank Andreas Viðstein, skipper of *K. J. V. Steenstrup,* for his support despite difficult ice navigation; Peter Hyldegaard Jensen and Olav Winding for field assistance; and Erik Arnholtz and Jørgen Madkjær (Thule Air Base) for liaison of the field activity. T. F. is grateful for transport to and from Greenland by aircraft of the Polar Continental Shelf Project and the Canadian Forces, respectively.

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Sedimentological observations in Cretaceous and Tertiary rocks in the northern part of the West Greenland sedimentary basin

Frank Andreasen

As part of the programme to produce geological maps at a scale of 1:100000 field work was carried out in the eastern part of the area covered by map sheet 71 V.1 N (Svartenhuk Halvø). Reconnaissance work was carried out in parts of the area covered by map sheet 72 V.1 S.

At a number of localities detailed sedimentological sections were measured at a scale of 1:100. Emphasis was laid on the registration of primary sedimentary structures and grain-size distribution. A large number of palaeocurrent measurements were carried out in order to describe the depositional environments and to enable an interpretation of the development and geometry of the sedimentary basins to be made.

Itsako

In spite of relatively poor exposures a more or less continuous section could be measured through both Cretaceous and Tertiary rocks on the north-eastern slope of the Itsako peninsula. Formal names have not yet been given to the Cretaceous and Tertiary rocks in the Svartenhuk area.

The lower part of the Cretaceous sedimentary sequence is dominated by medium and coarse grained arkosic sandstones deposited by large braided rivers. Transport directions were towards the west and north-west. The middle part of the sequence consists of sandstones similar to the lower part but deposited between thick units of black marine mudstones with abundant plant fragments. The mudstone sedimentation was a consequence of basinal downwarp resulting in an upstream trapping of fluvial sands. The upper part of the Cretaceous sequence on Itsako consists of a thick unit of black mudstones.

In the (?)Paleocene (Croxton, 1978) a 5–10 m thick coarse conglomerate with well rounded boulders up to 50 cm in diameter initiates Tertiary sedimentation in the area as a result of renewed tectonic activity. The conglomerate is in turn followed by fine grained sandstones and by a thick unit of black mudstones with intercalations of fine grained