



The North-East Greenland project 1988–1990

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The third and last season of the North-East Greenland project between latitudes 75° and 78°N was completed in July and August 1990. The main aims of the studies in North-East Greenland include compilation of a 1:500 000 geological map sheet covering the area between Grandjean Fjord (75°N) and Jökelbugten (78°N), and regional geological investigations to provide an understanding of the general geology of the region. A preliminary evaluation of the potential for hydrocarbons and mineral resources was included in the project, and took the form of investigations of the onshore remnants of Phanerozoic sedimentary basins (Stemmerik & Piasecki, 1990) and a geochemical exploration reconnaissance.

North-East Greenland is geologically part of the c. 400 million year old East Greenland Caledonian fold belt, which can be traced for over 1100 km along the east coast of Greenland between Scoresby Sund in the south and Kronprins Christian Land in the north (Fig. 1). This fold belt is developed at the eastern border of the Precambrian Greenland shield and includes reactivated Precambrian crystalline complexes and deformed thick Upper Proterozoic – Ordovician sedimentary sequences. During the Caledonian orogeny the Precambrian crystalline complexes and the overlying sediments were folded and metamorphosed, and uplifted regions of Caledonian deformed rocks were transported westwards over the foreland of the Greenland shield on major thrusts. In the southern part of the fold belt, south of 76°N, Caledonian granites and associated plutonic rocks were intruded. The post-Caledonian development was characterised by the formation of sedimentary basins with deposition of thick sequences of Devonian – Lower Permian continental sediments and Upper Permian – Cretaceous mainly marine sediments. Remnants of these sequences are preserved in faulted blocks in the coastal areas. During the Tertiary, basaltic lava flows were extruded over wide areas and basic sills were intruded into the sedimentary sequences; this volcanic activity was associated with the opening of the North Atlantic Ocean. Tertiary basalts and sills mainly occur in the easternmost coastal region south of 76°N.

Geological activities in the 1990 season included: (1) Mapping of the crystalline complexes north of Dove

Bugt and on Store Koldewey (mainly between c. 76° 40' and 78°N, Fig. 2), and collection of material for radiometric age determinations. (2) Detailed structural investigations of a key area in inner Dove Bugt previously mapped in 1989. (3) Mineral prospecting including sampling of stream sediments for geochemical reconnaissance exploration and investigations of anomalies determined from 1988 and 1989 sampling programmes. (4) Continued sedimentological studies of the Late Precambrian Eleonore Bay Group between Canning Land and Lyell Land (71° 40'–73°N) south of the main mapping area. (5) Studies of the Quaternary geology in an east–west zone between the outer coast and the Inland Ice, north of Dove Bugt, in order to investigate the history of the region mainly in relation to the late and post-glacial development. (6) Glaciological studies of the Inland Ice margin by a group from the Alfred Wegener Institute for Polar and Marine Studies, Bremerhaven, Germany, a continuation of the 1989 programme.

Logistic organisation

North-East Greenland is uninhabited apart from a few military outposts and the weather station at Danmarkshavn; these are the only support facilities in the region. The Survey's work had therefore to be organised on an expedition basis as a self-supporting activity, which included supply of all provisions and equipment and operation of chartered aircraft. The logistic framework was organised by the Geological Survey of Greenland (GGU), and made possible by cooperation with other institutions active in the region: notably Grønlands Landsmuseum, Godthåb/Nuuk and the Alfred Wegener Institute for Polar and Marine Studies. The expedition numbered in all 38 persons. Twenty-five of these made up the GGU party: 17 were geologists and assistants and the remaining eight formed the support and transport group. The field season extended from 1st July to 27th August.

A tent base camp was established near Hvalrosodden at the site also used in 1989 (Fig. 2). Local transport was provided by two small helicopters from Uni-Fly, Svendborg, and a Twin Otter aircraft from Flugfélag Norður-



Tightly folded banded gneiss with lenses and schlieren of amphibolite (former basic intrusions). The finely banded structure is the result of intense ductile shear in high strain zones, prior to the folding episode. Germania Land, 4 km west of Danmarkshavn, North-East Greenland. Photo: N. Henriksen.

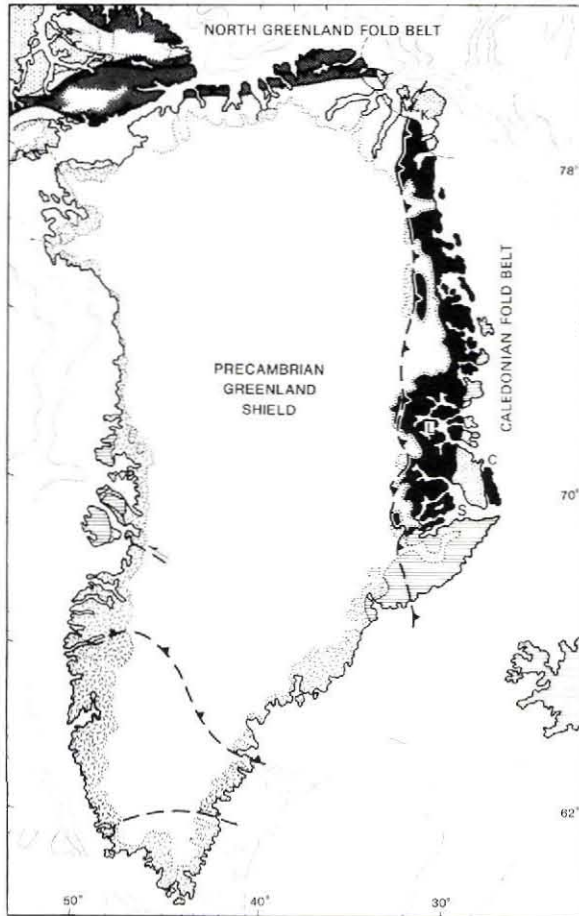


Fig. 1. Structural divisions of Greenland. Post-Caledonian rocks shown by open dotted signature (Upper Palaeozoic and Mesozoic) and horizontal lines (Tertiary volcanics). K: Kronprins Christian Land, L: Lyell Land, C: Canning Land, S: Scoresby Sund.

lands, Akureyri; both were chartered through Greenlandair Charter. Transport between Denmark and East Greenland was by C-130 Hercules aircraft chartered from the Royal Danish Air Force.

Crystalline rocks

Crystalline rocks dominate the Caledonian fold belt in North-East Greenland. Marginal zones of the fold belt and parautochthonous foreland units crop out in nunataks along the margin of the Inland Ice to the west, whereas the bulk of the crystalline units in the present day exposures are thought to represent uplifted deep levels of the Caledonian fold belt. The folded cover of Upper Proterozoic Eleonore Bay Group is preserved only in areas south of Bessel Fjord (76°N).

In the Dove Bugt region (76° – 77°N) a very complex structural history has been unravelled; an old supra-crustal suite and later orthogneisses have been subjected to at least four periods of deformation (Chadwick *et al.*, 1990; Chadwick & Friend, 1991). It is not yet known how much of this deformation history is Caledonian and how much is a relict of pre-Caledonian orogenies. In Dronning Louise Land there is a clear west to east increase in Caledonian deformation and metamorphism from weak influence in the foreland furthest west, to a strongly folded zone in the east where amphibolite facies metamorphism accompanied deformation (Friderichsen *et al.*, 1990).

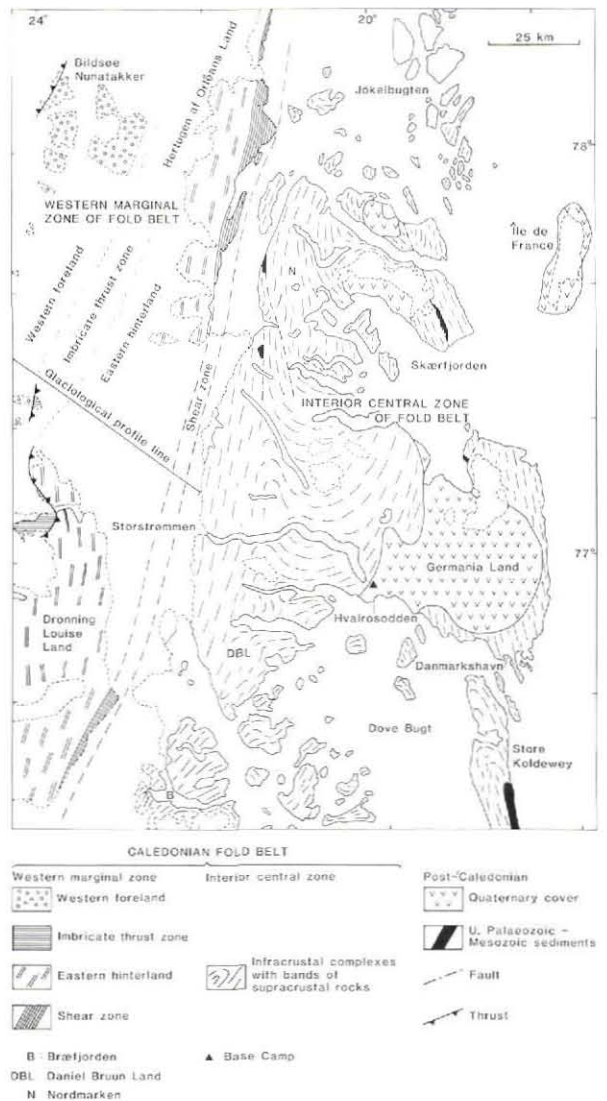


Fig. 2. Geological sketch map of the Dove Bugt – Jökelbugten region in North-East Greenland.

The 1990 work in the crystalline areas included investigations by four two-man teams in the western sector of the fold belt in Hertugen af Orléans Land and on Bildsøe Nunatak, and in the central zone of the fold belt north of Dove Bugt and on Store Koldewey (Fig. 2). The work in the western sector was concentrated on a major NNE-trending ductile shear zone in Hertugen af Orléans Land (Strachan *et al.*, 1991). The autochthonous or parautochthonous foreland rocks which make up Bildsøe Nunatak and other nunataks west of the shear zone were investigated only by helicopter reconnaissance. They appear to have a similar tectono-stratigraphic framework to that established in Dronning Louise Land where a crystalline basement of early Proterozoic age is overlain by two metasedimentary sequences of Middle Proterozoic and Upper Proterozoic – Cambrian age (Friderichsen *et al.*, 1990).

Mapping in the crystalline complexes north of Dove Bugt and on Store Koldewey has shown that this region of the fold belt is dominated by a heterogeneous complex of high-grade orthogneisses with inclusions and bands of older mafic intrusions and metasedimentary rocks (Friderichsen *et al.*, 1991). The structural development includes at least three fabric forming events, as well as formation of late to post-orogenic mylonites and faults, and is probably partly Caledonian and partly pre-Caledonian. The brittle deformation in the fault zones is probably post-Caledonian.

Locally, fault bounded outcrops of Carboniferous and Mesozoic sedimentary sequences unconformably overlie the crystalline complexes (Stemmerik & Piasecki, 1990). The 1990 regional mapping located several new outcrops, and pollen and fossils isolated from samples collected indicate Upper Carboniferous and Jurassic ages (L. Stemmerik & S. Piasecki, personal communication, 1990).

A sampling programme for a radiometric age determination project on the crystalline complexes using the $^{40}\text{Ar}/^{39}\text{Ar}$ method was undertaken in collaboration with R. D. Dallmeyer, partly financed by a grant from the U.S. National Science Foundation. Results from this work, together with results from other radiometric age determination programmes are expected to provide a basis for distinction of the Caledonian and pre-Caledonian elements within this part of the Caledonian fold belt.

Detailed structural investigations in south-west Dove Bugt

A detailed structural study of the high-grade orthogneisses and interbanded supracrustal rocks in the south-west part of Dove Bugt was carried out by

B. Chadwick and C. R. L. Friend. Mapping of this area in 1989 (Chadwick *et al.*, 1990) revealed an extremely complex group of gneisses that showed evidence of at least four phases of folding and several periods of mylonitisation. As the area is very well exposed and was thought geologically representative of a substantial part of the crystalline complexes of North-East Greenland, the opportunity was taken to make detailed studies of a limited area. Mapping was carried out at a scale of 1:20 000 between Bræfjorden (76° 25'N) and south-east Daniel Bruun Land (76° 45'N) (Chadwick & Friend, 1991).

Mineral prospecting and geochemical exploration

Geochemical exploration, largely based on collection of water and stream sediment samples, has been carried out in all three seasons of the project (Henriksen, 1989, 1990). In 1989 and 1990 all geological parties participated in the sampling programme, and in 1990 approximately 200 sand and silt samples were collected between latitudes 77°N and 78°N, corresponding to a sampling density of one sample to 30 km². All samples will be analysed for about 50 elements and the resulting data used to evaluate the mineral prospecting potential.

Ground control of geochemical anomalies and various other indications detected in earlier seasons was undertaken in 1990 and 10 sites were studied in detail (Jensen & Stendal, 1990). In addition supplementary stream sediment sampling was made where there were gaps in the regional coverage. The detailed studies included scintillometer measurements, sampling of mineralised rocks and their host rocks for whole rock analyses and sampling for Pb-isotope studies of ore minerals. Mineralisation was investigated in some of the major NNE-trending Caledonian shear zones in Dronning Louise Land and in Hertugen af Orléans Land, as well as fault-hosted pyrite mineralisation in Nordmarken and Germania Land, and mineralisation at contacts between granites and metasediments and gneisses.

A particularly interesting mineralisation found in 1990 was located in one of the late faults cutting the crystalline units in northern Germania Land which contained oil relicts in small cavities in a brecciated, silicified fault zone with pyrite mineralisation; the rock had a strong petroliferous odour. The oil probably migrated along the brecciated fault zone from a source area in one of the post-Devonian sedimentary basins. Preliminary geochemical investigations of this altered crude oil point towards a non-marine source rock, presumably of Carboniferous or Jurassic age (F. G. Christiansen, personal communication, 1990).

Upper Proterozoic sediments

Sedimentological studies of the Upper Proterozoic Eleonore Bay Group were initiated in 1988 in the area between 73° 45' and 76°N (Sønderholm *et al.*, 1989). Further investigations were carried out in 1989 (Sønderholm & Tirsgaard, 1990) and in 1990 (Tirsgaard & Jakobsen, 1990), partly financed by a grant from the Danish National Science Research Council. The main aims of these studies have been to provide a sedimentological description and analysis of the lower and central part of the Upper Eleonore Bay Group (the so-called Quartzite 'series' and Multicoloured 'series') and to establish the general depositional evolution of the Eleonore Bay Group basin; a transition from dominantly siliciclastic deposition (the Argillaceous–Arenaceous 'series', Lower Eleonore Bay Group) to extensive, carbonate platform deposition (Limestone–Dolomite 'series'; Upper Eleonore Bay Group), is represented. A lithostratigraphical revision of the group according to modern nomenclature rules will be made.

Quaternary geology

A reconnaissance of the Quaternary geology was carried out between eastern Dronning Louise Land and Île de France. This work was arranged in co-operation with the PONAM project (Late Cenozoic Evolution of the Polar North Atlantic Margins, partially financed by the European Science Foundation), which in 1990 had its main activity in the Scoresby Sund region (*c.* 71°N).

The Quaternary geological work included detailed investigations of sedimentary sections, mapping of ice margin positions and observations of the raised shore lines and marine limits; material was collected for radiocarbon dating and aminoacid diagenesis analysis (Landvik, 1990).

The investigations have shown that the marine limits occur at *c.* 30 m a.s.l. in the inner fjords and at *c.* 60 m a.s.l. on the outer coast, and that an almost continuous till cover exists above the marine limits. Four major successive stages of ice-front positions have been identified between the outer coast and the present margin of the Inland Ice. In three regions Quaternary sediments were found underlying till deposits, and these probably contain material older than the last glaciation.

Glaciology

Investigations of the present dynamic and climatic conditions at the margin of the Inland Ice west of Germania Land were continued by a team from the Alfred Wegener Institute for Polar and Marine Studies. The

work included a survey along an 80 km long profile established in 1989 (Reeh & Oerter, 1990) extending WNW from the ice margin. Studies of ice movements and mass balance were undertaken along this profile with reference to a set of survey poles drilled into the ice in 1989. Detailed precision and height measurements of a new set of poles gave an indication of short time variations in movement and ablation. A major part of the glaciological programme comprised collection of surface ice samples for oxygen isotope analyses with a view to establishment of a palaeoclimatic record for North-East Greenland. A continuation and elaboration of the work initiated in 1989 along a 2000 m long profile near the ice margin, from which samples had been collected at $\frac{1}{2}$ –1 m intervals, was carried out in 1990, when a further 2200 samples were collected. An automatic meteorological station established at the rim of the ice was in continuous operation for about two months (July and August), whereas a similar automatic meteorological station erected on the ice about 40 km from the ice margin was in operation for three weeks in July.

Topographic mapping

In connection with the geological mapping, the entire region between 75°N and 78°N has, in the course of the project, been subjected to photogeological interpretation in GGU's photogrammetric laboratory (Hougaard *et al.*, 1991). At the same time a new set of 1:100 000 topographic maps with 100 m contour intervals was prepared, based on aerial photographs and ground control points supplied by Kort- og Matrikelstyrelsen (KMS), Denmark. In cooperation with KMS, the topographic data in these maps are used in the production of new KMS 1:100 000 orthophotographic maps.

Status and future work

With the completion of this project the entire region between Grandjean Fjord – Shannon (75°N) in the south and Bildsøe Nunatakker – Jökkelbugten (78°N) in the north has been mapped in sufficient detail for publication of a 1:500 000 geological map (Dove Bugt – sheet 10). At the same time general geological investigations in this and adjacent areas have been carried out covering most aspects of the regional geology: Precambrian and Caledonian crystalline complexes, Proterozoic and Lower Palaeozoic sediments, post-Caledonian sediments and Tertiary basalts. A geochemical exploration programme has been undertaken in the greater part of the mapped region, and anomalies of interest in connection with mineral prospecting have been followed up on the ground. Quaternary geological investigations have

been undertaken in an east-west zone at about 77°N, selected to provide a representative picture of the glacial geology of the region. In collaboration with the Alfred Wegener Institute for Polar and Marine Studies, a study of the present dynamic and climatic conditions at the margin of the Inland Ice were included in the project. The various programmes were all completed essentially as planned, working up of the collected material is in progress, and results will be published in international journals and GGU's own publication series.

In the Survey's 1:500 000 geological map series one of the few essentially unmapped regions is that of map sheet 9, Lambert Land (78°–81°N) in North-East Greenland. It is planned that essential field work will be undertaken here after 1993, and depots of some camp equipment and supplies have been made at Hvalrosodden in preparation for this project.

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