Eastern North Greenland 1994, the 1:500 000 mapping project

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The second field season of the Geological Survey of Greenland's (GGU) mapping project in eastern North Greenland (1993–95) was carried out according to plan and with full accomplishment of all geoscientific goals. The programme aims at producing a general overview of the onshore geology of the Jøkelbugten to Kronprins Christian Land region (78–81°N) in eastern North Greenland (Fig. 1) to be compiled as sheet no. 9 in GGU's 1:500 000 geological map sheet series; this is the last remaining incomplete map sheet at this scale in North and North-East Greenland. The field work was initiated in 1993 with limited reconnaissance work (Henriksen, 1994a), and in 1994 the first of two more intensive field campaigns was carried out. In addition to establishing a general overview of the regional geology the work aims at obtaining an evaluation of the economic geological potential of the region, in respect of both minerals and hydrocarbons. Two glaciological programmes were fully integrated with the project: one was carried out by the Alfred Wegener Institute (AWI), Bremerhaven, Germany, while the other was partly based on a special grant from the Nordic Council of Ministers.

Field work was carried out during seven weeks in July–August with participation of a total of 47 persons, including 31 geoscientists. The work was supported by two helicopters and a small fixed wing aircraft, which operated from a tent base camp at Centrum Sø, south-west Kronprins Christian Land, the site used in 1993 (Fig. 1).

Regional geological studies

Eastern North Greenland encompasses the northern part of the East Greenland Caledonian fold belt. West of the fold belt an extensive foreland region comprises an unfolded Middle Proterozoic to Lower Palaeozoic sequence of sediments and volcanics, while in the coastal regions of eastern Kronprins Christian Land post-Caledonian sediments belonging to the Wandel Sea Basin are found. The Caledonian fold belt includes reactivated Precambrian crystalline basement rocks as well as folded and metamorphosed representatives of the Proterozoic–Palaeozoic sequences found in the foreland.

The field work in 1994 covered most aspects of the regional geology and included the following main projects:

- Structure and petrology of the crystalline complexes in the Caledonian fold belt.
- Sedimentology and stratigraphy of the Upper Proterozoic Rivieradal sedimentary succession in Kronprins Christian Land.
- Biostratigraphy and sedimentology of the Lower Palaeozoic carbonate sediments in Kronprins Christian Land.
- Thin-skinned structural studies of the Caledonian fold belt in Kronprins Christian Land.
- Sedimentology and biostratigraphy of the Upper Palaeozoic sediments of the post-Caledonian Wandel Sea Basin in the eastern coastal regions of Kronprins Christian Land.

Preliminary results of the field work have been summarised by the participating geoscientists in an internal GGU report (Henriksen, 1994b), which forms the basis for the following presentation.

The crystalline complexes which are widely exposed in the region between Jøkelbugten and Lambert Land (78°–79°N) mainly represent segments of the Precambrian Greenland shield which have been reactivated during the Caledonian orogeny; two mapping teams undertook investigations of these rocks in 1994. The region around Jøkelbugten and the nunataks to the west are dominated by basement gneiss complexes of Early Proterozoic age, which are overlain by Middle Proterozoic sandstones correlated with the Independence Fjord Group of North Greenland (Higgins *et al.*, 1991; Jepsen *et al.*, 1994). Both units are dissected by abundant basic dykes and sills, which may correlate with the 1250 Ma old Midsommersø Dolerites of North Greenland (Kalsbeek & Jepsen, 1983). All units were subsequently deformed and regionally metamorphosed to at least amphibolite facies during the Caledonian orogeny. On Lambert Land six Caledonian nappe units have been distinguished involving crystalline basement and Proterozoic cover sequences. The Middle Proterozoic sandstones and dykes are also widely exposed in Caledonian nappe units in central Kronprins Christian Land (Figs 1, 2). Several late Caledonian ductile shear zones occur in Lambert Land, the most prominent a NNE-trending shear zone which may be a continuation of the Storstrømmmen shear zone known further south (Strachan & Tribe, 1994).

The 'Rivieradal sandstone' succession is confined to allochthonous nappe units in the northern part of the East Greenland Caledonides, and is partly equivalent to the late Proterozoic Hagen Fjord Group (Clemmensen & Jepsen, 1992). Work in 1994 suggests the total thickness of this allochthonous succession is of the order of 7500–10 000 m, well in excess of previous estimates. In the northern part of the region near Ingolf Fjord a sequence more than 4500 m thick was recorded; basal conglomerates are succeeded by a thick phyllitic unit and more than 2 km of turbiditic sandstones and mudstones. Farther west part of the sequence has been interpreted as deposited on a storm and tide dominated shelf, a contrast with earlier interpretations of the 'Rivieradal sandstones' as an entirely deep-water succession.

The Lower Palaeozoic carbonates of East and eastern North Greenland were deposited in the coastal regions of a proto-Atlantic ocean (Iapetus), and studies of faunal and sedimentological developments are expected to shed light on the original relationships between the now separated areas, especially between Svalbard and eastern North Greenland. The studies of the Lower Palaeozoic carbonates in southern Kronprins Christian Land have shown that the Ordovician carbonate sequence occurring beneath the Caledonian Vandredalen nappe is not, as formerly described, a nappe unit containing distal equivalents of the shelf succession (Harefjeld Formation; Hurst 1984); the sequence is divisible into formations and members recognised in the foreland shelf succession, but sheared and folded to a variable degree during the Caledonian orogeny. The Lower Palaeozoic carbonate successions in both foreland and fold belt were systematically sampled for stratigraphical and palaeoecological studies based on conodonts and other fossils (stromatoporoids, corals, gastropods and cephalopods, together with rarer brachiopods and trilobites).

Structural and lithostratigraphical observations in the Caledonian thrust belt of Kronprins Christian Land resulted in confirmation and elaboration of the thin-skinned tectonic model proposed in 1993 (Jepsen *et al.*, 1994). An E–W trending cross-section through the Middle and Upper Proterozoic units making up the Vandredalen nappe suggests displacement is of the order of 35–50 km, somewhat less than the *c.* 150 km proposed by previous workers (e.g. Hurst & McKerrow, 1981). The platform sequence west of the main nappe front is disturbed by thin-skinned thrusts with generally minor displacements of a few kilometres, with associated open to tight folding developed on steep axial planes. A three stage thrust development model is suggested, with ramping in the Independence Fjord Group producing an elevated region, represented at the present day by the high alpine area of the Prinsesse Caroline Mathilde Alper which forms the backbone of the Caledonian fold belt in Kronprins Christian Land.

Work in the post-Caledonian Wandel Sea Basin sequence in the coastal areas of Holm Land and Amdrup Land included detailed sedimentological and biostratigraphic investigations of the Carboniferous to Permian part of the sequence. The lowest part of the succession comprises an over 100 m thick sequence of Lower Carboniferous fluviatile sandstones and shales (Stemmerik & Håkansson, 1991). These are overlain by marine mid-Carboniferous to Permian sediments dominated by carbonates. One of the main aims of the 1994 investigations was the collection of fusulinids for dating, and detailed section measurement and sampling. The successions occur in two fault blocks; southern Amdrup Land makes up one fault block where the succession shows only local deformation, while a northern Amdrup Land fault block is characterised by folding and shearing along NNW–SSE trending faults. A new Upper Palaeozoic unit was recognised in southern Amdrup Land, tentatively correlated with late Early Permian sediments known in eastern Peary Land (Håkansson & Stemmerik, this report).

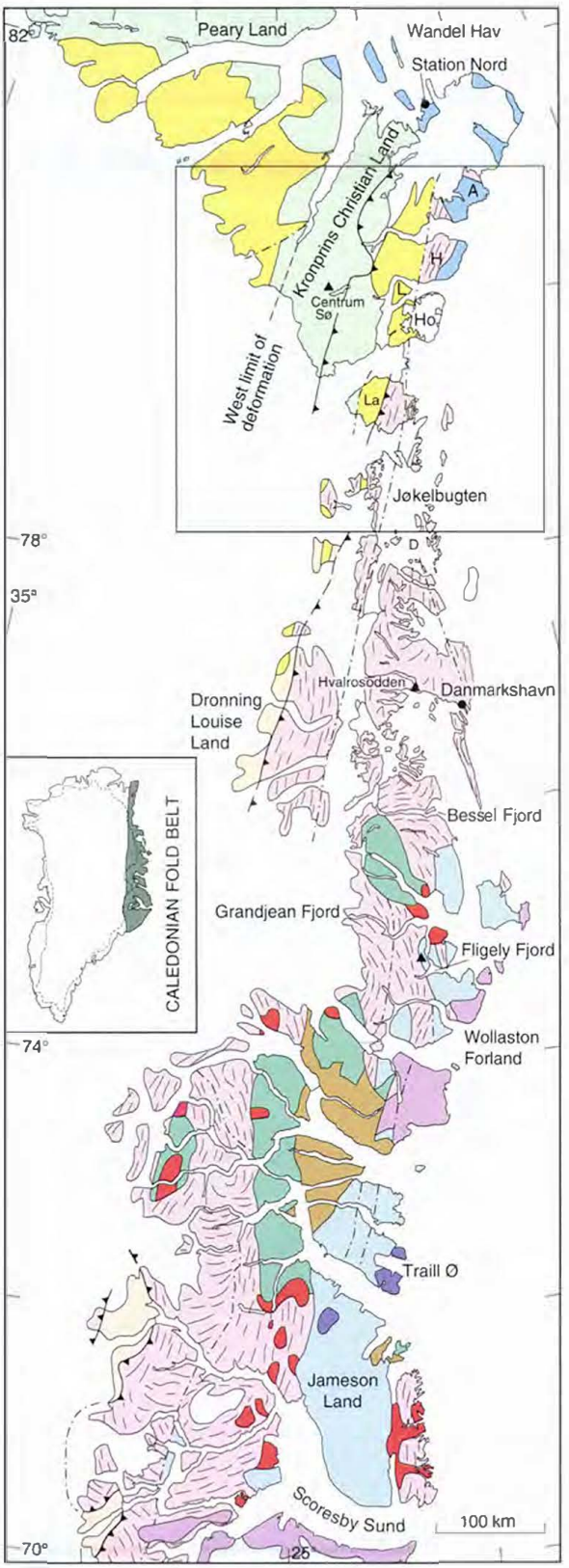
In addition to the main regional projects outlined above, two special research projects were undertaken in 1994, one concerning eclogites and the second $^{40}Ar/^{39}Ar$ radiometric dating.

Eclogitic rock assemblages were recognised during earlier GGU field work in North-East Greenland (Gilotti, 1994) and became the target for additional investigations because of their unique character and special importance as indicators of crustal thicknesses in excess of 60 km during the Caledonian orogeny. The investigations in 1994 expanded the already known extensive eclogite province in North-East Greenland to a region more than 300 km long and 120 km wide. Intensive sampling of the eclogites and detailed studies of their field occurrence will provide a basis for new laboratory investigations, which are expected to establish the age of emplacement of these rocks and provide clues to their history of formation in the crust. These considerations will influence plate tectonic models for the Caledonian orogeny in the North Atlantic region.

More than 80 large samples were collected from a variety of rock types for a programme of $^{40}Ar/^{39}Ar$ age dating within the Caledonian fold belt, a continuation of earlier studies (Dallmeyer *et al.*, 1994). The main aim of this study is to determine the age and character of the late phases of Caledonian tectonothermal activity. Other research objectives include the ages of detrital minerals in pre-Caledonian sediments, and the age of formation of late Caledonian shear zones.

Economic geology investigations

GGU's project in eastern North Greenland includes special investigations related to the mineral and petroleum potential of the region.



POST - CALEDONIAN

- Tertiary basalts
- Tertiary intrusions
- Wandel Sea basin: Carboniferous - Tertiary sediments
- East Greenland basin: Carboniferous - Cretaceous sediments

LATE TO POST - CALEDONIAN

- Devonian - continental sediments

CALEDONIAN FOLD BELT

- Late to post - kinematic granites
- Late Proterozoic - Ordovician sediments (East Greenland)
- Late Proterozoic - Silurian sediments (North Greenland)
- Middle Proterozoic sediments and basalts (North Greenland)
- Crystalline complexes (Archaean - Middle Proterozoic)

CALEDONIAN FORELAND

- Late Proterozoic - Silurian sediments (North Greenland)
- Middle Proterozoic sediments and basalts (North and North-East Greenland)
- Crystalline rocks - Greenland shield
- Thrust
- Fault/shear zone
- ▲ Base camp

Fig. 1. Geological map of the Jøkelbugten – Kronprins Christian Land region, eastern North Greenland. The limits of 1:500 000 map sheet 9 (78°– 81°N) are indicated by the frame. A: Amdrup Land; H: Holm Land; L: Lynn Ø; Ho: Hovgaard Ø; D: Dove Bugt; La: Lambert Land.

Fig. 2. Middle Proterozoic Independence Fjord Group sandstones cut by basic dykes and sills (Midsommersø Dolerites) in central Kronprins Christian Land; looking north-west across Ingolf Fjord. The dykes in the up to 1400 m high fjord cliffs outline major westward overturned Caledonian folds. Photo: Jakob Lautrup.

The 1994 reconnaissance geochemical programme included collection of *c.* 180 stream sediment and water samples by helicopter in a *c.* 100 km broad zone of Kronprins Christian Land, between the outer coast and the margin of the Inland Ice. In addition *c.* 100 stream silt samples were collected in more detailed ground traverses, and 47 large sand samples were taken for heavy mineral concentrates. The collections were undertaken in the area north of that sampled in 1993, and the entire region between Lambert Land and central Kronprins Christian Land (79°–81°N) is now covered by a reconnaissance geochemical survey. All the main geological units within the map sheet are represented in the stream sediment sample collection and the samples will be analysed for major and trace elements.

Indications of mineralisations detected by the 1993 programme were followed up in 1994 by ground work from camp locations in the crystalline basement, the shear zones of Lambert Land, Cu-mineralisation in Middle Proterozoic basic volcanic rocks (Zig-Zag Dal Basalt Formation and Midsommersø Dolerites), and various sulphide indications in Upper Proterozoic sediments (Hagen Fjord Group and 'Rivieradal sandstone'). The Ordovician–Silurian platform carbonate succession was also investigated, mainly in zones with prominent limonite staining. Preliminary results confirm the existence of widespread Cu-mineralisation in the Middle Proterozoic volcanic rocks and demonstrate the presence of stratabound Cu and Pb mineralisations within the Lower Proterozoic Hagen Fjord Group sediments.

The mineral resource programme included a study of anomaly indications obtained from processed Landsat TM satellite images. Areas with probable hydrothermal alteration were located, and checked during field work. The existence of rusty weathering horizons in some of the Proterozoic and Palaeozoic sediments was confirmed. A conspicuous enrichment of hydroxyl-bearing minerals in a N–S trending Caledonian shear zone was detected as an anomaly on the Landsat TM images (Tukiainen & Thorning, this report).

Oil geological investigations included work in the Lower Palaeozoic sediments of southern Peary Land and parts of the post-Caledonian Wandel Sea Basin in eastern Kronprins Christian Land. Previously identified source rock

levels in the Cambro-Silurian sequence in central and western North Greenland (Christiansen, 1989) were sampled in detail from 10 localities spanning a *c.* 150 km west to east zone. Analyses of these samples will supplement existing oil geological data from central and western North Greenland, and make it possible to complete an assessment of the Lower Palaeozoic Franklinian Basin. The petroleum geological studies in the Wandel Sea Basin sequence, aimed at generating data for basin modelling, include sampling for thermal maturity analyses in the Upper Palaeozoic sediments from Holm Land and Amdrup Land, and from Mesozoic–Tertiary sediments north-west of Station Nord. Data on the maturity conditions in the Wandel Sea Basin will be compared with those in the Lower Palaeozoic Franklinian Basin.

Co-operation with other institutions

The field work in 1994 involved an extensive scientific and logistic collaboration with other institutions and commercial companies. The long term close cooperation with the Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, was continued with respect to their glaciological programmes, which were carried out as a fully integrated part of GGU's field work. These glaciological investigations were a continuation of work at Storstrømmen, a glacier at the Inland Ice margin west of Danmarkshavn (*c.* 77°N; Reeh *et al.*, 1994), and on profile lines established in 1993 at the margin of the Inland Ice south-west of Centrum Sø, Kronprins Christian Land. A separate AWI programme, involving an aeromagnetic survey in the spring of 1994 over a large part of Peary Land and extending onto the offshore areas to the north, was based on a partial logistic cooperation with GGU. A glaciological programme at Hans Tausen Iskappe in western Peary Land was also carried out in close cooperation with GGU's field party in North Greenland in 1994. This glaciological project was funded by the Nordic Council of Ministers, and includes investigations of the present and past climate and glacier dynamics in North Greenland by means of ice core records, ice margin studies and investigations of the glacial geology around the ice cap.

The German Federal Institute for Geosciences and Natural Resources (BGR) undertook a field campaign in North Greenland in July and August 1994 as a part of their project 'Correlations of Alpine Structural Events in Spitsbergen and Greenland': CASE. This project aims at studying the structure and geotectonic development of the opening of the North Atlantic Ocean between North Greenland and Svalbard. Their field work was based on a close logistic cooperation between GGU and BGR, although the two groups operated in different areas in North Greenland; sharing of transport capacity on fixed wing aircraft worked to the benefit of both institutions. Logistic cooperation between GGU and the mining company Platinova A/S was carried out as part of the continued investigation of the major stratiform lead-zinc deposit at Citronen Fjord in northern Peary Land. In connection with Platinova's major mobilisation effort in the early summer, fuel supplies for GGU were flown in to Station Nord. In return, GGU supported a Platinova field team in Kronprins Christian Land for part of the season, by providing some of their air transport in the region.

Future work

Field work in connection with the eastern North Greenland project will be completed with the 1995 summer season. Laboratory studies based on the field results and samples collected are expected to continue for several years.

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