Conclusion of the 1:500 000 mapping project in the Caledonian fold belt in North-East Greenland

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The second and last field season of the mapping project in the southern part of North-East Greenland (72°–75°N) was carried out in 1998 with full accomplishment of all planned goals. The general overview mapping of the East Greenland Caledonian fold belt has now been completed, in total covering a stretch of more than 1300 km between latitudes 70°N and *c.* 81°30´N (Fig. 1). The Survey's systematic regional 1:500 000 mapping programme in the East Greenland Caledonides started with mapping in the Scoresby Sund region (70°–72°N) in 1968, and in the course of 13 field seasons spread over 30 years has involved more than 50 geologists for one or more field seasons each; several Survey geologists have participated in all 13 field seasons. The mapping of the Caledonian fold belt and the adjacent pre- and post-Caledonian rocks will be presented on five 1:500 000 map sheets of which three are already published and a fourth is under compilation. The scientific results are documented in numerous publications both in international journals and in the Survey's own Bulletins and Reports. Review articles on various parts of the East Greenland Caledonian fold belt include those of Haller (1971), Henriksen & Higgins (1976), Higgins & Phillips (1979), Henriksen (1985, 1986), Hurst *et al.* (1985), Peel (1985), Peel & Sønderholm (1991), Higgins (1994) and Jepsen *et al.* (1994). Preliminary results of the 1997 and 1998 field work have been published in Survey reports (Higgins & Frederiksen 1998, 1999), and are summarised by Henriksen (1998) and in this article.

East Greenland Caledonides

The East Greenland Caledonian fold belt developed as a consequence of collision between the continents Laurentia (North America including Greenland) to the west and Baltica (North-West Europe) to the east following the closure of the Iapetus ocean in the late Ordovician – Silurian *c.* 440–400 million years ago. In Greenland the Caledonian fold belt developed along the eastern rim of the stable Precambrian Greenland shield and large regions are characterised by reworked Precambrian crystalline complexes overlain by Mesoproterozoic metasediments and Neoproterozoic to Lower Palaeozoic sedimentary successions. Throughout the length of the fold belt these diverse rock units were transported westwards as major thrust sheets and nappes with displacements of over 100 km, perhaps several hundred kilometres in places. The western border of the fold belt approximately follows the margin of the Inland Ice, along which a series of autochthonous to parautochthonous window complexes are intermittently exposed beneath the thrusts.

The occurrence of autochthonous to parautochthonous foreland windows along the west margin of the Caledonides implies that a wide zone along the west of the fold belt is essentially thin-skinned (Higgins & Leslie 1998); a thin-skinned deformation style is particularly well seen north of latitude *c.* 79°N where the transition from the main thrust front via a thin-skinned parautochthonous thrust belt to the autochthonous foreland is completely exposed. The rock units exposed in the northern parautochthonous windows have similarities with the foreland successions of eastern North Greenland. In the southern parautochthonous windows the units preserved differ markedly from the equivalent allochthonous successions in the fold belt to the east in that units equivalent to the Neoproterozoic Eleonore Bay Supergroup are absent in the windows and the Vendian and Palaeozoic successions in the windows are very much thinner than in the allochthon.

East of and structurally overlying the windows are major thrust units of intensely deformed polyorogenic gneiss complexes and their metasedimentary cover. These gneiss complexes dominate the East Greenland Caledonides and vary in character from region to region. Between *c.* 72°40´N and 81°N Palaeoproterozoic ortho-

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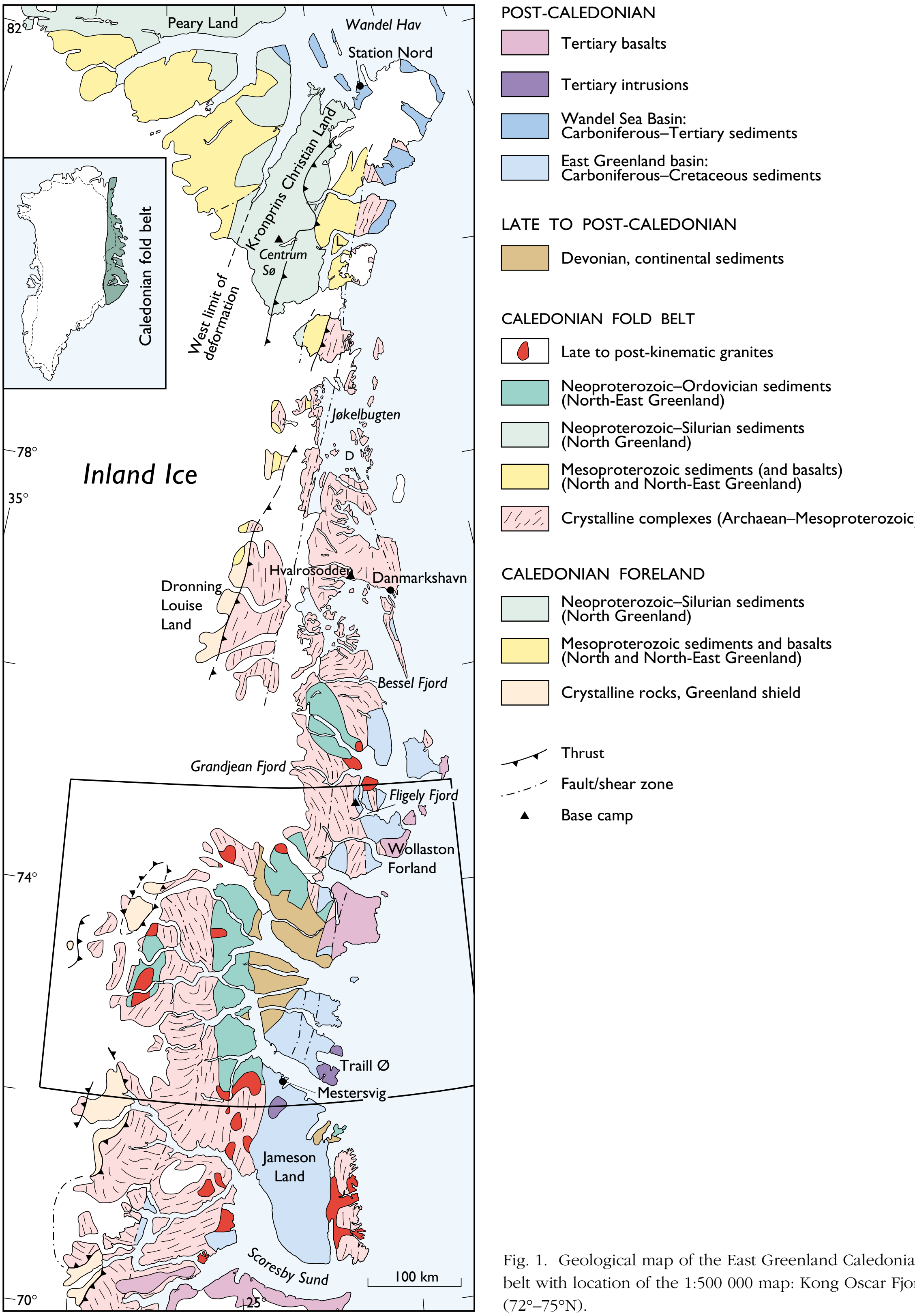

Fig. 1. Geological map of the East Greenland Caledonian fold belt with location of the 1:500 000 map: Kong Oscar Fjord (72°–75°N).

gneisses dominate, interpreted to have formed at the margin of an Archaean continent (Kalsbeek 1995). Exhumation of these gneiss complexes by thrusting during the Caledonian orogeny led to Caledonian deformation overprinting pre-existing deformation structures, and in some areas was accompanied by formation of Caledonian eclogites (Gilotti & Elvevold 1998). South of 72°40´N Archaean gneiss complexes prevail. In the southern half of the fold belt thick successions of Mesoproterozoic–Neoproterozoic metasediments structurally overlying the gneiss complexes are widespread.

Eastern parts of the southern half of the fold belt (*c.* 70°–76°N) have yielded isotopic evidence for Mesoproterozoic (Grenville) orogenic activity (950–1000 Ma). This activity included emplacement of a major suite of very coarse-grained granites as thick sheets and major bodies, and development of metamorphic overgrowths on detrital zircons in the Mesoproterozoic metasedimentary successions. Overlying these sequences in the central fjord zone of North-East Greenland are the thick successions of the Neoproterozoic Eleonore Bay Supergroup (14–15 km), Tillite Group (*c.* 1 km) and Cambro-Ordovician sediments (*c.* 3 km). The part of the fold belt preserving signs of Grenvillian activity (and the overlying sedimentary successions) may be confined to one or more major Caledonian thrust sheets. During the Caledonian orogeny the region affected by Grenvillian events was intensely reactivated, with widespread Caledonian migmatisation and granite emplacement. Distinction of Caledonian and Grenvillian deformation and plutonic events is a major problem in much of this region, which has only partially been resolved by isotopic studies. Both Grenville and Caledonian granites were apparently derived from melting of the same (or indistinguishable) Proterozoic metasedimentary rocks. Similarly the contact relationships of the Eleonore Bay Supergroup with underlying (older?) metasediments has provoked much discussion and intense study; in some areas the contact is an extensional fault, in other areas a thrust or shear zone.

Major westward and north-westward thrust displacements led to a piling up of nappes and thrust sheets to produce a major mountain chain, and it is known from the colour index of conodonts extracted from Ordovician sequences in the foreland windows that the overlying thrust pile reached thicknesses of 10–12 km (M.P. Smith and J.A. Rasmussen, personal communications 1999).

The field work in 1998 between latitudes 72°–75°N represents a re-investigation of areas extensively studied by geologists of Lauge Koch's expeditions (1926–58), whose results were published most notably in the compilations of Haller (1971) and Koch & Haller (1971) .

Field work organisation

The work in 1998 was a direct continuation of the field work in 1997 (Henriksen 1998) and based on the same basic logistic arrangements. The field investigations in 1998 were carried out during seven weeks between early July and late August with participation of a total

Fig. 2. Shifting of base equipment using a Twin Otter aircraft from a depot established in 1997 in the central part of Andrée Land.

of 43 persons including 29 geologists and ten student assistants (Henriksen 1999). The work was supported by two helicopters and a small, fixed wing Twin Otter aircraft (Fig. 2) which operated from Mestersvig, a former airport which is kept open for limited special operations by the military sledge patrol Sirius. The Survey group benefited substantially once again from base facilities at Mestersvig, organised and manned by the Danish Polar Center (DPC). Transport between Denmark and Mestersvig was carried out by the Swedish Air Force using a C-130 Hercules aircraft. As well as from Mestersvig, the helicopters operated during the season from a small unmanned satellite base established at Krumme Langsø 200 km to the north of Mestersvig.

In addition to the field teams working in the Caledonian fold belt the field party included three two-person Survey teams engaged in sedimentological studies in the post-Caledonian Upper Palaeozoic – Mesozoic successions, three Survey teams working with mineral prospecting and two teams from SAGA Petroleum working in co-operation with the Survey sedimentologists. Support was also given to a team from the Danish Lithosphere Centre (DLC) studying the Tertiary volcanic rocks of the nunatak region, and a group of four from the University Museum of Zoology, Cambridge, UK, engaged in palaeontological studies of vertebrate remains in Devonian sediments. During the season the Survey groups also co-operated with geologists from Oslo University, Norway and Massachusetts Institute of Technology (MIT), USA, who were investigating extensional structures and other late Caledonian features related to the formation of the Devonian–Carboniferous sedimentary basins.

Regional geological studies between 72°–75°N

The 1998 field work in the Caledonian fold belt supplemented the results from 1997 (Henriksen 1998), and was expanded northwards to cover the ground between latitudes 74° and 75°N. The terrain in the whole of the mapping region is characterised by rugged topography with mountains reaching almost 3000 m and dissected by wide fjords and glacial valleys, and with numerous local ice caps and glaciers. The main projects in 1998 included:

1. Pre-Caledonian basement in the crystalline complexes – a study using isotopic age determinations;
2. Structure and lithostratigraphy of the crystalline complexes;
3. Metamorphic studies of the infracrustal and supracrustal units;
4. Migmatisation processes and mechanisms, with studies of partial melting and emplacement patterns;
5. Sedimentology, lithostratigraphy and basin analytical studies of the Neoproterozoic Nathorst Land Group (Eleonore Bay Supergroup);
6. Sedimentology and basin analytical studies of the carbonate sediments in the Neoproterozoic Andrée Land Group (Eleonore Bay Supergroup);
7. Mineral resource investigations and follow-up of already located mineralisation sites and anomalies – especially those related to late Caledonian fault systems.

Preliminary results of the field work have been summarised by the participating geoscientists in a volume in the Survey's Rapport series (Higgins & Frederiksen 1999) which forms the basis of the following presentation.

Crystalline basement complexes

The Caledonian fold belt in the region mapped (72°–75°N) includes elements of at least four cycles of plate tectonic activity spanning from Archaean through Palaeoproterozoic and Mesoproterozoic to Caledonian time. The pre-Caledonian basement complexes are overlain by an up to 18–19 km thick succession of Neoproterozoic–Ordovician shallow-water sediments which are preserved as a low grade to non-metamorphic cover sequence and form part of a major Caledonian thrust complex. Caledonian granites are particularly concentrated in the contact zone between the Neoproterozoic sediments and the basement complexes.

The oldest, late Archaean, part of the basement complex lies in the southern part of the mapped region (Fig. 3). This extends southwards into the Scoresby Sund region (Henriksen 1986), where it is described as the Flyverfjord infracrustal complex. The characteristic rock types are amphibolite-banded orthogneisses with abundant ultrabasic lenses and cross-cutting amphibolitic basic dykes; Archaean ages of *c*. 3000–2600 Ma have been obtained from major orthogneiss units (Steiger *et al.* 1979; Rex & Gledhill 1981). During the present investigations this complex has been traced northwards to *c*. 72°40´N in Gletscherland (Thrane & Friderichsen 1999) and its Archaean age has been confirmed by a number of SHRIMP age determinations (F. Kalsbeek

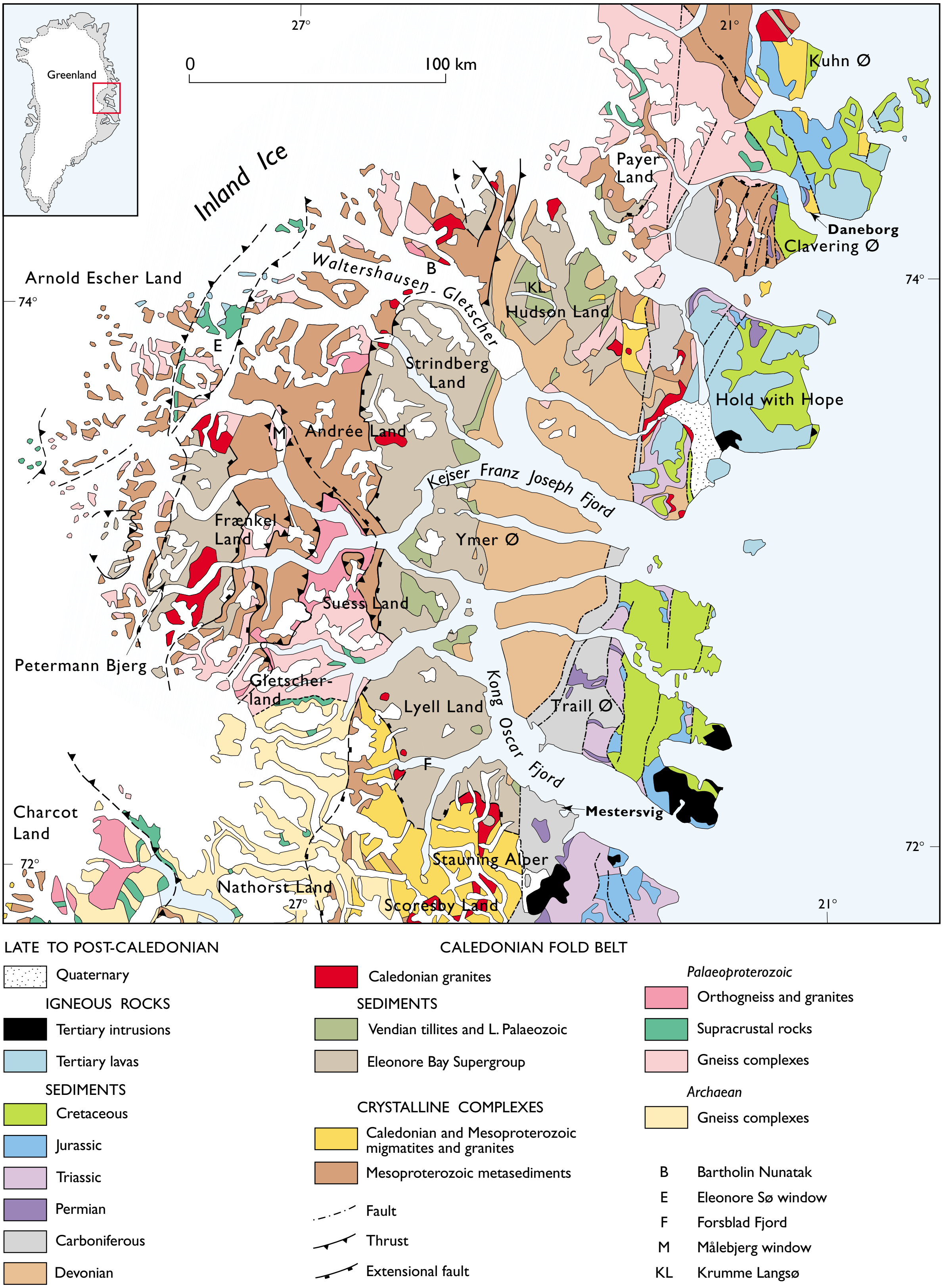

Fig. 3. Geological map of the Kong Oscar Fjord region, North-East Greenland.

and K. Thrane, personal communications 1999). A boundary between the Archaean complex and the Palaeoproterozoic gneiss complex to the north could not be established on field criteria alone, but its approximate position will probably be clarified by ongoing isotopic Rb/Sr model age studies and SHRIMP U–Pb zircon analyses.

The Palaeoproterozoic basement complexes north of 72°40´N comprise mainly grey gneisses with thin layers of supracrustal rocks and metamorphosed granitoid rocks. They represent remnants of a Palaeoproterozoic collisional orogen formed near the margin of an Archaean continent, and continue westwards and north-westwards to make up a major part of the Precambrian Greenland shield (Kalsbeek 1995). In the East Greenland Caledonides the Palaeoproterozoic basement complexes continue northwards to *c*. 80°N, and isotopic studies have revealed a spread of ages between *c*. 2000 and 1740 Ma (Kalsbeek *et al*. 1993); these imply that the orogenic cycles responsible for their formation extended over a period of *c*. 250 Ma. Within the study area of the present project (72°–75°N) new SHRIMP isotopic ages on zircons have yielded ages in the range 2000–1900 Ma (F. Kalsbeek and K. Thrane, personal communications 1999).

Evidence for a Mesoproterozoic (Grenvillian) event was previously documented by age determinations from both south and north of the present mapping area (Steiger *et al*. 1979; Strachan *et al*. 1995). It was therefore a particular aim of the present project to verify the extent of Grenvillian events in the area between 72° and 75°N. The results of these investigations now clearly show the existence of both a high-grade metamorphic event and formation of anatectic granites at around 930 Ma (Fig. 4; Thrane *et al*. 1999; Kalsbeek *et al*. in press). Mesoproterozoic metasediments are widespread, and are referred to as the Krummedal supracrustal sequence; they comprise a several kilometres thick cover sequence dominated by arenaceous and argillaceous lithologies, now folded together with its gneissic basement. Analyses of detrital zircons from the Krummedal sequence indicate that the sediments were deposited *c*. 1100–1200 Ma ago. The range of ages of the detrital zircons present do not match with the ages of the underlying crystalline basement, and must be derived from younger unknown source areas (Kalsbeek *et al*. in press). It is still an open question whether the Grenvillian events in this region relate to an orogeny or to an event of rifting and crustal thinning at around 1000–930 Ma.

Fig. 4. Foliated augen granite from Bartholin Nunatak giving an U–Pb zircon age of 934 ± 9 Ma (Grenvillian). Age determination by K. Thrane in Kalsbeek *et al*. in press. Photo: K. Thrane.

Neoproterozoic – Lower Palaeozoic sediments

Subsequent to the Mesoproterozoic (Grenvillian) events a thick succession of Neoproterozoic–Ordovician shallow-water sediments, with a composite thickness of up to *c*. 18–19 km, was laid down. The Precambrian part of the succession includes the up to 14–15 km thick Eleonore Bay Supergroup (EBS), dominated by siliciclastics in the lower part (Smith & Robertson 1999a) and with an upper part of sandstones, mudstones and carbonates (Sønderholm & Tirsgaard 1993; Frederiksen *et al*. 1999a). The EBS is overlain by the Vendian Tillite Group, in turn overlain by Cambro-Ordovician carbonates which contain a diversified shelf-type Pacific fauna indicative of an original position on the west side of the Iapetus ocean (Peel & Cowie 1979; Peel 1982).

Fig. 5. Succession in part of the Neoproterozoic Nathorst Land Group (Eleonore Bay Supergroup) at the type locality; west side of Alpefjord. The section is *c.* 800 m high.

Conodonts from the youngest sediments in the succession belong to the Llandeillian stage of the uppermost part of the Middle Ordovician (Peel 1985; Smith & Bjerreskov 1994), corresponding to an age of 462–465 Ma. Deposition of the entire sedimentary succession from early in the Neoproterozoic to Middle Ordovician spans a time interval over 400 Ma. The succession is ensialic and comprises shallow marine deposits throughout, implying that sedimentation and subsidence rates were roughly equal. The absence of angular unconformities in the Lower Palaeozoic reflects a non-tectonic environment during this part of the deposition. Opening of the Iapetus ocean is generally envisaged to have commenced in the latest part of the Neoproterozoic, but in Greenland there are no direct indications of the initiation of this event; no volcanic rocks are known, suggesting that the continent–ocean boundary must have been situated some distance to the east.

Prior to the 1998 field season the lowest division of the Eleonore Bay Supergroup was only known from investigations by members of Lauge Koch's expeditions (e.g. Fränkl 1953; Haller 1971) and limited Survey studies in the 1970s (Caby 1976). There was therefore a great need for a modern lithostratigraphical and basin analysis of this important clastic sedimentary succession. The lowest levels of the Eleonore Bay Supergroup are now known as the Nathorst Land Group (Sønderholm & Tirsgaard 1993). Investigations in 1998 (Smith & Robertson 1999a) established a lithostratigraphical division of the Nathorst Land Group into seven formations (NLG1–NLG7) with a total thickness of 9 km in the type area around Forsblad Fjord (Figs 3, 5). The lower boundary is nowhere preserved in an intact, unaltered condition; the lowest preserved levels are metamorphosed at medium to high grade, and the contact against the crystalline complexes is either an extensional fault or a shear zone. The upper boundary is conformable with the overlying Lyell Land Group in the south (Sønderholm & Tirsgaard 1993). However, in Andrée Land in the north, 2.5–3 km of the Nathorst Land Group were eroded away prior to the deposition of the Lyell Land Group, producing a hitherto unsuspected angular unconformity (Smith & Robertson 1999a). The Nathorst Land Group is dominated by sandstone and heterolithic mudstone and sandstone. One formation (NLG5), only present in the south, is a characteristic silty limestone band. Cross-bedding, wavy bedding and ripple lamination are common throughout; the depositional environment is interpreted as shelf to shoreface. The age of deposition is between about 920 Ma and Sturtian (*c.* 700 Ma).

The Petermann Bjerg Group in western Frænkel Land, west of the main outcrop area, is partly equivalent to the Nathorst Land Group. Mapping by Escher & Jones (1998) had strongly suggested a close similarity in development, and Smith & Robertson (1999a) established a correlation between the two successions, showing that the lower Petermann Bjerg Group is probably correlatable with formation NLG3 of the Nathorst Land Group and that the uppermost part of the Petermann Bjerg Group correlates with the lowest part of the Lyell Land Group.

Detailed sedimentological studies of the Andrée Land Group, the uppermost part of the Eleonore Bay Supergroup, were continued in 1998 (Frederiksen & Craig 1998; Frederiksen *et al.* 1999a). In 1998 a further 11 detailed profiles through the group were measured, and data now cover a belt of exposures extending for more than 250 km from north to south. The Andrée Land Group comprises limestones, dolomites and shales. It was divided into seven informal formations, AL1–AL7 by Sønderholm & Thirsgaard (1993) with a total thickness of *c.* 1200 m. The succession was mainly deposited in a marine shallow-water carbonate ramp environment with stromatolitic back ramp lagoon sediments, oolitic/pisolitic inner shallow shoal/barrier complex sediments, tidal channel breccias and conglomerates, and mid- to outer deep ramp storm-induced sediments (Frederiksen & Craig 1998). Deeper water marine slope environments represented by distal turbidites occur only in formation AL6. Evidence from the Andrée Land Group indicates an approximately east–west trend for the shoreline, which is in contrast to the north–south orientation with eastward dip of the shelf proposed from studies of the underlying Lyell Land Group (Tirsgaard & Sønderholm 1997) and Ymer Ø Group (Tirsgaard 1996).

The Andrée Land Group includes several thick dolomitic units, and a study of their diagenesis was included in the 1998 field work (Frederiksen *et al.* 1999b). At least two generations of dolomitisation are recorded, an early regional stratiform type, and a later cross-cutting type associated with minor faults and folds.

Caledonian orogeny: structures and metamorphism

The collision of Laurentia and Baltica which gave rise to the Caledonian orogen took place after the latest deposition on the continental margin *c.* 460 Ma ago. Emplacement of the widespread late orogenic granites *c.* 430 Ma ago may, however, be related to the late extensional phase of the orogen rather than the major compressional events which resulted in possibly several hundred kilometres of westwards thrusting. The continental collision and crustal thickening which affected East Greenland are thus of uppermost Ordovician to lowermost Silurian age, while subsequent exhumation and crustal thinning are of Late Silurian to Middle Devonian age.

One of the most significant results of the new field work in the region 72°–75°N in East Greenland has been the confirmation of the existence of major nappes and thrust sheets which have transported both crystalline basement and metasedimentary cover units westwards across the Precambrian shield that forms the Caledonian foreland to the west of the fold belt. Evidence of significant displacement is seen in the occurrence of major tectonic windows below Caledonian thrusts in the innermost fjord zone and the nunatak zone; thin Neoproterozoic – Lower Palaeozoic successions occur below major thrust complexes of higher grade infracrustal and supracrustal units (Leslie & Higgins 1998, 1999; Escher & Jones 1999; Smith & Robertson 1999b). Within the Målebjerg window the Vendian–Ordovician succession totals 206 m (Smith & Robertson 1999b) whereas the equivalent succession in the allochthonous areas of the fjord region totals 5–5.5 km; furthermore, the 14–15 km of the Eleonore Bay Supergroup at the base of the allochthonous succession in the fjord region are not represented in the foreland windows. Smith & Robertson (1999a, b) point out that as 20 km of sediment deposited in a predominantly non-rift setting, wedge out in a fraction of the width of the orogen, then the orogenic shortening due to thrusting must be substantial.

The Eleonore Sø window in the nunatak region is the largest of the tectonic windows in the study area, extending for over 100 km in a NNE–SSW direction (Leslie & Higgins 1998, 1999). It outcrops beneath a broad arched roof thrust which transports kyanite-grade metasediments, in places with granite veins, towards the north-west. The window exposes three distinct rock successions. A *c.* 1800 Ma old gneiss and granite basement is overlain by the Palaeoproterozoic Eleonore Sø supracrustal complex of pillow lavas, tuffs, gabbroic intrusions and various sediments, which in turn is unconformably overlain by a thin sequence of Cambro-Ordovician sediments. The Eleonore Sø complex is probably equivalent to the Charcot Land supracrustal sequence described from a similar tectonic window in the north-west part of the Scoresby Sund region (Steck 1971). The thin Lower Palaeozoic succession in the Eleonore Sø window comprises a *c.* 200 m thick quartzite unit with *in situ Skolithos* trace fossils indicative of a lowest Cambrian age, and an overlying 0–50 m thick carbonate succession of presumed Ordovician age (cf. Fig. 6).

One of the most difficult problems in relation to the structural interpretation of the fold belt is distinction between Caledonian and pre-Caledonian deformation and fold patterns in the crystalline complexes. It has not so far been possible to establish valid field criteria for distinguishing the Archaean, Palaeoproterozoic and Mesoproterozoic deformation phases from the later Caledonian deformation. However, most geologists have interpreted the dominant deformation seen in the metasedimentary successions as Caledonian. Thus Leslie & Higgins (1998) distinguished three phases of Caledonian compressional deformation in northern Andrée

Fig. 6. View of Målebjerg in western Andrée Land (see Fig. 3) showing part of the Målebjerg tectonic window. Grey gneisses beside the glacier are overlain by a prominent yellow-white to orange coloured quartzite 143 m thick which contains *Skolithos* trace fossils at several levels. A thin grey carbonate of probable Ordovician age occurs above the quartzite and immediately below a prominent flat-lying thrust, about half-way up the mountain in the field of view. The dark grey succession above the thrust comprises Proterozoic metasedimentary rocks of the Krummedal supracrustal sequence. Målebjerg is 1873 m high, and the glacier surface is at about 300 m altitude. Photo: A.K. Higgins.

Land and the nunatak region. A more complex history of deformation is described in the Frænkel Land region by Escher & Jones (1999), with distinction of five Caledonian phases of deformation: (1) an early phase of crustal thickening, (2) an early phase of granite emplacement associated with crustal extension, (3) northwards-directed thrusting, (4) upright folding on N–S, orogen-parallel axes and (5) late Caledonian extension. The late extensional phase is seen throughout the region as top-down-to-the-east displacements on major structural lineaments (e.g. Andresen *et al.* 1998; Elvevold & Gilotti 1998; Escher & Jones 1999).

Within the Caledonian fold belt high-pressure granulite facies rocks are found in gneiss complexes in Payer Land (Elvevold *et al.* 1999), and retrogressed high granulite facies rocks are also preserved in the Gletscherland region (Elvevold & Gilotti 1998) and on Clavering Ø (Jones & Escher 1999). The overall metamorphic grade in the crystalline complexes reflects amphibolite facies metamorphism, but there are all variations from low grade to high grade in the metasedimentary successions. The metamorphic grade in the Eleonore Bay Supergroup ranges from amphibolite facies in the lowest levels to non-metamorphic in the upper parts and in the overlying Tillite Group and Lower Palaeozoic rocks.

Granites and migmatites

Migmatisation and granite formation is a prominent feature of the southern part of the Caledonian fold belt in East Greenland (70°–76°N), corresponding to the region in which Mesoproterozoic and Neoproterozoic metasediments are abundant. Field relationships indicate clearly that migmatitic development and granite generation are closely associated with high-grade metasediments. The numerous granite sheets in the Mesoproterozoic Krummedal supracrustal sequence are anatectic and of

Fig. 7. Caledonian granite dykes and sheets intruding metasediments of the Nathorst Land Group (lowermost part of Eleonore Bay Supergroup). North side of outer Forsblad Fjord (see Fig. 3).

two distinct age groups; some are *c*. 930 Ma old (Grenville) and others are *c*. 430 Ma old (Caledonian) (Kalsbeek *et al.* in press). It is not generally possible to distinguish the two age groups either on field criteria or petrologically, except for those that penetrate into the lower parts of the Eleonore Bay Supergroup which must be Caledonian (Fig. 7). The granites in the region from 72° to 76°N are all interpreted as of low-temperature S-type, typically related to extensional tectonics (Kalsbeek *et al.* in press); they do not appear to be derived from deep-seated sources related to continental collision and subduction of crustal material.

Migmatites and Caledonian granites are the dominant rock units in the Stauning Alper region at about 72°N. In this region both metasediments of the Nathorst Land Group (Eleonore Bay Supergroup) and the Mesoproterozoic Krummedal supracrustal sequence are invaded by sheets of granitic material. Some of the granites which invade the Nathorst Land Group are cross-cutting and were originally described as post-tectonic, whereas others which are deformed were considered as synkinematic and thus older. However, Watt & Friderichsen (1999) consider both granite types to be of similar age, consistent with age dating results of 430–420 Ma for granite sheets and anatectic high grade neosome material in the migmatites. The difference between deformed and undeformed granitic material appears to reflect the structural environment in which they were formed. Above an intense deformation zone the granites are undeformed, while below this level they are deformed and associated with high-grade cordierite-sillimanite-garnet-bearing migmatitic metasediments.

Mineral resource investigations

Mineral resource investigations were integrated with the mapping in the crystalline areas and continued the work carried out in 1997 (Stendal & Wendorff 1998). Opportunity was also taken in the 1998 season to follow-up anomalies revealed by a transient electromagnetic and magnetic survey (AEM) carried out in 1997 (Thorning & Stemp 1998) that covered a region of over 5000 km^2 of the Mesozoic sedimentary basin in the northern part of Jameson Land (Fig. 1).

In the Caledonian fold belt and the adjacent areas with Devonian sediments investigations followed up earlier studies of mineralisation sites to obtain a better understanding of their size, character and occurrence in order to establish genetic models for their formation. The investigations were concentrated in the region between Kejser Franz Joseph Fjord and Clavering Ø, where post-Caledonian sediments are in fault contact with the underlying folded rock units. The region is characterised by the occurrence of a series of approximately N–S trending post-Devonian normal faults and lineaments, which have been exploited by various mineralisation types. The post-Devonian main fault system can be traced for a distance of more than 400 km. The mineralisations found in Caledonian crystalline complexes as well as post-Caledonian rocks are mostly of vein type and include base-metal mineralisations with pyrite, chalcopyrite, bornite and arsenopyrite (Stendal 1999). Gold anomalies previously detected by stream sediment analyses were also reinvestigated. A prominent rust zone in the crystalline complexes on southern

Clavering Ø has been known as a potential gold mineralisation since the beginning of the 1930s, when an exploratory 'mine' shaft was excavated. The area with this mineralisation was studied in detail, and rock, soil and stream sediment samples were collected for analytical and petrographic studies (Stendal *et al.* 1999b). The results of the field investigations indicate that the mineralisations are dominated by pyrite and arsenopyrite with quartz and fluorite in breccias. They are all related to fault zones.

The follow-up on the AEM survey in the Mesozoic basin in Jameson Land involved visiting 14 of the over 60 anomalies indicated by the survey (Stendal *et al.* 1999a). The anomalies are mainly associated with Tertiary sills intruded into Jurassic sandstones of the Kap Stewart Group (Dam & Surlyk 1998; Surlyk *et al.* in press). The most prominent type of mineralisation contained magnetite, pyrrhotite and pyrite with assessory chalcopyrite, ilmenite and galena.

Concluding remarks

With completion of the 1997–98 field mapping project, the entire length of the East Greenland Caledonian fold belt has now been mapped. Five map sheets at 1:500 000 cover the fold belt, the foreland areas in the west and the post-Caledonian basins in the east; three sheets are published, one is under compilation and field work for the final sheet is now complete. General regional overviews of the geology and the economic geological aspects of the region 72°–75°N have been obtained, and insights gained will help in understanding and interpreting other already mapped regions to the north and south. Laboratory investigations continue, and the results will be documented in Survey bulletins and maps and articles in international publications.

In addition to financing from Survey sources, some aspects of the project were based on funding from the Danish Natural Science Research Council and Carlsberg Foundation, the external sources funding mainly research in special topics concerning the pre-Caledonian basement terrain, Caledonian metamorphism, and studies of the Neoproterozoic carbonate sediments. With respect to the mineral exploration activities financial support was obtained from the Government of Greenland and the Danish Research Councils.

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