Two major unconformities beneath the Neoproterozoic Murchisonfjorden Supergroup in the Caledonides of central Nordaustlandet, Svalbard

DAVID G. GEE and ALEXANDER M. TEBEN'KOV

Gee D. G. & Teben'kov A. M. 1996: Two major unconformities beneath the Neoproterozoic Murchisonfjorden Supergroup in the Caledonides of central Nordaustlandet, Svalbard. *Polar Research 15(1)*, 81–91.

Two unconformities have been found in central Nordaustlandet. New mapping has located a major unconformity at the base of the Neoproterozoic Murchisonfjorden Supergroup, with quartzites and basal conglomerates of the Djevleflota Formation unconformably overlying dark phyllites of the Helvetesflya Formation and metavolcanic rocks of the Svartrabbane Formation. A second unconformity separates the Helvetesflya from the Svartrabbane formations. These rocks were isoclinally folded, metamorphosed in lower greenschist facies, and, apparently, syntectonically intruded by Grenville-age granites, prior to uplift, erosion and Neoproterozoic deposition. Caledonian tectonothermal activity, *as recorded in the Neoproterozoic strata*, appears to vary very little across Svalbard's Eastern Terrane from Ny Friesland, in the west, to Murchisonfjorden in western Nordaustlandet and, via Wahlenbergfjorden, to the central Nordaustlandet area, described here. Upright folds with associated high angle, usually E-dipping cleavages, characterise the Caledonian deformation over an east-west distance of about 100 km. This evidence allows the possibility that the pre-Devonian basement, to the east of Nordaustlandet, beneath the northern Barents Sea (Barentsia), may be composed of Grenville-age complexes little influenced by Caledonian tectonothermal activity. Alternatively, Barentsia is dominated by Caledonian hinterland tectonics, with extensive middle Paleozoic tectonothermal reworking of a Precambrian basement.

David G. Gee, Department of Geophysics, Uppsala University, Villavägen 16, S–752 36 Uppsala, Sweden; Alexander M. Teben'kov, Polar Marine Geological Expedition, ul. Pobedy 24, 189 510 Lomonosov, Russia.

Introduction

Some of the most inaccessible, exposed areas of the Barents Shelf occur in northeastern Svalbard, where crystalline complexes of granites, augen gneisses and migmatites have long been known (Nordenskiöld 1864, 1866) to be overlain by nearly unmetamorphosed sedimentary rocks (the Hecla Hoek formations) of Neoproterozoic and Early Paleozoic age (Kulling 1932, 1934). The relationships between these crystalline rocks and the fossiliferous successions have been much disputed, and only recently (Gee et al. 1995) has clear evidence been presented of a Grenville age for some of the granites. The latter intrude both the migmatites and some of the metasedimentary rocks (Fig. 1).

In northwestern parts of Nordaustlandet, an unconformity, first documented by Ohta (1982a), separates low grade metasedimentary rocks (the Brennevinsfjorden Group) intruded by ca. 950 Ma granites (Gee et al. 1995), from an overlying volcanic and volcaniclastic sequence (the Kapp Hansteen Group); the latter underlies well-documented Neoproterozoic sandstones, shales and carbonates of the Murchisonfjorden Supergroup (Kulling 1934; Flood et al. 1969; Ohta 1982a, b). A significant unconformity is inferred to also exist at the base of the Murchisonfjorden Supergroup, but the contact, occurring beneath Lady Franklinfjorden, is apparently not exposed on land in western areas.

Further east, in central Nordaustlandet, a similar unconformity (or unconformities) has been inferred by various authors, but not previously demonstrated. Thus, Sandford (1950, 1956), on the basis of several expeditions to the area, concluded that a major unconformity should exist between underlying metamorphic complexes and overlying little-metamorphosed sedimentary and volcanic rocks; however, neither he nor Flood et al. (1969) were able to unambiguously demonstrate a regionally significant unconformity. This paper documents two major breaks in the stratigraphy; we now know that the problems of their identification relate to the existence of low grade metasedimentary rocks of both Mesoproterozoic and Neoproterozoic age.

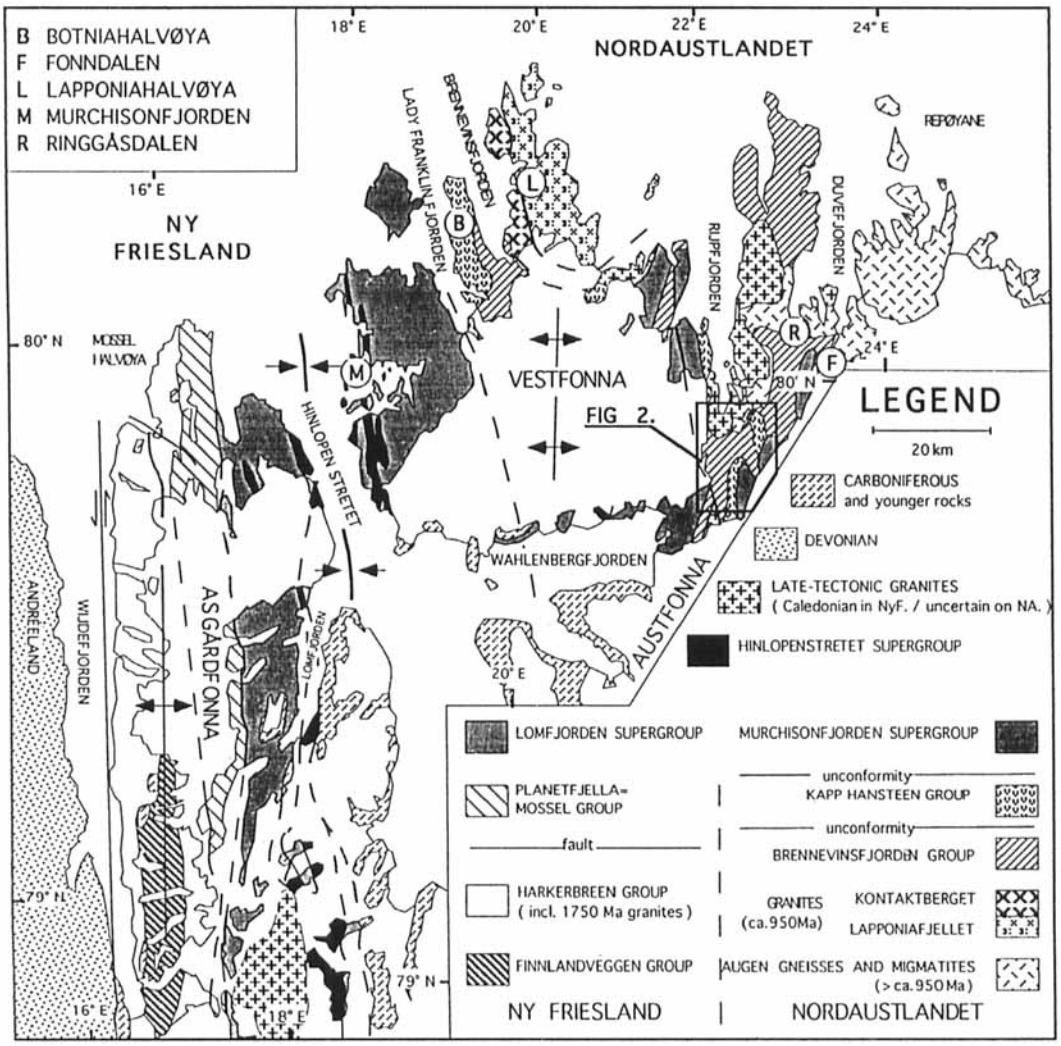


Fig. 1. Geological map of Nordaustlandet and Ny Friesland (from Gee et al. 1995), with location of Fig. 2.

Previous work in central Nordaustlandet

The Caledonian bedrock of central Nordaustlandet is exposed between two major ice-caps, Vestfonna and Austfonna, in the vicinity of Rijpfjorden and inner Wahlenbergfjorden and in the broad open N-trending valley connecting these two waterways. South of Wahlenbergfjorden, flat-lying Carboniferous successions unconformably overlie the Caledonian rocks. Geological maps of the area have been published by Sandford (1956), Flood et al. (1969), Hjelle (1978), Ohta (1982c) and Lauritzen and Ohta (1984), and several Russian expeditions have provided unpublished reports of the pre-Carboniferous geology.

The regional structural relationships in central Nordaustlandet were established by Sandford (1956). He showed the approximate distribution of the rock units, with migmatites and granites (his "metamorphic complex") occurring in a major N-trending antiform extending through Rijpdalen, from innermost Wahlenbergfjorden to

Rijpfjorden, and flanked to the east and west by synforms containing Neoproterozoic successions. The Rijpdalen Antiform plunges north in the south and south in the north, and, from the latter area, the migmatites and granites spread northeastwards to occupy most of northeastern Nordaustlandet.

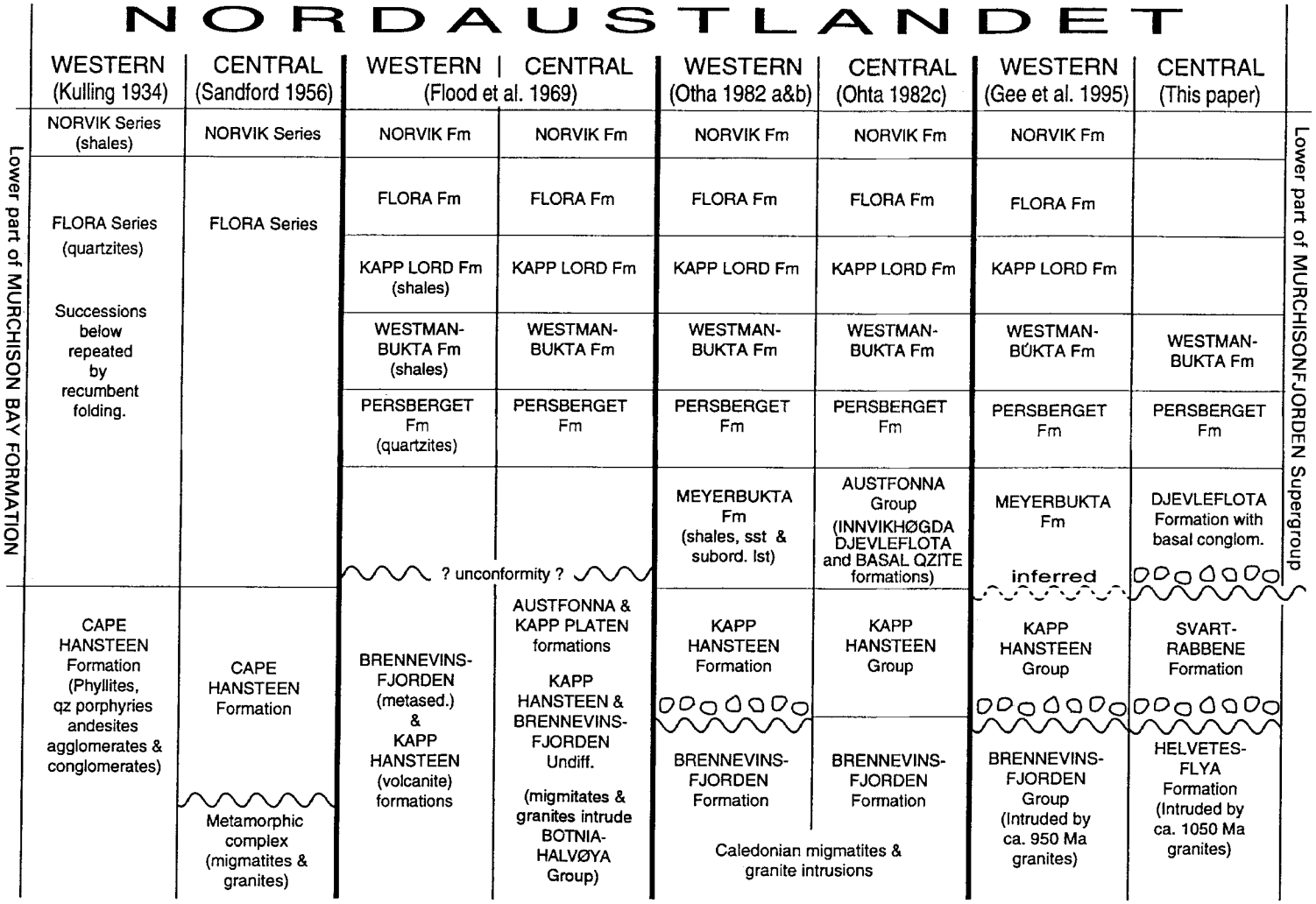
Sandford (1956) recognised several of the Neoproterozoic formations that had been defined further west by Kulling (1934) in the classical Murchisonfjorden area. Kulling (1934) had shown that the various pre-Vendian units in that area — dolomites, limestones, shales and sandstones (his Murchison Bay Formation) — were underlain, on Botniahalvøya, by a succession of volcanic and low grade sedimentary rocks that he referred to as the Cape Hansteen Formation. In central Nordaustlandet, similar lithologies, though with only subordinate volcanites, were found by Sandford to separate the sandstone units (Flora Series) of the Murchison Bay Formation from the underlying "metamorphic complex". Pink granites were recorded to cut both the Cape Hansteen Formation and the underlying rocks. Sandford commented (1956, p. 358), "It is pertinent, then, to consider whether the Cape Hansteen Formation is stratigraphically unconformable on the metamorphic complex, or is a part of a disharmonic mass between the surface of the complex and the competent beds of the Flora Series." He noted (1956, p. 357) the presence of "sheets of metamorphosed sediments" between the granitic rocks of the "metamorphic complex", but no evidence of metamorphic transition into the low grade Cape Hansteen rocks; he therefore concluded that an unconformity must exist between them. The structural complexity of the migmatites and the granites, contrasting with the relatively simple more or less cylindrical folding of the Neoproterozoic strata, also prompted this interpretation.

Flood et al. (1969) carried out an extensive helicopter-supported mapping program of Nordaustlandet in 1965. In central Nordaustlandet, they recognised that there was a metamorphic transition from the underlying migmatites and foliated augen granites into the so-called Cape Hansteen Formation, with staurolite, andalusite and garnet crystallising syntectonically in the immediate contact zone. Metamorphic grade decreases rapidly to lower greenschist facies away from the contact. Younger reddish granites cut all these rock units. Flood et al. (1969) showed that the low grade metamorphosed sedimentary and volcanic rocks had a more complex structural history than the overlying Murchisonfjorden lithologies and they therefore preferred the hypothesis (Flood et al. 1969 pp. 95–96) that a major unconformity separated these two stratigraphic units. Nevertheless, the exact location and interpretation of the importance of the unconformity were disputed, being influenced not only by the field relationships, but also by the first isotope age-determination studies — Rb/Sr whole rock and mineral ages of ca. 600 Ma ages on schists of the "metamorphic complex" (Hamilton & Sandford 1964). Support for the interpretation that the Murchisonfjorden Neoproterozoic strata were underlain by a basement complex of migmatites, granites and low grade volcano-sedimentary rocks was found locally, for example, east of Bengtssonbukta, where a quartzite conglomerate was recognised (Winsnes in Flood et al. 1969, p. 37) to discordantly overlie low grade metasediments.

In general, the lithologies below the Murchisonfjorden Supergroup in central and western Nordaustlandet are similar. However, whereas in western Nordaustlandet Flood et al. (1969) recognised that the sub-Murchisonfjorden rocks composed two major mappable units, the Brennevinsfjorden and Kapp Hansteen formations (together comprising their Botniahalvøya Group), in central Nordaustlandet they were unable to distinguish these formations. And in the latter area, an independent quartzite and dark phyllite unit, with subordinate intercalations of carbonates, was identified — the Austfonna Formation, overlying the other formations of the Botniahalvøya Group in the Rijpdalen Antiform. Subsequent work on Botniahalvøya (Gee et al. 1995) has demonstrated that the Brennevinsfjorden and Kapp Hansteen units are both subdivisible into formations and therefore should have group status. Because a major unconformity separates these units on Botniahalvøya (Ohta 1982c), the term Botniahalvøya Group was abandoned (Gee et al. 1995).

The stratigraphy of the Murchisonfjorden Supergroup (Table 1) has also been modified since its early definition by Kulling in 1934 (the Murchison Bay Formation) and correlation from the type areas, eastwards into central Nordaustlandet is not without problems. In the Murchisonfjorden area, below Vendian tillites, Kulling (1934) distinguished six series (for-

Table 1. Stratigraphic correlation of the Meso- and Neoproterozoic successions of central and western Nordaustlandet.



mations) grouped into two main units, and interpreted the lower part of the succession to be repeated by recumbent folding. Flood et al. (1969) placed the upper units (dominated by dolomites and limestones) into the Roaldtoppen Group and the lower (shales and quartzites) into the Celsiusberget Group. They rejected Kulling's (1934) "recumbent fold" interpretation and recognised beneath the Celsiusberget Group a third cycle of shales and quartzites, the Franklinsundet Group. Subsequently, Ohta (1982b) showed that the lowermost quartzites of the Franklinsundet Group (the Persberget Formation) were underlain by another, somewhat different shale-dominated unit, which he named the Meyerbukta Formation.

In central Nordaustlandet, the general Murchisonfjorden Supergroup relationships were established by the mid 1950s (e.g. Sandford 1956), with the Vendian tillites exposed on the northern side of inner Wahlenbergfjorden, underlain by the carbonates of the Roaldtoppen Group and shales and quartzites of the Celsiusberget Group. Flood et al. (1969) recognised the formations of the Franklinsundet Group, northeast of Vestfonna (north and south of Bengtssonbukta) and further south in inner Wahlenbergfjorden (north of Etonbreen). The basal quartzites of the Franklinsundet Group were correlated with the Persberget quartzites and shown to directly overlie the Austfonna Formation along the eastern margin of Vestfonna. Further east, quartzites and overlying shales in the Venesjøen Synform were shown to be similar to the Persberget and Westmanbukta formations. However, in these eastern areas, they rest on the undifferentiated volcano-sedimentary rocks of the "Botniahalvøya Group" and unconformable relationships were therefore inferred.

Ohta's (1982c) map of central Nordaustlandet revised the stratigraphic relationships between the Murchisonfjorden Supergroup and underlying rocks. He interpreted the Austfonna Formation lithologies to be equivalent to his newly defined Meyerbukta Formation (from western Nordaustlandet) of the basal Murchisonfjorden succession. He upgraded the Austfonna unit to group status and included within it three formations, a Basal Quartzite, a middle shale-dominated section (the Djevleflota Formation) and an upper sandstone-shale unit (the Innvikhøgda Formation). He also documented the local development of an unconformity beneath his "Basal Quartzite" (Ohta 1982c, p. 52), entertaining the possibility of a regional break beneath the Murchisonfjorden Supergroup. However, both granite intrusions and migmatisation were thought to influence the Austfonna Group, and these were regarded therefore as Caledonian.

New mapping of central Nordaustlandet

In 1994, a camp was established on Helvetesflya, in the watershed between Rijpdalen and Flaumdalen. This allowed a ten day investigation of the central part of the area between Vestfonna and Austfonna and a closer examination of the relationships between the Murchisonfjorden Supergroup strata and underlying volcano-sedimentary rocks.

The new mapping (Fig. 2) extended from the Murchisonfjorden basal contact along the margin of Vestfonna in the western limb of the Rijpdalen Antiform, eastwards via the Venesjøen Synform to the Kvartsitthaugen Synform, exposed along the edge of Austfonna. The type area for the Austfonna Group was not within the range of the 1994 operations, but was examined briefly in 1995. Similar major Caledonian folds, further west along Wahlenbergfjorden, involve Vendian tillites and, in the vicinity of Hinlopenstretet, Cambro-Ordovician strata; in central Nordaustlandet, these are upright structures, with a cleavage in the shales dipping generally at high angles eastwards. A variety of faults complicate the fold geometry of the major N-trending Rijpdalen Antiform and flanking synforms.

Described below are the lithologies and structures of the Helvetesflya area, with a focus on the evidence for major unconformities beneath the Murchisonfjorden Supergroup strata and within the underlying volcano-sedimentary succession.

Lithologies and stratigraphy

The stratigraphy of central Nordaustlandet is treated here in two parts: underlying units, equivalent to Flood et al's (1969) Botniahalvøya Group (referred to here as the Helvetesflya and Svartrabbane formations), and unconformably overlying units in the basal part of the Murchisonfjorden Supergroup. With regard to the latter, one of the formations included by Ohta

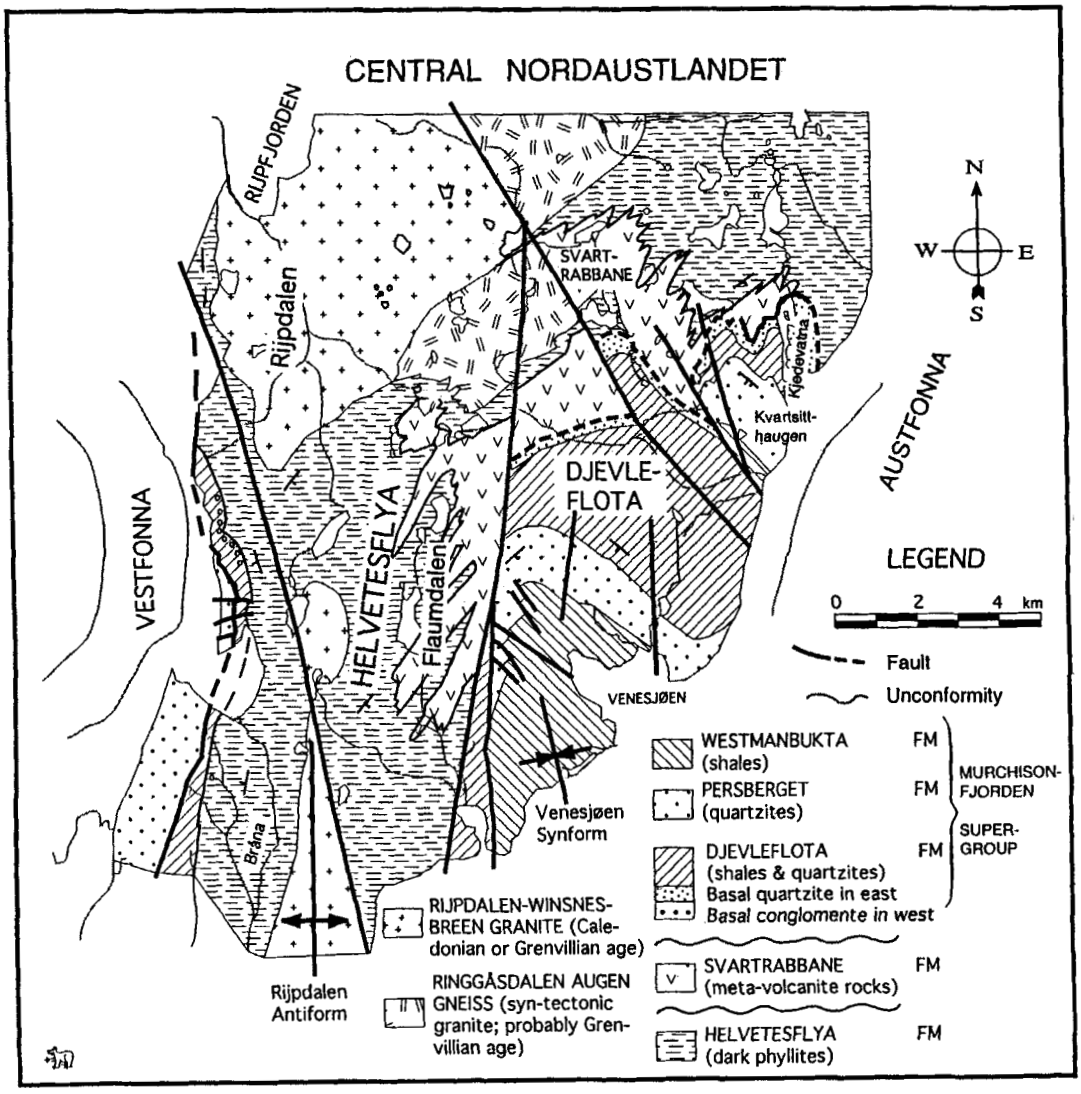


Fig. 2. Geological map of the area between Vestfonna and Austfonna, central Nordaustlandet.

(1982c) in the Austfonna Group dominates on Helvetesflya — the Djevleflota Formation. We therefore distinguish only the Djevleflota Formation on the new geological map (Fig. 2), with underlying thin basal quartzites in eastern areas and basal conglomerates outcropping along the margin of Vestfonna.

Djevleflota Formation and basal quartzites and conglomerates

Flood et al. (1969) and Ohta (1982c) showed the distribution of the Persberget Formation quartzites in the eastern and western limbs of the Rijpdalen Antiform and their relationship to underlying strata. Ohta (1982c) recognised that, in the Venesjøen Synform on Djevleflota, these quartzites were underlain by a varied packet, estimated to a little over 1000 m in thickness, of shales and subordinate calcareous sandstones, quartzites and minor limestones; he therefore defined a new formation in this area. The succession is well preserved and primary structures are abundant (Fig. 3).

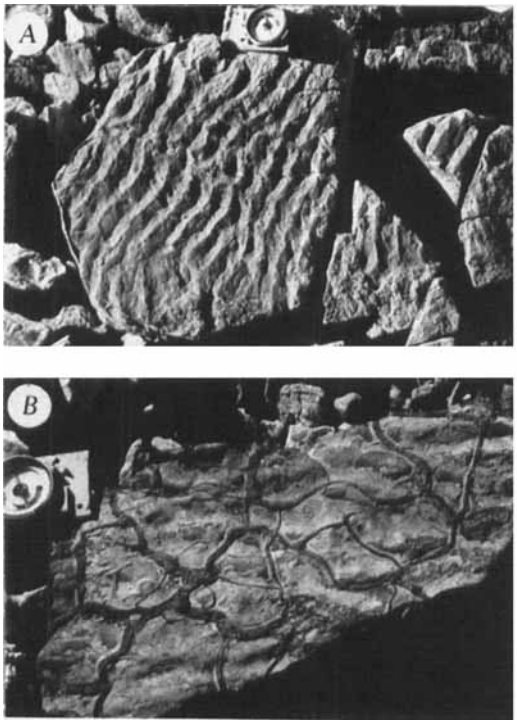


Fig. 3. Sedimentary structures in the sandstones of the Djevleflota Formation. A. Ripple marks. B. Mud cracks.

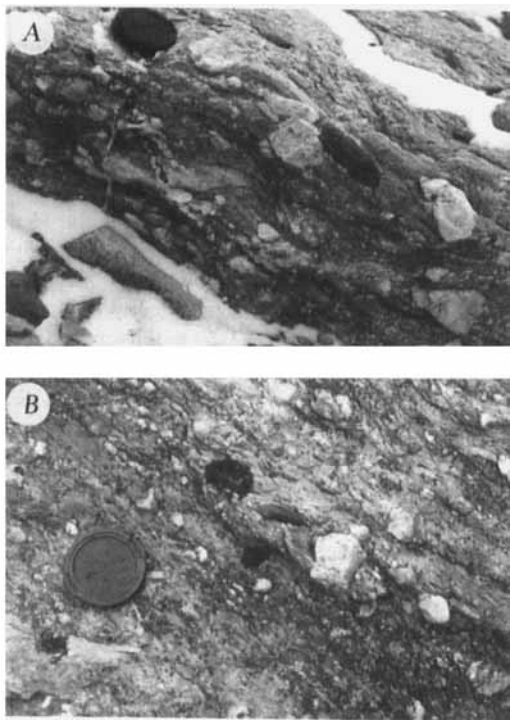


Fig. 4. Basal conglomerates of the Murchisonfjorden Supergroup: Locality close to the eastern margin of Vestfonna (see Fig. 2). Clasts of quartzite, vein-quartz and dark metavolcanites in both A and B.

In the western limb of the Rijpdalen Antiform, only about 100 m of the Djevleflota Formation is exposed beneath the Persberget quartzites (thickness probably reduced by normal faulting), and basal conglomeratic beds are locally preserved. Conglomerates, described by Winsnes, in Flood et al. (1969, p. 37) from west of Rijpfjorden, in the base of the Persberget Formation, may also be part of this Murchisonfjorden basal unit. Ohta (1982c, p. 47) referred to a "basal breccia" at the base of the Persberget Formation, west of Bråna, in southwestern Rijpdalen and inferred that it marked the base of a separate sedimentary cycle within the Murchisonfjorden Supergroup. This unit probably also coincides with our basal Murchisonfjorden conglomerate.

Beneath these basal conglomerates, in the western limb of the Rijpdalen Antiform, the lithologies are dominated by dark phyllites of the Helvetesflya Formation. In this area, the new mapping does not support the correlation (Ohta 1982c) of these metasediments with the Djevleflota Formation.

In the eastern limb of the Venesjøen Synform, the basal part of the Djevleflota Formation is poorly exposed; a few quartzite outcrops occur and the base is not seen. Further to the northeast, this formation is exposed again beneath the Persberget quartzites in the Kvartsitthaugen Synform. Here, the succession beneath the quartzites contains much green-grey cross-laminated silt and graded fine sandstone with quartzites at the base. However, the contact to the underlying Helvetesflya dark phyllites and Svartrabbane andesites is tectonic.

The basal conglomerates of the Murchisonfjorden Supergroup are of particular interest. In the field, a variety of clasts were recorded, including red quartzites, vein quartz, dark phyllites, dark greenish mafic volcanic rocks, and light acid volcanics (Fig. 4). In thin section, the metavolcanic rocks in the clasts are similar to those in the Svartrabbane Formation. Relic fluidal and porphyritic textures are recognisable; quartz and feldspar are altered to quartz-sericite aggregates and the glass in the acid rocks has recrystallised to

form a fine-grained matrix. Tourmaline-bearing clasts are conspicuous in these basal conglomerates.

Helvetesflya and Svartrabbane volcano-sedimentary rocks

Two mappable formations occur below the Murchisonfjorden Supergroup. The one (Helvetesflya Formation) is dominated by dark phyllites, locally, with volcanic intercalations; the other (Svartrabbane Formation) is mainly composed of andesites with subordinate rhyolites. The Helvetesflya metasedimentary rocks are often relatively well preserved and "way-up" has been recorded locally. It may prove possible, with more detailed mapping, to better control the stratigraphy, but the occurrence of tight to isoclinal folding and local inversion do not allow this on the present data base. The Svartrabbane volcanic rocks are widespread in the upper structural levels of the Rijpdalen Antiform in the eastern limb where they overlie the sedimentary units. Similarity of the latter to the Brennevinsfjorden Formation and the former to the Kapp Hansteen Formation, noted by previous investigators, supports correlation with Botniahalvøya. A major unconformity separates these units.

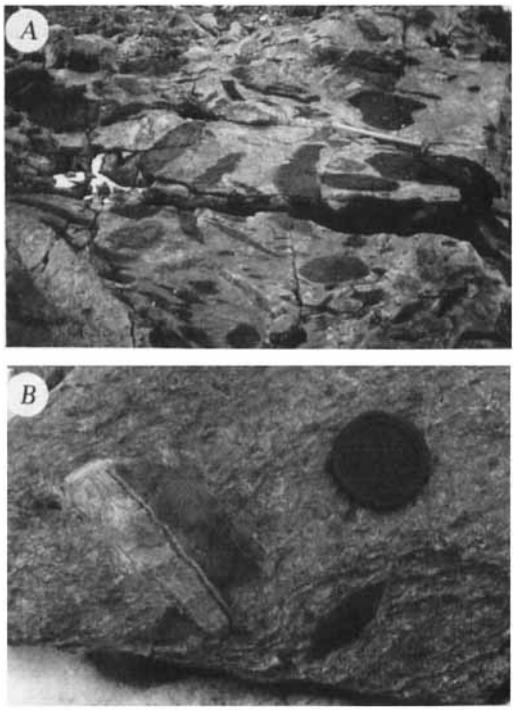


Fig. 5. Svartrabbane Formation volcanic rocks: A. Agglomerates cut by granite sheet (bottom left). B. Rhyolites with sedimentary clasts, probably derived from the underlying Helvetesflya Formation.

Helvetesflya Formation (dark phyllites).—Monotonous dark phyllites, some of them black (1–2% graphite), dominate this phyllite formation. Many of these lithologies have been described previously as shales or slates, but all that we have mapped have a strong, penetrative, fine-grained, sericitic schistosity and a superimposed crenulation that is usually conspicuous. Thin (a few centimetres) sandy intercalations are frequent and usually graded. Thicker quartzites are rare in this formation. Isoclinal folding makes thickness estimates very uncertain, but the formation is at least a few hundred metres thick; it is interpreted to be largely of turbidite origin.

Svartrabbane Formation (volcanites).—The Svartrabbane volcanic and associated sub-volcanic intrusions of central Nordaustlandet have been described in some detail by Teben'kov (1983) and Ohta (1985). The fine-grained penetrative schistosity makes it often difficult to be sure whether the massive, volcanic rocks are extrusive or intrusive. However, in many outcrops, good exposures of transitions from volcaniclastic rocks to massive volcanites occur; in addition, the presence of sedimentary clasts in rhyolites and the intercalation of agglomerates with andesites, provide good evidence of extrusion (Fig. 5).

The massive mafic rocks have been previously referred to as diabase and basalt, but have been shown by geochemical studies to be andesitic in composition (Teben'kov 1983; Ohta 1985). Interbedded dark phyllites occur locally and subordinate quartzites are also present. Ohta (1982c) reported thin carbonate units in the contact between the Svartrabbane and Helvetesflya formations.

In 1995, a major unconformity was found to separate Helvetesflya turbidites from Svartrabbane volcaniclastic rocks. Ohta (1982c, p. 50) referred to the presence of conglomerates separating these volcanic and sedimentary rocks at Kjedevatna and inferred local unconformity. Our 1995 mapping shows that the Helvetesflya metasediments, with well-preserved sedimentary structures (e.g. graded bedding and cross-lamination), are locally inverted and overlain by a thin (up to ca. 5 m) quartzite pebble conglomerate,

passing up into rhyolites and andesites of the Svartrabbane Formation.

Granites (Rijpdalen–Winsnesbreen)

Red granites occur in a main massif in Rijpdalen, developing a conspicuous thermal aureole in the host rocks to a distance of about 100 m from the contact. This Rijpdalen Granite (Hjelle 1966; Flood et al. 1969) occurs in the core of the Rijpdalen Antiform and appears to be connected from the northern outcrop areas of inner Rijpfjorden, southwards to the Winsnesbreen Granite near Wahlenbergfjorden. The mineralogy of the granite is dominated quartz, albite and microcline with subordinate muscovite (up to 10%) and minor biotite. Tourmaline is frequently present, particularly in association with pegmatites. The aureole mineralogy in the metasedimentary rocks is characterised by garnet and biotite, locally with staurolite; tourmaline also occurs commonly in the metasediments near the granite contact. Shear zones and a semi-penetrative foliation with accompanying brittle deformation are generally present.

Augen gneisses (Ringgåsdalen)

In the northern part of Fig. 2, augen gneisses and augen granites are in contact with the Helvetesflya rocks. The ductile foliation in the these igneous rocks is cut by the Rijpdalen granite. Contact relationships between the augen gneisses and the Helvetesflya Group have been observed in the area of Fig. 2, north of Svartrabbane and, further north (Flood et al. 1969, pp. 105–112), in Ringgåsdalen (Fig. 1); in both areas, garnet, straurolite and andalusite crystallise in narrow thermal aureoles. These gneisses have been interpreted (Flood et al. 1969) to be derived from granites that were intruded during deformation; the latter was probably of Grenville age, based on recently presented U/Pb zircon age-determination studies (Johansson pers. com. 1994).

Deformation of the Helvetesflya and Svartrabbane Formations

Flood et al. (1969) described the deformation of the Helvetesflya and Svartrabbane formations (their Botniahalvøya Group) to be more complex than that in the Murchisonfjorden Supergroup

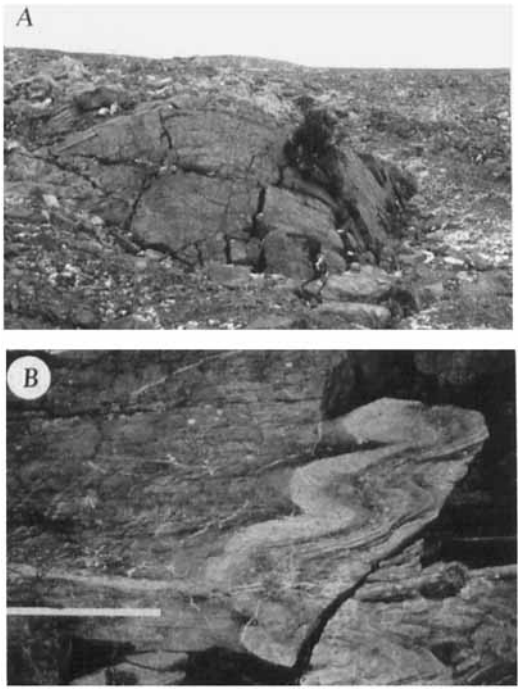


Fig. 6. Folding in central Nordaustlandet. A. Upright S-plunging Caledonian anticline in the Djevleflota Formation. B. Sideways-closing Precambrian folds in graded Helvetesflya turbidites (length of hammer shaft 40 cm).

strata; this conclusion is supported by our new work and Ohta's unpublished data (Y. Ohta pers. com. 1996). Major N-trending folds, such as the Rijpdalen Antiform and the Venesjøen and Kvartsitthaugen synforms, with their related high angle E-dipping cleavages, are apparently the only major structures to deform the Neoproterozoic strata; they clearly fold an earlier generation of tight to isoclinal folds in the Helvetesflya and Svartrabbane formations (Fig. 6). These older folds, as shown by Flood et al. (1969, pp. 85–87), have generally transverse axes (ca. WNW–ESE) and a well-developed axial surface cleavage, with associated fine-grained schistosity. Crenulation of the latter is generally due to the refolding by the N-trending Rijpdalen Antiform and related structures. Beneath the basal Murchisonfjorden Supergroup unconformity of eastern Vestfonna, the axial surface schistosity dips nearly concordantly beneath the overlying conglomerates, implying that the folds in the older rocks were recumbent prior to Caledonian deformation.

Regional metamorphism

A fine-grained schistosity, well defined by sericite and chlorite, characterises the Helvetesflya metasedimentary rocks in most of the area of Fig. 2. Crenulation of this fabric resulted in partial reorientation of these phyllosilicates, but only minor recrystallisation. The latter is compatible with the evidence in the overlying shales of the Murchisonfjorden Supergroup of only incipient growth of sericite and chlorite in the cleavages.

Discussion and conclusions

It can be concluded that a major unconformity separates the sedimentary rocks of the Helvetesflya Formation from the volcanic Svartrabbane Formation. A second unconformity occurs at the base of the overlying Neoproterozoic strata of the Murchisonfjorden Supergroup. Syntectonic intrusion of early granites, during recumbent folding of the Helvetesflya and Svartrabbane formations was followed by post-tectonic intrusion of the Rijpdalen–Winsnesbreen granite. The latter is not seen to cut the Murchisonfjorden Supergroup sediments. The possibility exists that this granite may be Caledonian in age; however, the presence of tourmaline in the clasts of the basal Murchisonfjorden Supergroup conglomerate and the association of this mineral with the aureole of the Rijpdalen granite favours the interpretation that the Rijpdalen–Winsnesbreen granite is of Grenville age.

The Ringgåsdalen augen gneisses, derived from the syntectonic granites intruding the Helvetesflya Formation, have not as yet been investigated isotopically, but their age is probably pre-Neoproterozoic. Recent work by Johansson (pers. com. 1994) has shown that a variety of megacrystic augen granite/gneiss, outcropping along the northwestern margin of Austfonna (Fonndalen, Fig. 1) is of Grenvillian (ca. 1050 Ma) age; it may be related to the syntectonic intrusions referred to above.

Although granite clasts have not been found amongst the greenschist facies pebbles in the base of the Murchisonfjorden Supergroup of central Nordaustlandet, it is worth noting that they are present in the Vendian tillites, higher in the Neoproterozoic succession (Kulling 1934). A wide range of low-grade metasedimentary and metavolcanic rocks together with granite boulders have been described by Krasil'ščikov (1967, translated by Harland et al. 1993, pp. 48–49) and by Edwards (1976). An attempt was made by Edwards and Taylor (1976) to date these granites by the Rb/Sr method. No isochron was obtained, but an indication of a Mesoproterozoic age was suggested; new studies are in progress. These granite clasts have been said by Hjelle (in Edwards & Taylor 1976, p. 256) to be similar to the Rijpdalen–Winsnesbreen Granite.

The presence of granite boulders (up to 1 m in diameter) in the tillites of eastern Wahlenbergfjorden and their smaller size further west prompted Edwards (1976) to suggest that the source area lay within a few kilometres distance from the outcrops. Without evidence for major facies changes in the Murchisonfjorden Supergroup, from the type area of western Nordaustlandet to inner Wahlenbergfjorden, this would suggest that latest Proterozoic extensional faulting locally defined an eastern margin to the Neoproterozoic basin, exposing basement to Vendian erosion.

The new work in central Nordaustlandet, reported here, supports previous conclusions (Gee et al. 1995) that Caledonian tectonothermal activity on Nordaustlandet is of a fundamentally different character than that found in western Ny Friesland. Within the Neoproterozoic successions, from eastern Ny Friesland, via Murchisonfjorden and Wahlenbergfjorden to Rijpdalen, the folding is upright to westerly inclined and the recrystallisation in the associated cleavages is generally lower greenschist facies, with growth of fine-grained sericite and chlorite. Only in the immediate contact to the Planetfjella Group and in the contact aureole to the Chydeniusbreen Granite massif in southern Ny Friesland are higher greenschist facies conditions recorded in the Neoproterozoic strata. The Caledonian lower greenschist facies tectonothermal overprint may increase a little in grade towards the east, as suggested by K/Ar and Rb/Sr mica ages (Ohta 1994) in the underlying migmatites, but the possibility remains that the pre-Devonian basement of the northern Barents Sea is essentially a Grenvillian complex, partially covered by a slightly deformed blanket of Neoproterozoic and early Paleozoic strata.

Acknowledgements. – Our field party in eastern Nordaustlandet in 1994 included three students, J. Gustafsson, J. Nilsson and S. Sandelin and geomorphologist L. Semenova. In 1995, we were assisted by E. Tagesson. We thank them all for their

contribution to the field investigations, at times under difficult wintery conditions. Our work on Nordaustlandet has been supported by the Swedish Polar Research Secretariat in Stockholm, the Polar Marine Geological Expedition (PMGE) in St. Petersburg and the Swedish Natural Science Research Council. We also greatly appreciate excellent communication with Norsk Polarinstitutt and PMGE colleagues and, particularly, discussion and review of this paper by A. Krasil'ščikov and Y. Ohta. We also thank P. Witt-Nilsson and M. Friberg for help with the final preparation of the diagrams.

References

Edwards, M. B. 1976: Sedimentology of Late Precambrian Sveanor and Kapp Sparre Formations at Aldousbreen, Wahlenbergfjorden, Nordaustlandet. *Norsk Polarinst. Årbok 1974*, 51–61.

Edwards, M. B. & Taylor, P. M. 1976: A Rb/Sr age for granite-gneiss clasts from the late Precambrian Sveanor Formation, central Nordaustlandet. *Norsk Polarinst. Årbok 1974*, 255–258.

Flood, B., Gee, D. G., Hjelle, A., Siggerud, T. & Winsnes, T. S. 1969: The geology of Nordaustlandet, northern and central parts. *Norsk Polarinst. Skr. 146*, 139.

Gee, D. G., Johansson, Å., Ohta, Y., Teben'kov, A. M., Krasil'ščikov, A. A., Balašov, Y. A., Larionov, A. N., Gannibal, L. F. & Ryungenen, G. I. 1995: Grenvillian basement and a major unconformity within the Caledonides of Nordaustlandet, Svalbard. *Precambrian Research* 70, 215–234.

Hamilton, E. I & Sandford, K. S. 1964: Rubidium-strontium ages from some Spitsbergen rocks. *Nature. 201*, 1208–9. London.

Harland, W. B., Hambrey, M. J. & Waddams, P. 1993: Vendian Geology of Svalbard. *Norsk Polarinst. Skr. 193*, 1–150.

Hjelle, A. 1966: The composition of some granitic rocks from Svalbard. *Norsk Polarinst. Årbok 1965*, 7–30.

Hjelle, A. 1978: An outline of the Pre-Carboniferous geology of Nordaustlandet. *Polarforsch. 48 (1/2)*, 62–77.

Krasil'ščikov, A. A. 1967: Tillitopodobnye porody Severo-Vostočnoj Zemli (Tillite-like rocks of North East Land). Pp. 36–62 in Sokolov, V. N. (ed.): *Materialy po stratigrafii Špicbergena* (Data on the Stratigraphy of Spitsbergen), *NIIGA, Leningrad*.

Kulling, O. 1932: Några geologiska resultat från expeditionen till Nordostlandet 1931. *Geol. Fören. Förh.* Bd 54, 138–145. Stockholm 1932.

Kulling, O. 1934: Scientific results of the Swedish–Norwegian Arctic Expedition in the summer of 1931, Part XI. The "Hecla Hoek Formation" round Hinlopenstredet. *Geograph. Ann. 16 (Stockholm)*, 161–254.

Lauritzen, Ø. & Ohta, Y. 1984: Geological map of Svalbard 1:500,000, sheet 4G Nordaustlandet. *Norsk Polarinst. Skr. Nr. 154–D*, 14 pp.

Nordenskiöld, A. E. 1864: Geografisk och geognostisk beskrifning öfver nordöstra delarne af Spetsbergen och Hinlopen Strait. *K. Svenska Vetensk. Akad. Handl. 4(7)*, 1–25.

Nordenskiöld, A. E. 1866: Utkast till Spitsbergens geologi. *K. Svenska Vetensk. Akad. Handl. 6(7)*, 1–35.

Ohta, Y. 1982a: Relation between the Kapp Hansteen Formation and the Brennevinsfjorden Formation in Botniahalvøya, Nordaustlandet, Svalbard. *Norsk Polarinst. Skr. 178*, 5–18.

Ohta, Y. 1982b: Murchisonfjorden Supergroup of Lågøya, northwest Nordaustlandet, Svalbard. *Norsk Polarinst. Skr. 178*, 19–40.

Ohta, Y. 1982c: Lithostratigraphy of the Hecla Hoek rocks in central Nordaustlandet and their relationships to the Caledonian granitic-migmatitic rocks. *Norsk Polarinst. Skr. 178*, 41–60.

Ohta, Y. 1984: Caledonian and Precambrian history in Svalbard: a review, and an implication of escape tectonics. *Tectonophysics 231*, 183–94.

Ohta, Y. 1985: Geochemistry of the late Proterozoic Kapp Hansteen igneous rocks of Nordaustlandet, Svalbard. *Polar Res. 3 n.s.*, 69–92.

Ohta, Y. 1994: Caledonian and Precambrian history in Svalbard: a review, and an implication of escape tectonics. *Tectonophysics 231*, 183–194.

Sandford, K. S. 1950: Observations on the geology of the northern part of North-East Land (Spitsbergen). *Quart. J. Geol. Soc. Lon. 15*, 461–93. London.

Sandford, K. S. 1956: The stratigraphy and structure of the Hecla Hoek Formation and its relationship to a subjacent metamorphic complex in North-East Land (Spitsbergen). *Quart. J. Geol. Soc. Lon. 112*, 339–362.

Teben'kov, A. M. 1983: Pozdnedokembrijskie magmatičeskie formacii Severo-Vostočnoj Zemli (Late Precambrian magmatic formations of Nordaustlandet). Pp. 74–86 in Krasil'ščikov, A.A. (ed.): *Geologija Špicbergena, PGO*. Sevmorgeologija, Leningrad.