

Fig. 85. Cambrian succession at the head of Nordenskiöld Fjord showing the markedly thickened Bistrup Land Formation (BL; 150–180 m thick in this section) overlying the banded slopes of the Henson Gletscher Formation (HG). Note the pale olistolith blocks in the megabreccia bed that caps the Aftenstjernesø Formation (A). BU, Buen Formation; B3, Blue Cliffs Formation; f-f, fault. From Higgins *et al.* (1991a).

Brønlund Fjord and Tavsens Iskappe Groups: northern outcrop belt

The Brønlund Fjord and Tavsens Iskappe Groups crop out in a series of anticlinal inliers and thrust slices within the southern part of the North Greenland fold belt from Nyeboe Land eastward to western Peary Land (Fig. 86). Three formations are recognised, corresponding to the lower three units of the four-part Cambrian – Lower Silurian ‘starved basin’ sequence described by Higgins & Soper (1985). The lower two of these formations are assigned to the Aftenstjernesø and Henson Gletscher Formations of the Brønlund Fjord Group, as defined from the southern outcrop belt around Henson Glet-

scher. The Kap Stanton Formation, representing the third unit of Higgins & Soper (1985), was defined by Ineson *et al.* (1994; Peel, 1994a) and assigned to the Tavsens Iskappe Group. The fourth unit, composed of cherty black graptolitic mudstones, has been referred to the Amundsen Land Group as defined from the trough succession (Friderichsen *et al.*, 1982; Higgins *et al.*, 1991a, b).

Correlation between the northern and southern outcrop belts (Figs 10, 87) was discussed by Ineson *et al.* (1994). The boundaries of the Aftenstjernesø Forma-

tion are considered essentially isochronous throughout North Greenland. In contrast, the overlying Henson Gletscher Formation in the northern outcrop belt is equivalent to the Henson Gletscher, Sydpasset, Ekspedition Bræ and lower Fimbuldal Formations of the southern outcrop belt (Figs 10, 87). The Kap Stanton Formation equates roughly to the uppermost Fimbuldal, Holm Dal and Perssuaq Gletscher Formations of the southern outcrop.

Brønlund Fjord Group

The Brønlund Fjord Group typically ranges in thickness from 50 m to 100 m, but thickens westward and is up to 150 m thick in northern Nyeboe Land (Fig. 88).

Aftenstjernesø Formation

This formation is readily recognised throughout the northern outcrop belt where it is 25–80 m thick, thinning northwards and eastwards. It conformably overlies dark shaly mudstones of the Buen Formation (Figs 88, 89). The base of the Aftenstjernesø Formation is typically marked by a pyritic and phosphoric horizon (cf. the 'Member A' interval of the southern

outcrop belt). The formation is composed of nodular, thin-bedded argillaceous, dark grey to black lime mudstones or dolomites, capped by a laterally continuous, clast-supported carbonate breccia bed up to 20 m thick (Fig. 89). Graded limestone beds occur rarely. The formation has yielded a late Early Cambrian fauna from several localities (see Higgins & Soper, 1985; Davis & Higgins, 1987). Blaker (1991) described trilobites *Serrodiscus daedalus*, *S. speciosus*, *S. latus?* and *Olenellus* in association with *Latouchella* and inarticulate brachiopods. *Hadimopanella arctica* Wrona, 1982 is abundant in some samples (Peel & Larsen, 1985; Bendix-Almgreen & Peel, 1988).

Henson Gletscher Formation

This formation forms a dark grey or black recessive interval between the more resistant carbonates of the Aftenstjernesø and the Kap Stanton Formations (Figs 88, 89). It is commonly between 20 m and 60 m thick but attains 90 m in northern Nyeboe Land. The Henson Gletscher Formation is characterised by black, calcareous, shaly mudstones and black cherts, with subordinate spicule-rich argillaceous carbonates. Massive or medium- to thin-bedded, white, very fine-grained sandstones form units up to several metres thick in the

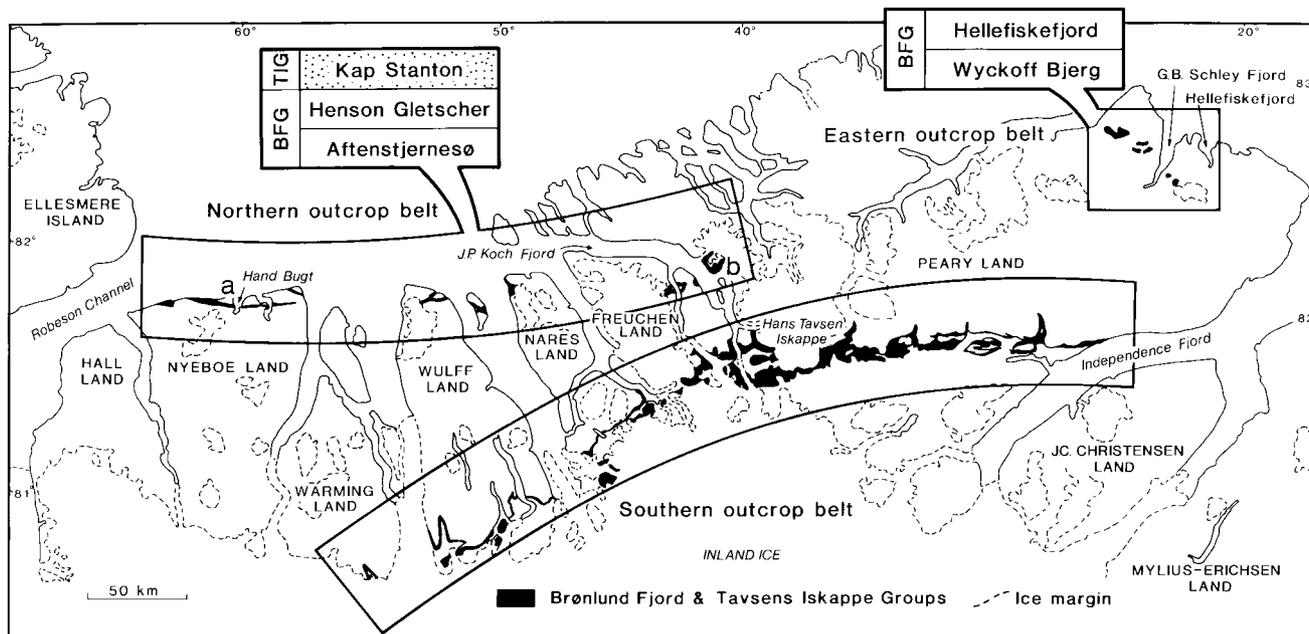


Fig. 86. Map showing the distribution of the Brønlund Fjord and Tavsens Iskappe Groups and the stratigraphic subdivision of the northern and eastern outcrop belts. Localities a and b in the northern outcrop belt indicate the position of stratigraphic sections a and b in Fig. 88. Modified from Ineson *et al.* (1994).

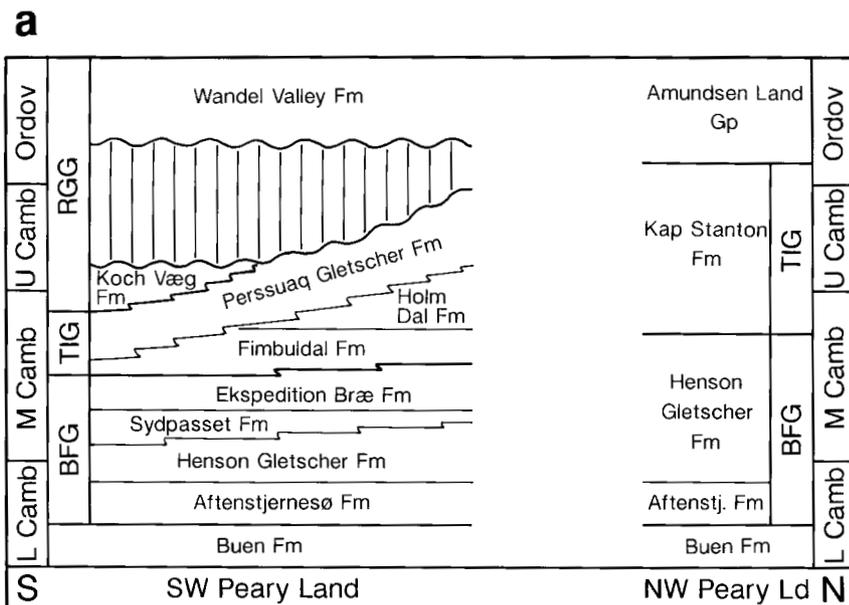
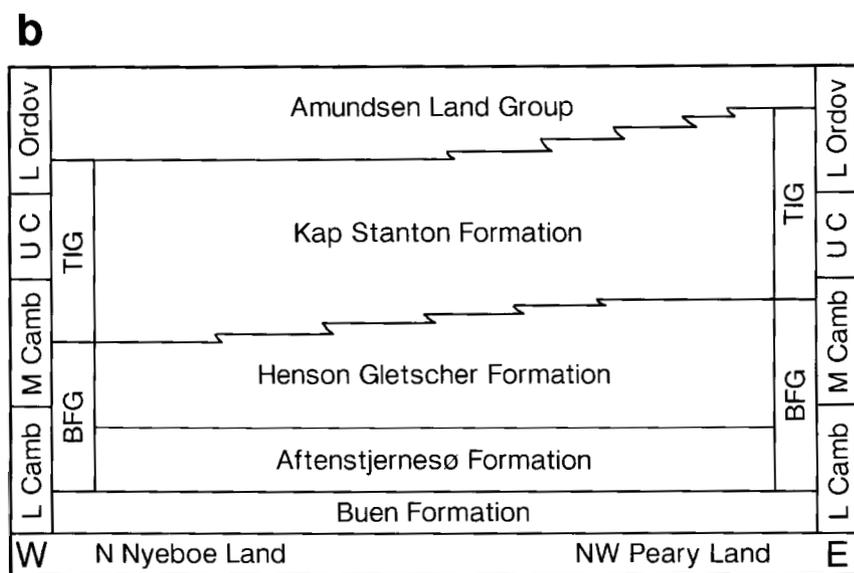


Fig. 87. Lithostratigraphy of the Brønlund Fjord (BFG) and Tavsens Iskappe Groups (TIG) in (a) a south-to-north transect in west Peary Land, showing the relationship between the stratigraphies of the southern and northern outcrop belts, and (b) a west-to-east transect in the northern outcrop belt (i.e. from locality a to locality b in Fig. 86). RGG, Ryder Gletscher Group. From Ineson *et al.* (1994).



lower half of the formation in northern Wulff Land and northern Nyeboe Land; they are typically structureless but locally display hummocky cross-stratification or dish structures.

The thick succession assigned to the Henson Gletscher Formation in northern Nyeboe Land (Fig. 88a) has yielded rich agnostoid and polymeroid trilobite faunas indicative of the *Glossopleura*, *Ptychagnostus gibbus* and *Ptychagnostus atavus* Zones of the Middle Cambrian. Detailed taxonomy and discussion of these and other faunas are given by Babcock (1994a, b), Robison (1994) and Peel (1994b). At this locality, the Henson Gletscher Formation ranges in age from the late Early Cambrian to the medial Middle Cambrian but the top of the formation probably extends up into

the late Middle Cambrian in eastern sections of the northern outcrop belt (Fig. 87; Ineson *et al.*, 1994).

Tavsens Iskappe Group

The Tavsens Iskappe Group is 100–350 m thick in the northern outcrop belt and is represented by a single formation, the Kap Stanton Formation (Ineson *et al.*, 1994; Peel, 1994a).

Kap Stanton Formation

History. Strata of this formation have been previously referred to informally as the ‘dolomite unit’, the third of four units making up the ‘Cambrian–Lower Silurian

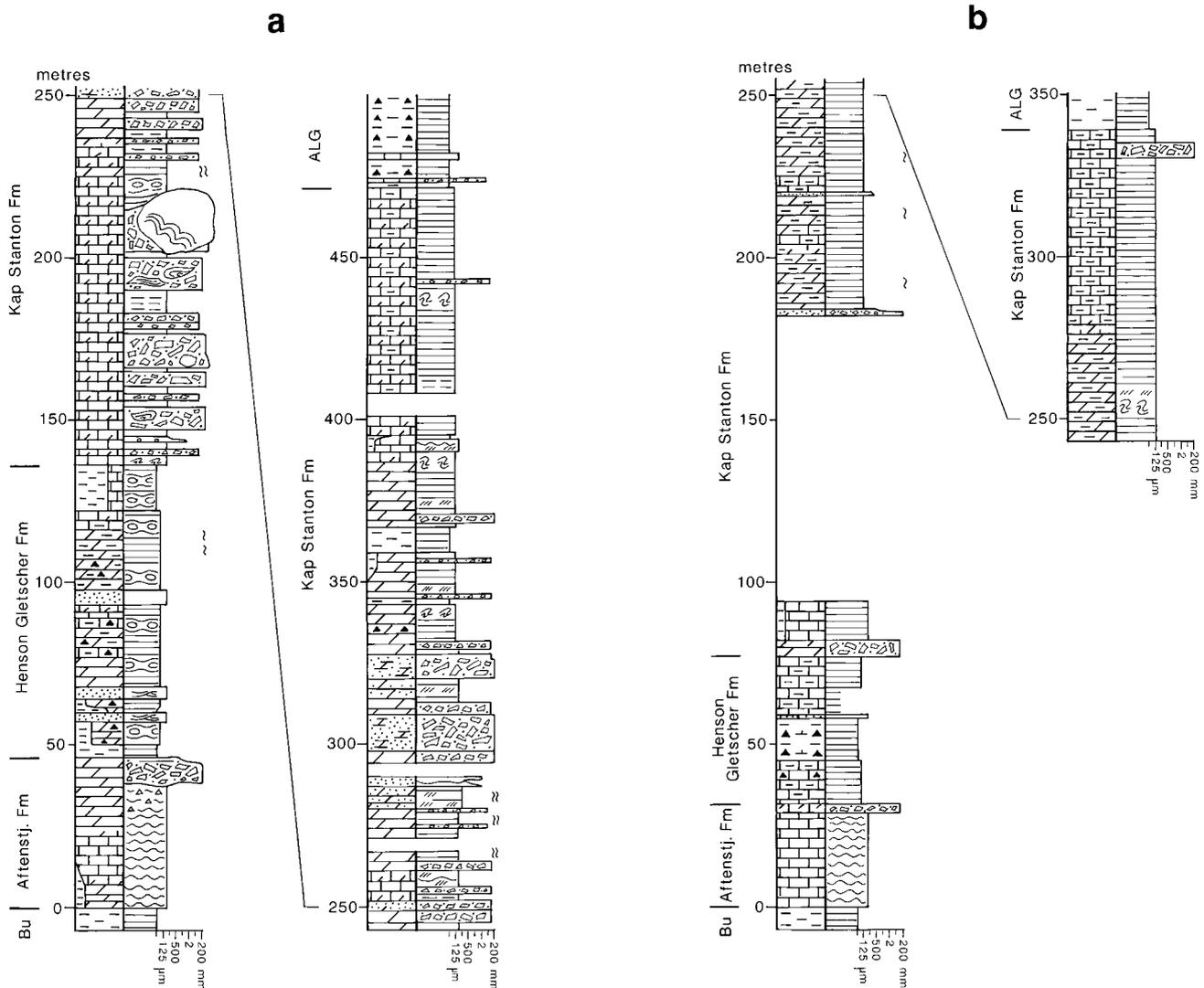


Fig. 88. Stratigraphic sections through the Brønlund Fjord and Tavsens Iskappe Groups in the northern outcrop belt. **a**, northern Nyeboe Land; **b**, outer J. P. Koch Fjord (see Fig. 86). Bu, Buen Formation, Aftenstj., Aftenstjernesø; ALG, Amundsen Land Group. Modified from Ineson *et al.* (1994).

starved basin sequence' described by Higgins & Soper (1985). The Kap Stanton Formation was formally defined by Ineson *et al.* (1994; see also Peel, 1994a).

Name. After Kap Stanton, a prominent cape in northern Nyeboe Land (Fig. 90).

Type section. Fig. 91; the type section is about 1 km west of Hand Bugt on the north coast of Nyeboe Land. The section of steeply dipping, overturned strata crops out along the east side of a small north-south stream gully, on the ridge overlooking the west shore of Hand Bugt (Fig. 90).

Thickness. About 350 m at the type section. The Kap

Stanton Formation varies in thickness from *c.* 100 m in northern Wulff Land and Lauge Koch Land to nearly 200 m in south-east Nansen Land and over 300 m in Nyeboe Land (Fig. 88).

Lithology. The carbonate-rich, yellow weathering strata of this formation contrasts strongly with the black or dark grey mudstones, cherts and shaly carbonates above and below (Fig. 89). The Kap Stanton Formation is dominated by dark grey or black argillaceous dolomites and limestones. The proportion of siliciclastic mud to carbonate mud is variable both vertically and laterally within the formation. The dark carbonate-rich mudstones typically show parallel-lamination but in some sections laminated carbonates alternate with paler,

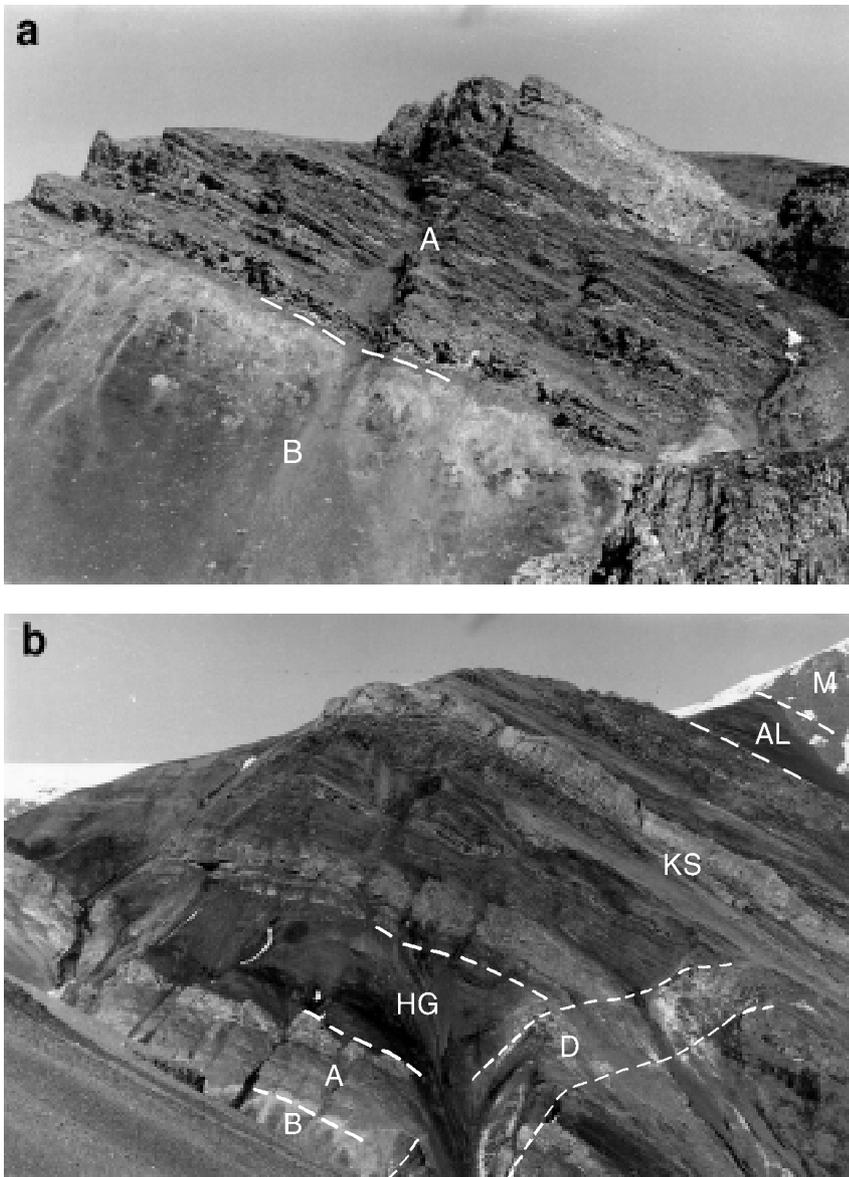


Fig. 89. **a.** Aftenstjernesø Formation (A) overlying the scree-covered Buen Formation (B). The pale scree at the base of the Aftenstjernesø Formation reflects the presence of a distinctive pyritic marker bed at this boundary. Note also the massive carbonate breccia bed (c. 7 m thick) capping the formation. East side of Navarana Fjord, Lauge Koch Land. **b.** Cambrian to Silurian succession on the east side of Navarana Fjord, Lauge Koch Land. B, Buen Formation (Lower Cambrian); A, Aftenstjernesø Formation (Lower Cambrian); HG, Henson Gletscher Formation (Lower – Middle Cambrian); KS, Kap Stanton Formation (Middle Cambrian – Ordovician); AL, Amundsen Land Group (Ordovician); M, Merqujoq Formation (Lower Silurian); D, Tertiary dyke. The Aftenstjernesø Formation is about 30 m thick. From Ineson *et al.* (1994).

burrowed carbonate mudstones producing a distinctive banded structure on a scale of tens to hundreds of centimetres.

At the type section, the formation is carbonate-rich relative to eastern outcrops and consists of nodular or thin-bedded argillaceous lime mudstones and dolomites interbedded frequently with carbonate turbidites (e.g. Fig. 13C) and clast-supported carbonate breccia beds (Fig. 91). The nodular carbonates commonly display slope-creep deformation structures: pull-aparts, brittle slumps and interstratal breccia lenses and bands (Fig. 92); partially dolomitised nodular carbonates often weather to a striking orange-dark grey banding – the tiger limestones of Dawes (1976). The clast composition of the mass-flow breccias suggests that they were

mostly derived locally (Higgins & Soper, 1985), but the type section also includes a large (20 m) olistolith of light grey stromatolitic limestone (Fig. 91).

Farther east, the succession is less varied (Fig. 88b), composed largely of laminated dark shaly carbonate mudstones, interspersed locally with paler burrowed intervals, rare units of ripple cross-laminated peloidal grainstone and prominent carbonate breccia beds. The mass-flow breccias are more varied in composition than those at the type section, containing quartz sand and equidimensional blocks of pale carbonate in addition to the dominant platy lime mudstone clasts (see Fig. 13D).

Boundaries. The Kap Stanton Formation lies conform-

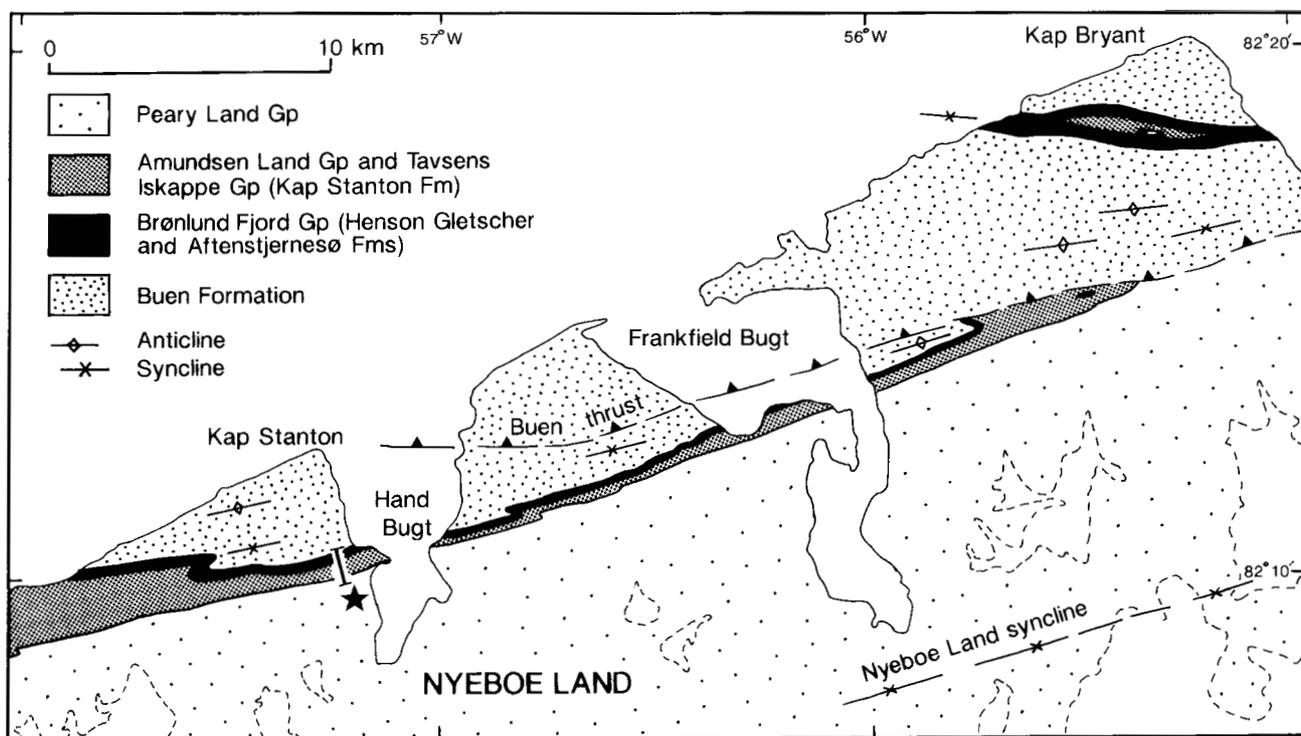


Fig. 90. Sketch geological map of north-eastern Nyeboe Land, showing the location (star) of the type section of the Kap Stanton Formation, west of Hand Bugt. From Ineson *et al.* (1994).

ably between the dark mudstones, cherts and carbonates of the Henson Gletscher Formation beneath and the Amundsen Land Group above (Fig. 89b). The base is placed at the transition from black mudstones, cherts and subordinate platy lime mudstones to thin-bedded or nodular argillaceous carbonate mudstones. In places (e.g. Fig. 88b), the base of the formation is marked by a thick carbonate breccia bed.

The top is placed where argillaceous platy carbonates (or carbonate-rich siliciclastic mudstones) are succeeded by black cherts and mudstones assigned to the Amundsen Land Group. At many localities, a carbonate breccia bed occurs immediately beneath the top of the Kap Stanton Formation.

Distribution. The formation crops out in thrust slices and anticlinal inliers near the north coast of central North Greenland, from north-west Peary Land in the east to northern Nyeboe Land in the west (Fig. 86).

Fauna and age. As discussed by Ineson *et al.* (1994; see also Peel, 1994a), the boundaries of the Kap Stanton Formation are demonstrably diachronous (Fig. 87b); the formation has a maximum proven age range of medial Middle Cambrian to Early Ordovician. In north-

ern Nyeboe Land, the base of the formation lies within the *Ptychagnostus atavus* Zone of the medial Middle Cambrian whereas in eastern sections this boundary is of late Middle Cambrian (*Lejopyge laevigata* Zone) age. Graptolites in the upper levels of the formation and in the overlying Amundsen Land Group indicate that the upper boundary is also diachronous across the northern outcrop belt (Fig. 87b; Higgins *et al.*, 1992; Ineson *et al.*, 1994).

Babcock (1994b; see also Fletcher *et al.*, 1988) noted that polymeroid trilobite faunas from the Kap Stanton Formation described by Babcock (1994a) are of Baltic aspect, representing cool, deeper water, outermost shelf to upper slope biofacies. The presence in underlying strata of the Henson Gletscher Formation (and throughout North Greenland) of trilobite faunas of Laurentian aspect, living in warmer shallow waters, allowed Babcock (1994b) to recognise clear segregation of trilobite biofacies, which he interpreted as evidence of a Middle Cambrian thermocline in marine waters around Laurentia.

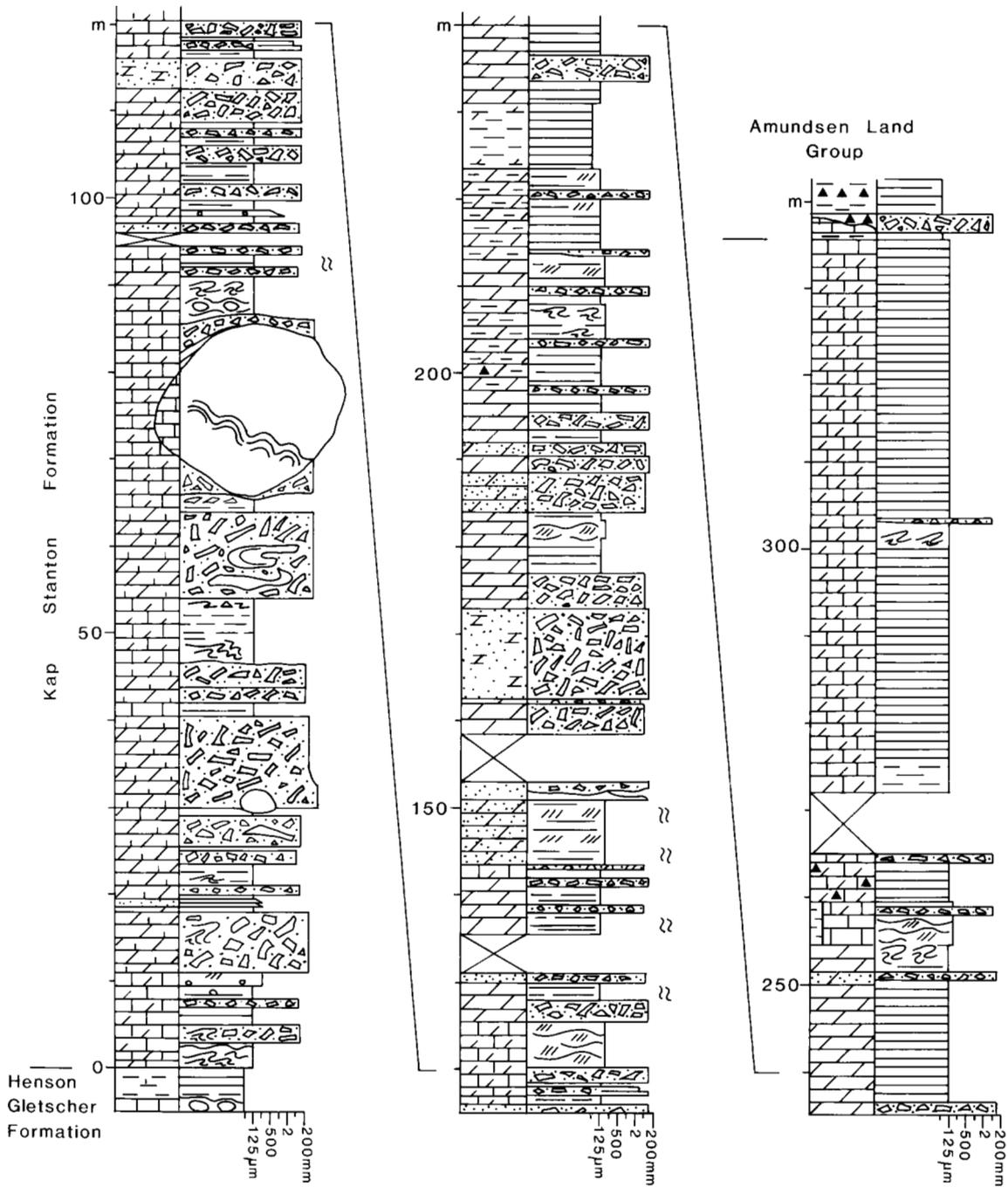
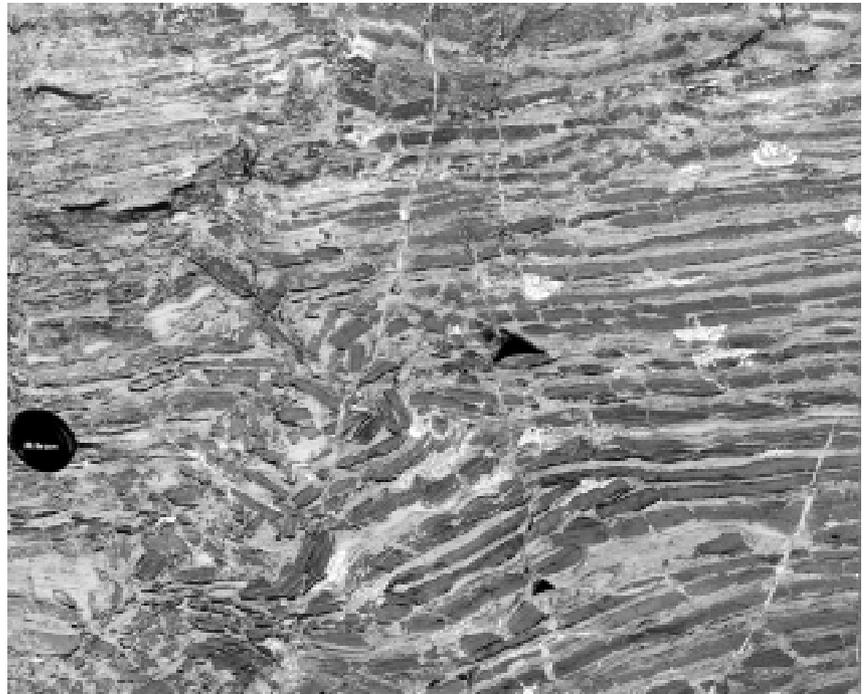


Fig. 91. Type section of the Kap Stanton Formation, northern Nyeboe Land (Fig. 90). See Fig. 14 for legend. From Ineson *et al.* (1994).

Fig. 92. Platy nodular argillaceous lime mudstones of the Kap Stanton Formation in the type section showing pull-aparts and brittle slump folds of inferred slope creep origin. Additional facies of the Kap Stanton Formation were illustrated by Ineson *et al.* (1994). From Ineson *et al.* (1994).



Brønlund Fjord Group: eastern outcrop belt

Cambrian shelf strata crop out intermittently in block-faulted terrain in the G. B. Schley Fjord area of north-eastern Peary Land (Christie & Ineson, 1979), between Frederick E. Hyde Fjord in the north-west and the eastern coast of Wyckoff Land (Figs 86, 93). The Brønlund Fjord Group conformably succeeds dark grey-green, shaly mudstones of the upper Buen Formation (the Schley Fjord shale of Troelsen, 1956) and is itself overlain with probable unconformity by light grey dolomites of the Wandel Valley Formation of late Early – Middle Ordovician age (Fig. 86, 94). The correlation between these isolated, poorly fossiliferous outcrops and the more extensive southern and northern outcrop belts is not attempted at formation level.

Brønlund Fjord Group

The Brønlund Fjord Group ranges in thickness from 115 m to 265 m in this area and is subdivided into the Wyckoff Bjerg and the Hellefiskefjord Formations.

Wyckoff Bjerg Formation

new formation

History. Described informally as the 'lower unit' of the Brønlund Fjord Group by Christie & Ineson (1979).

Name. After Clarence Wyckoff Bjerg, a prominent peak in eastern Wyckoff Land (Fig. 93).

Type section. Fig. 95A; east side of narrow valley, approximately 500 m south of the shoreline, eastern Wyckoff Land (Fig. 93).

Reference section. Fig. 95B; south side of north-west-erly trending river valley, approximately 13 km east of the head of G. B. Schley Fjord, Wyckoff Land (Figs 93, 94).

Thickness. The formation is 105 m at the type section (Fig. 95A) and at least 125 m thick at the reference section (Fig. 95B). It thins rapidly towards the north-west across G. B. Schley Fjord and is only 35 m thick in central Hans Egede Land.

Brønlund Fjord Group

-  Hellefiskefjord Fm.
-  Wyckoff Bjerg Fm.

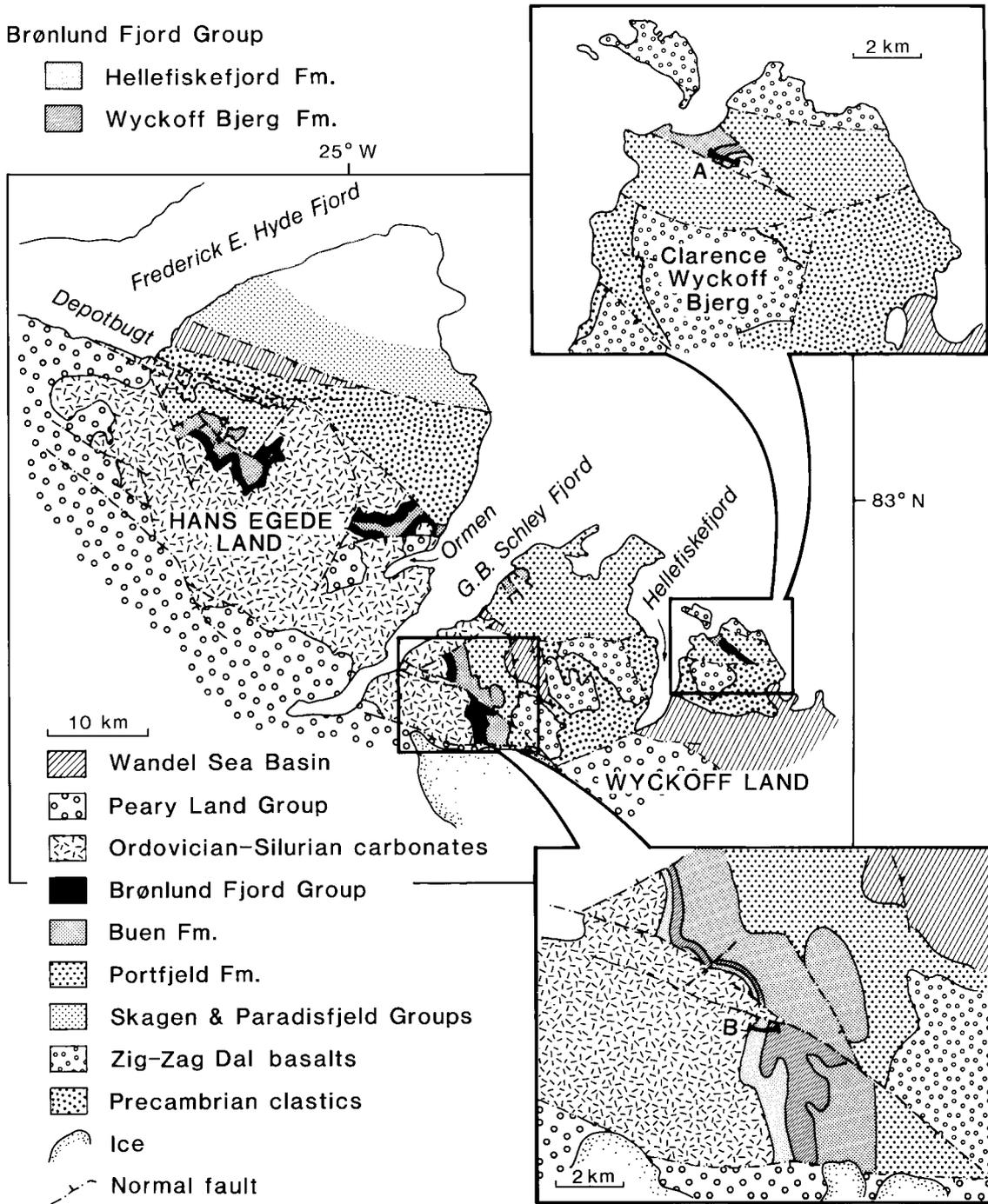


Fig. 93. Geological sketch map of the eastern outcrop belt of the Brønlund Fjord Group in north-east Peary Land. The inset maps show the locations of the type (A) and reference (B) sections of the Wyckoff Bjerg and Hellefiskefjord Formations of the Brønlund Fjord Group. Based on field mapping by R. L. Christie and J. R. Ineson.



Fig. 94. View north-west from Wyckoff Land in the foreground across G. B. Schley Fjord to Hans Egede Land and, in the far distance, Frederick E. Hyde Fjord and the mountains of eastern Johannes V. Jensen Land (Fig. 93). Cambrian and Ordovician strata in the foreground young to the south-west (left); the Portfeld (Pf) and Buen (Bu) Formations form the low-lying land whilst the succeeding Brønlund Fjord Group (BF) and Ordovician-Silurian carbonates (O-S) produce more resistant features. Note the distinctive banded outcrop of the Wandel Valley Formation, immediately overlying the Brønlund Fjord Group. The reference section of the Wyckoff Bjerg and Hellefiskefjord Formations is located at the mouth of the deeply shaded valley (arrow indicates top of section). Photo: Kort- og Matrikelstyrelsen, Copenhagen – route 548C-N 4298.

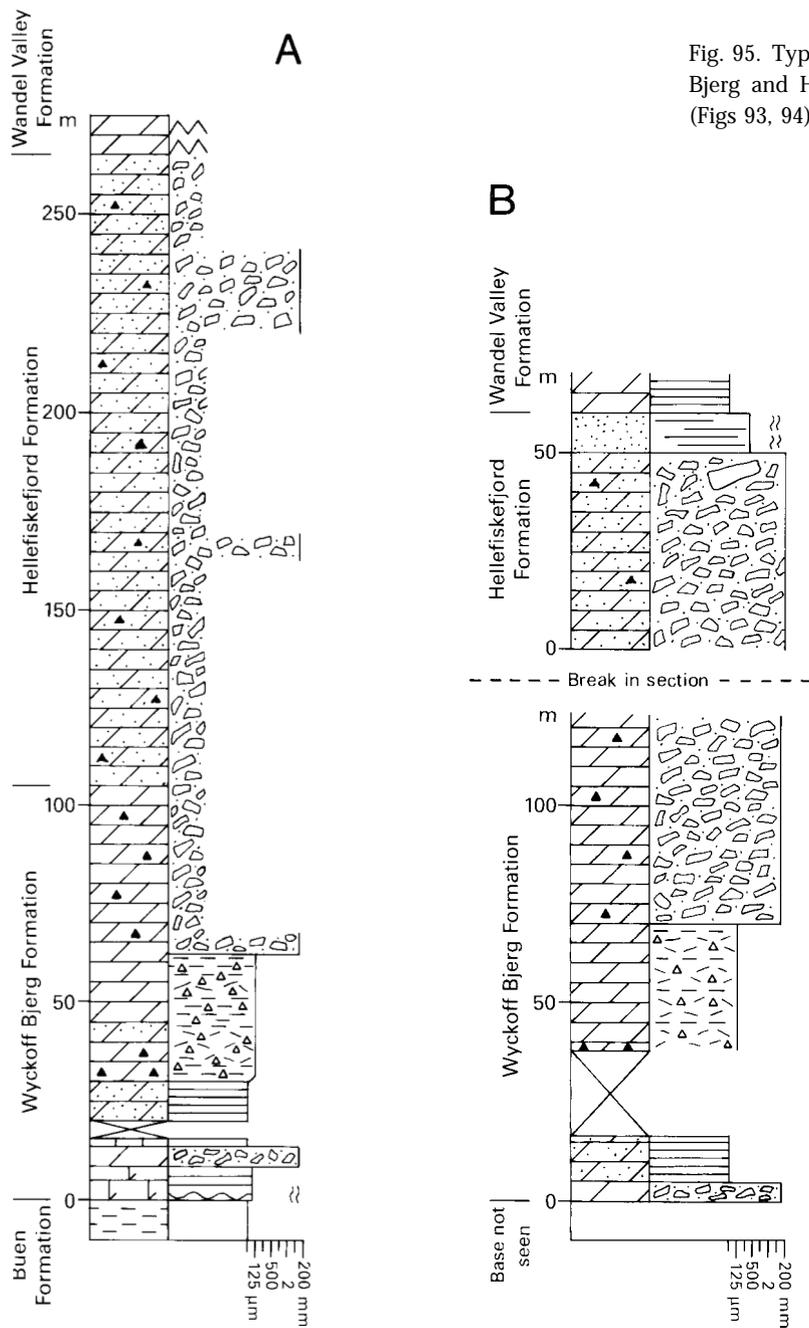


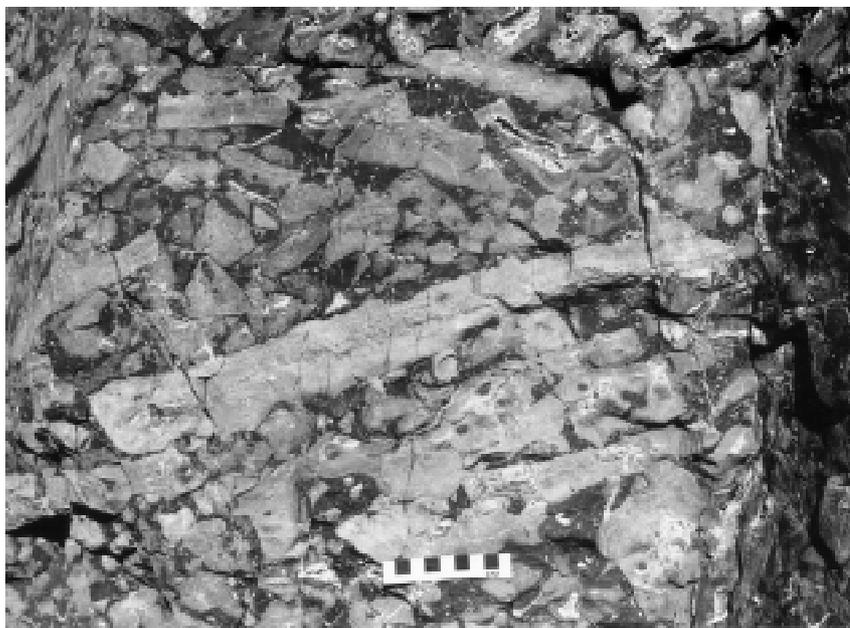
Fig. 95. Type (A) and reference (B) sections of the Wyckoff Bjerg and Hellefiskefjord Formations, north-east Peary Land (Figs 93, 94). See Fig. 14 for legend.

Lithology. The Wyckoff Bjerg Formation typically comprises pale grey weathering, cliff-forming, dolomite breccias and platy, nodular dolomites alternating with intervals of sooty black, laminated dolomites and rare limestones. At the type section, grey-green fossiliferous mudstones of the Buen Formation are succeeded by a thin interval (4.4 m) of bioturbated, dolomitic, skeletal wackestones and packstones rich in trilobite fragments. Pyrite and argillaceous partings are common. These beds pass upwards into parallel-laminated, dark grey-black, silty, sandy limestones (lime mudstones, peloidal wackestones) and dolomites, which locally display small-scale syndepositional deformation structures such

as microfaults, pull-aparts and minor slump folds. A massive, clast-supported dolomite breccia bed forms a prominent ledge in these recessive sediments at both the type and reference sections (Figs 95, 96).

The upper 75 m of the formation are composed of prominent, pale grey weathering, medium to coarse crystalline dolomites. Platy nodular dolomites (Fig. 97), showing abundant evidence of *in situ* brecciation, are overlain by chaotic dolomite breccia with randomly oriented clasts (commonly 5–20 cm) in a pale, vuggy, dolomite matrix. Chert is common, forming up to 10% of the rock. A discrete black chert bed up to 1 m thick occurs at the base of the platy nodular dolomites but,

Fig. 96. Clast-supported mass-flow dolomite breccia of the Wyckoff Bjerg Formation in the reference section; note the irregular, nodular form of clasts.



in general, chert is more widely disseminated, replacing platy nodules and breccia clasts.

To the west of G. B. Schley Fjord, the Wyckoff Bjerg Formation is poorly exposed but is apparently composed mainly of chaotic dolomite breccia comprising platy, tabular clasts (5–15 cm) in a pale grey, locally sandy, dolomite matrix.

Boundaries. The Wyckoff Bjerg Formation conformably overlies the Buen Formation and, in turn, is overlain by the Hellefiskefjord Formation (Fig. 95). The lower boundary is abrupt and is defined where grey-green, shaly mudstones (Buen Formation) are over-

lain by pale, locally rusty-brown weathering, dolomitic limestones.

Pale grey, cherty dolomite breccias of the Wyckoff Bjerg Formation pass gradationally upwards into golden-brown weathering, dolomite-sandstone breccias assigned to the Hellefiskefjord Formation (Fig. 95). The boundary is taken at the change in weathering colour from pale grey to golden-brown; this is a distinctive, readily-mapped junction and, in outcrop, coincides with an abrupt increase in the silica content of the rock (replacive chert and primary sand grains) from less than 10% to over 50%. Being partly a diagenetic feature, this boundary is probably diachronous.

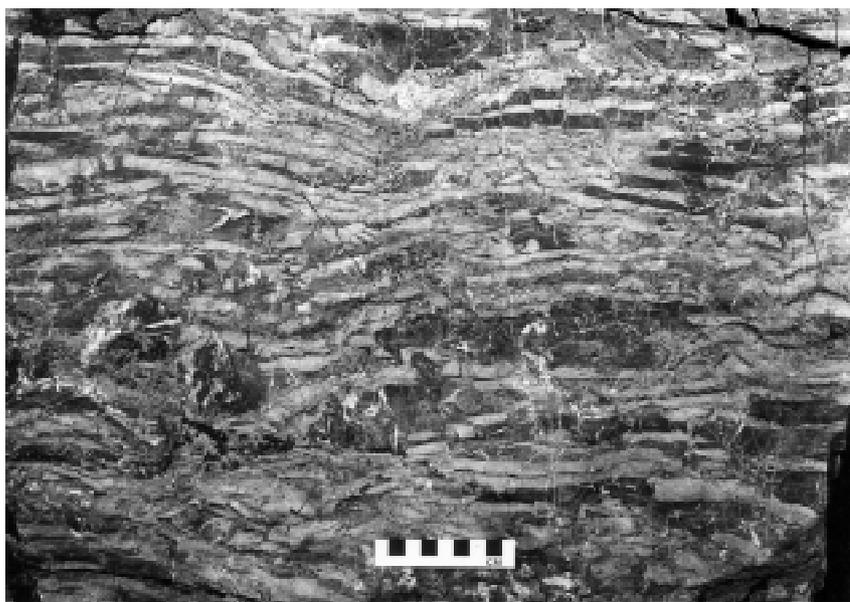


Fig. 97. Cherty platy nodular dolomites of the Wyckoff Bjerg Formation in the type section.



Fig. 98. Clast-supported mass-flow breccia composed of sandstone clasts in a partially silicified dolomite matrix. Hellefiskefjord Formation, Hans Egede Land.

Distribution. Between G. B. Schley Fjord and Hellefiskefjord, the main outcrop of the formation trends approximately north–south, bounded by major faults which juxtapose the Cambrian rocks against Silurian carbonate and siliciclastic sediments (Figs 93, 94). The type section, east of Hellefiskefjord, occurs in a fault-bounded outlier, flanked by older Cambrian and Precambrian rocks (Fig. 93).

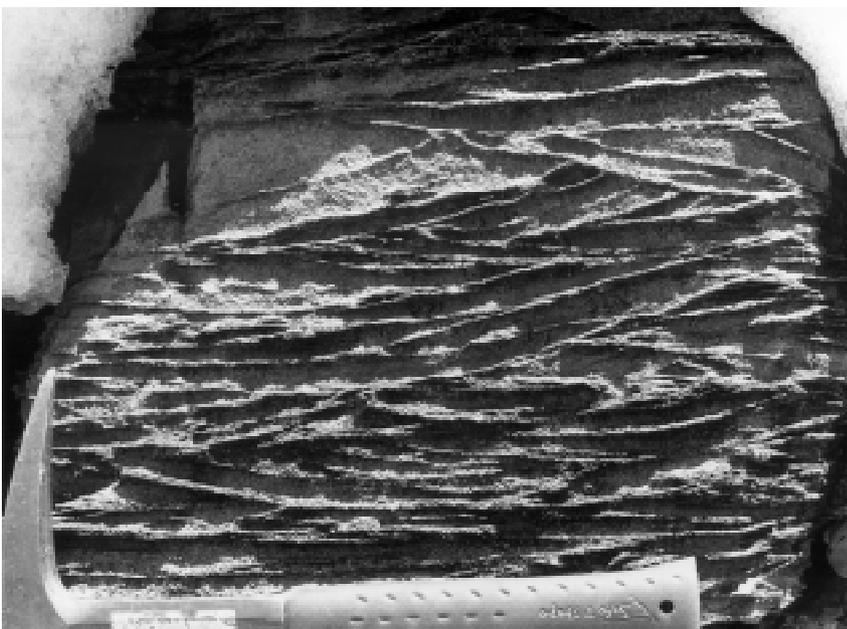


Fig. 99. Sandy ooidal dolomites showing trough cross-bedding. Hellefiskefjord Formation, east of G. B. Schley Fjord, north-east Peary Land.

West of G. B. Schley Fjord, the formation crops out in two areas: north of Ormen and in a discontinuous NW–SE trending belt, south-east of Depotbugt (Fig. 93). Dips are variable and normal faults are numerous but, in general, the succession youngs towards the south or south-west.

Fauna and age. Diagnostic fossils have not been recovered from the Wyckoff Bjerg Formation. The formation conformably overlies argillaceous rocks of the Buen Formation which contain olenellid trilobite faunas of Early Cambrian age (V. Poulsen, 1974; Palmer & Peel, 1979; Blaker, 1991) and hence is assigned a similar Early Cambrian age.

Hellefiskefjord Formation

new formation

History. Informally described as the ‘upper unit’ of the Brønlund Fjord Group by Christie & Ineson (1979).

Name. After Hellefiskefjord, the north–south trending fjord east of G. B. Schley Fjord in north-eastern Peary Land (Fig. 93).

Type section. Fig. 95A; east side of the narrow valley traversing fault-bounded outlier of Cambro–Ordovician rocks north of Clarence Wyckoff Bjerg, eastern Wyckoff Land (Fig. 93). The intermittent exposures and frost-heaved float of the type section provide a measure of

formation thickness and a crude indication of lithological variation. Elsewhere, superior exposure is marred by limited stratigraphic extent and probable fault complications.

Reference section. Fig. 95B; steep western slopes of north–south trending river valley, approximately 12 km east of the head of G. B. Schley Fjord, Wyckoff Land (Figs 93, 94).

Thickness. 150 m at the type section. The formation thins towards the north-west into Hans Egede Land where it has a measured thickness of 80 m.

Lithology. The Hellefiskefjord Formation weathers a characteristic golden-brown colour, in sharp contrast to the grey carbonates of the underlying Wyckoff Bjerg Formation and the overlying Wandel Valley Formation. It comprises a thick amalgamated succession of clast-supported chaotic breccia beds, which are generally indivisible in the poor exposures available and individual bed thicknesses are generally unknown. The breccias are composed of rectangular slabs (commonly 5–30 cm) of brown weathering, dolomitic sandstone and silicified laminated dolomite, set in a pale grey, cherty dolomite or sandy dolomite matrix (Fig. 98). The sandstone clasts are medium to fine grained, display cross-bedding, parallel lamination and bioturbation, and in places are up to 4 m thick and 15 m long.

Trough cross-bedded, sandy, ooidal dolomites (Fig. 99) outcrop within a succession of sandstone-dolomite breccias a few kilometres east of G. B. Schley Fjord (Fig. 93); exposure is poor so that it is not clear if these cross-bedded dolomites are *in situ* or if they form

part of large, derived slabs, as seen elsewhere in the formation.

Boundaries. The Hellefiskefjord Formation overlies conformably the Wyckoff Bjerg Formation; the boundary is placed at the weathering colour change (grey to golden-brown) which coincides with an abrupt increase in the proportions of chert and quartz sand.

The formation is overlain by pale grey, laminated dolomites of the Wandel Valley Formation (late Early – Middle Ordovician). Although poorly exposed in the type section, the boundary is sharp and planar in the reference section and is placed at the junction between laminated, bioturbated sandstones (possibly a large breccia clast) and pale grey, silty dolomites (Fig. 95B).

In the absence of reliable biostratigraphic data, the stratigraphic significance of this planar, apparently conformable boundary is not clear; by analogy with the southern outcrop belt of the Brønlund Fjord Group (see Fig. 5), it probably represents a major hiatus (see also Peel & Smith, 1988; Higgins *et al.*, 1991a).

Distribution. The distribution of the Hellefiskefjord Formation closely follows that of the underlying Wyckoff Bjerg Formation (see above).

Fauna and age. Fossils have not been found in the Hellefiskefjord Formation and its age is thus poorly constrained. It conformably overlies the Wyckoff Bjerg Formation of probable Early Cambrian age and is overlain, with inferred unconformity, by the late Early – Middle Ordovician Wandel Valley Formation. A late Early–Middle Cambrian age is considered most likely.

Ryder Gletscher Group: amended definition

The Ryder Gletscher Group is a thick succession of platform carbonates and subordinate siliciclastics of late Early Cambrian to Middle Ordovician age. It occurs from Kronprins Christian Land in the east to Inglefield Land in the west (see below). Four Cambrian formations, equivalent in age to the Brønlund Fjord (in part) and Tavsens Iskappe Groups, are defined here from central North Greenland (see Fig. 8).

Ryder Gletscher Group

History. The Ryder Gletscher Group was defined by Peel & Wright (1985) to encompass a succession of platform carbonates and subordinate siliciclastic sediments of largely Cambrian age outcropping in the southern Wulff Land – southern Warming Land area; earlier references to these strata are noted by Peel & Wright (1985). Following subsequent fieldwork, Ineson & Peel

(1987) expanded the scope of the group both stratigraphically, to include platform carbonates of Early to Middle Ordovician age, and geographically to include Cambrian–Ordovician strata that crop out across northern Greenland from Kronprins Christian Land in the east to Inglefield Land in the west. Ineson & Peel (1987) also transferred the lowermost two formations of the original Ryder Gletscher Group (informally referred to as formations RG1 and RG2 by Peel & Wright, 1985) to the Brønlund Fjord Group (the Kap Troedsson and Bistrup Land Formations as defined here).

Name. After Ryder Gletscher, the larger glacier between Wulff Land and Warming Land (Figs 2, 78).

Type area. The area around Ryder Gletscher in southern Wulff Land and south-east Warming Land.

Dominant lithology. The Ryder Gletscher Group comprises a heterogeneous succession of platform carbonates with subordinate siliciclastic sediments and evaporites. In the type area, the Cambrian portion of the group comprises dark, burrow-mottled dolomites and subordinate lime mudstones interbedded with pale weathering, mud-cracked, microbial laminites, dolomitised ooid grainstones and stromatolitic biohermal dolomites. Siliciclastic facies occur towards the top of the Cambrian succession and become increasingly important towards the east. Ordovician strata of the Ryder Gletscher Group in the type area comprise a basal, highly distinctive white sandstone formation (the Permin Land Formation of Bryant & Smith, 1985, 1990), succeeded by a varied association of interstratified dark, brown-grey, burrowed and light-coloured, stromatolitic, mud-cracked dolomites; fine-grained sandstones and evaporites occur at certain levels. The lithostratigraphy of the Ordovician portion of the Ryder Gletscher Group in the type area was described by Sønderholm & Due (1985; see also Higgins *et al.*, 1991a). Comparable facies, with local variations, occur in the Ryder Gletscher Group of Inglefield Land and Washington Land to the west (Peel & Christie, 1982; Peel, 1982b) and Peary Land and Kronprins Christian Land to the east (Christie & Peel, 1977; Peel, 1982b; Ineson *et al.*, 1986; Peel & Smith, 1988).

Boundaries. In the type area of southern Wulff Land, the Ryder Gletscher Group conformably overlies the Bistrup Land Formation of the Brønlund Fjord Group;

the boundary is placed where burrow-mottled, dark grey-brown oncolitic dolomites abruptly succeed hummocky cross-stratified, yellow weathering dolomite grainstones. The Ryder Gletscher Group is conformably succeeded in its type area (and throughout North Greenland) by the Morris Bugt Group; the boundary in the type area is placed where grey microbially laminated dolomites of the Cape Webster Formation are succeeded by dark grey to black, bituminous, micritic limestones (see Sønderholm & Due, 1985).

In Inglefield Land and Washington Land, to the west, the Ryder Gletscher Group conformably overlies Cambrian siliciclastic sediments of the Dallas Bugt and Humboldt Formations (Peel & Christie, 1982; Higgins *et al.*, 1991a). In eastern areas of North Greenland, the Ryder Gletscher Group gradually oversteps the Tavsens Iskappe and Brønlund Fjord Groups (Early – Late Cambrian) in Peary Land to lie directly on the Lower Cambrian Buen Formation in Valdemar Glückstadt Land. In Kronprins Christian Land, Early Ordovician strata of the Wandel Valley Formation assigned to the Ryder Gletscher Group rest unconformably on Proterozoic siliciclastic sediments.

Distribution. From Inglefield Land in the west to Kronprins Christian Land in the east (Fig. 2). Cambrian formations assigned to the group are only recognised west of Hans Tavsens Iskappe.

Geological age. Late Early Cambrian to Middle Ordovician.

Subdivision. The Ryder Gletscher Group comprises a total of 25 formations as described by Ineson & Peel (1987; see also Fig. 2 in Higgins *et al.*, 1991a). Four previously undefined Cambrian formations of the Ryder Gletscher Group are geographically and geologically associated with Cambrian units described herein from the southern outcrop belt and these formations are formally proposed below. They are the Koch Væg Formation in the Henson Gletscher region of westernmost Peary Land, and the Blåfjeld, Brikkerne and Blue Cliffs Formations in the type area of the Ryder Gletscher Group in southern Wulff Land and adjacent Warming Land.

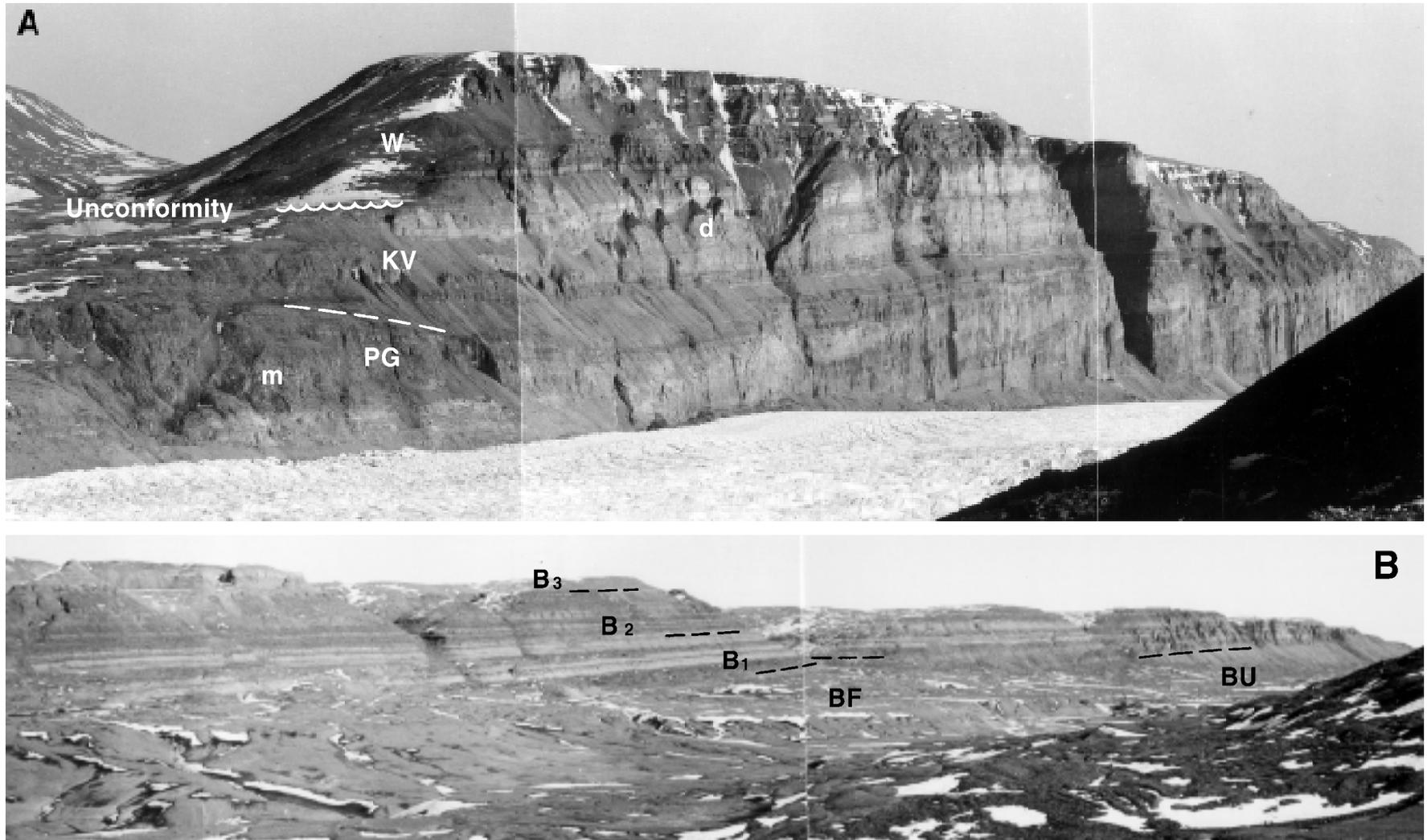


Fig. 100. **A.** Cambrian and Ordovician strata exposed in Koch Væg on the east side of Henson Gletscher, west Peary land (Fig. 23). The Perssuaq Gletscher Formation (PG, Tavsens Iskappe Group) shows spectacular clinoform bedding reflecting northward (left) progradation of the platform margin; a mound-like structure (m) is developed in this formation at the northern end of Koch Væg. The conformably overlying succession of shallow-water platform carbonates and subordinate siliciclastics are assigned to the Koch Væg Formation (KV) of the Ryder Gletscher Group. The Cambrian succession is capped by an unconformity beneath the well-bedded dolomites of the Wandel Valley Formation (W, Lower – Middle Ordovician, Ryder Gletscher Group). The cliff is about 600 m high and is cut by a Tertiary dyke (d). **B.** Cambrian strata in south-west Wulff Land on the eastern side of the broad north–south valley (Fig. 78, section C indicated by annotation BF–B3). Shelf siliciclastics of the Buen Formation (BU, extreme right) are succeeded by ramp and incipient platform margin strata of the Brønlund Fjord Group (BF, Kap Troedsson and Bistrup Land Formations). The overlying platform interior carbonates of the Ryder Gletscher Group are assigned to the Blåfjeld (B1), Brikkerne (B2) and Blue Cliffs (B3) Formations; note the well-developed cyclicity and lateral persistence of stratal units, in contrast to the platform margin sediments of the Perssuaq Gletscher Formation (see above). The Blåfjeld Formation (B1) is c. 100 m thick. From Higgins *et al.* (1991a).

Ryder Gletscher Group: southern outcrop belt

The Cambrian platform carbonates defined herein and assigned to the Ryder Gletscher Group (Early Cambrian – Middle Ordovician) occur within the southern outcrop belt (Figs 2, 78) with main outcrops in southern Warming Land, southern Wulff Land and the land area south of Nares Land. To conform to the geographical regions adopted earlier, the four new formations are grouped under the Henson Gletscher region (Koch Væg Formation) and the Nordenskiöld Fjord – southern Warming Land region (Blåfjeld, Brikkerne and Blue Cliffs Formations; see Figs 5, 8).

Henson Gletscher region

Cambrian strata in this area are mainly assigned to the Brønlund Fjord and Tavsens Iskappe Groups, as described earlier. Cambrian platform carbonates assigned

to the Ryder Gletscher Group crop out on the east side of the northern extension of Henson Gletscher near its junction with J. P. Koch Fjord (Fig. 23) and are well exposed in the steep cliffs of Koch Væg, above the glacier (Fig. 100A).

Koch Væg Formation

new formation

History. Previously described informally as formation T4 of the Tavsens Iskappe Group (Ineson & Peel, 1980), the Koch Væg Formation is equivalent to the ‘medium-grained dolomite and limestone’ forming the upper beds of Unit G of Dawes (1976b).

Name. After Koch Væg, the precipitous east side of

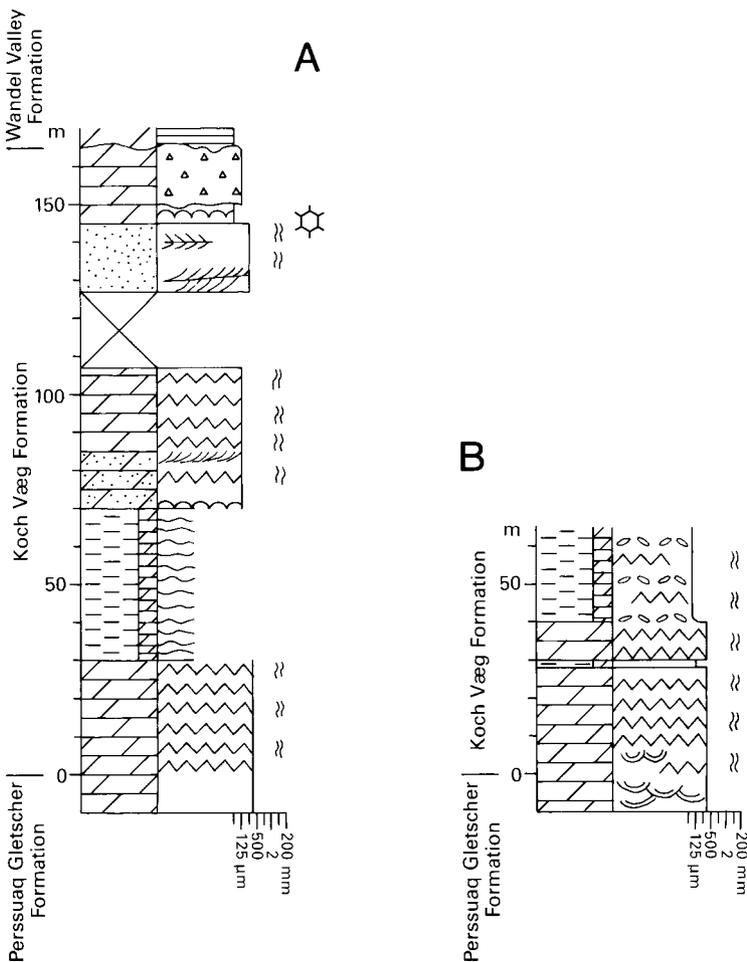
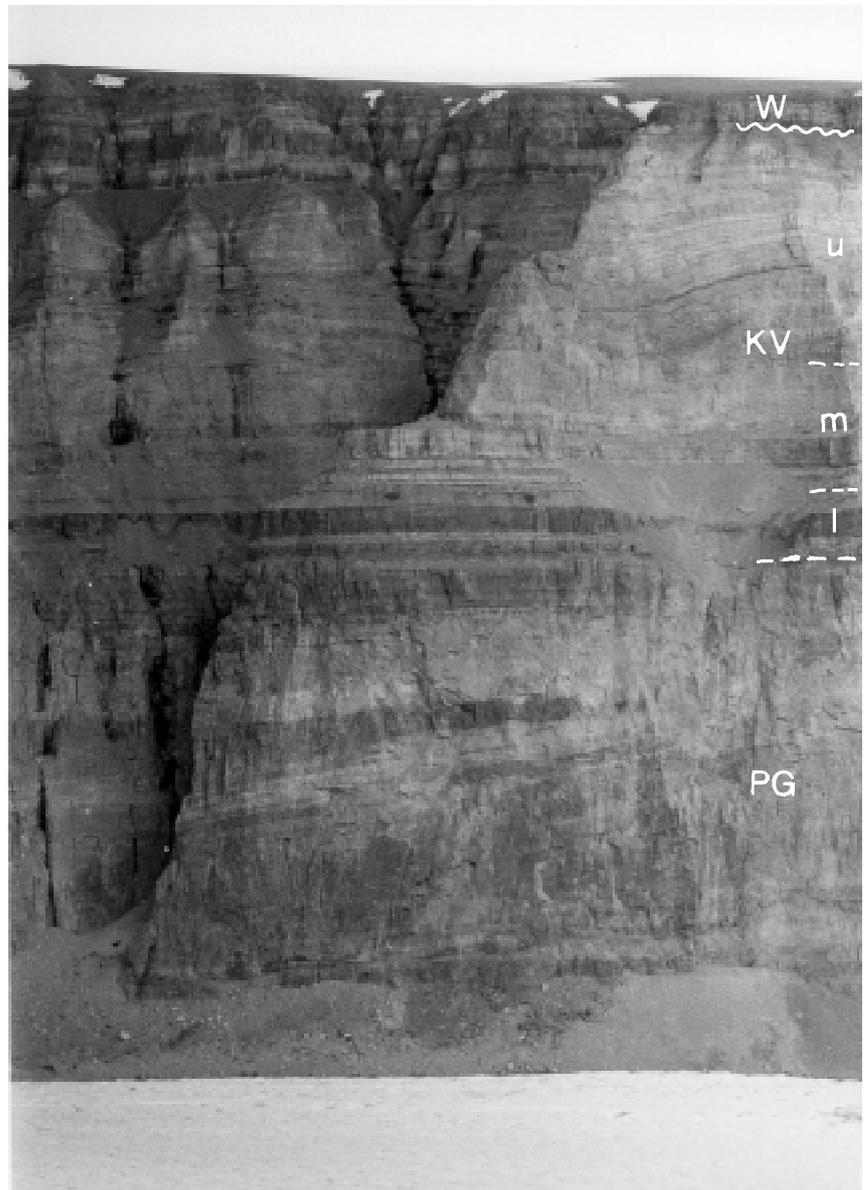


Fig. 101. Type (A) and reference (B) sections of the Koch Væg Formation at the north and south ends, respectively, of Koch Væg, west Peary Land (Figs 23, 100A). The distinctive dark band observed in this formation at Koch Væg (see Figs 100A, 102) occurs at 30–40 m in the reference section. See Fig. 14 for legend.

Fig. 102. Close-up view of central Koch Væg (Fig. 100A, right, at the prominent deep cleft). The Perssuaq Gletscher Formation (PG) shows well-developed clinofolds, dipping northwards (left), and is succeeded by more regularly bedded strata assigned to the Koch Væg Formation (KV); the lower (l), middle (m) and upper (u) units of the Koch Væg Formation are described in the text. Note the distinctive resistant dark band within the lower unit, the dark-light rhythmic banding and the sharp, locally irregular top of the middle unit and the gentle open folds in the bedding of the upper unit. W, Wandel Valley Formation.



Henson Gletscher, south-west Peary Land (Figs 23, 100A).

Type and reference sections. The type section (Fig. 101A) is defined just south of the major east-west trending fault (Troelsen's Fault; Figs 23, 100A), by Henson Gletscher, Peary Land. Owing to heavily weathered and locally inaccessible exposures, the type section alone does not fully characterise the formation. Thus, following Hedberg (1976), the formation is defined here from a composite section comprising the type section and a reference section located at the south end of Koch Væg (Fig. 101B).

Thickness. The thickness of this formation is poorly

known. Accessible sections are rare and generally poorly exposed, but the formation is about 165 m thick at the type section. Estimates from cliff sections further south (see Fig. 102) yield values of 150–200 m.

Lithology. The formation is composed of generally pale weathering dolomites, argillaceous dolomites and sandstones. As noted above, the Koch Væg Formation is poorly exposed where accessible and correlation from the measured sections to the vertical cliff sections is tentative. The formation is broadly divisible into three units. The lower unit is roughly 70 m thick in the type section but appears to be only half this thickness in the cliff section farther south (Fig. 102). It is dominated by bioturbated, burrow-mottled, unfossiliferous



Fig. 103. Burrow-mottled dolomites in the Koch Væg Formation at the reference section.

dolomites that become more argillaceous up-section. The lowermost 30–40 m comprises medium to thick-bedded, light cream and yellow-brown weathering, medium to coarse-crystalline dolomites. Mottling is common, often delineating burrows (Fig. 103), and is defined by variation in colour, porosity and grain size, and locally by chert blebs and stringers. Although not recognised in the type section, a prominent dark grey weathering interval (c. 10 m thick) of intensely bioturbated dolomite caps these beds farther south along

Koch Væg where it forms a distinctive marker (Figs 100A, 102). The succeeding beds of this lower unit of the Koch Væg Formation are thinner bedded and more argillaceous, forming a recessive ledge in cliff sections (Figs 101, 102). Flaggy, pale-weathering burrowed dolomites are interbedded with grey-green weathering silty mudstones and thin (3–20 cm) beds of flat pebble conglomerate. This interval is poorly exposed at the type section but is better represented at the reference section (Fig. 101B).

The middle, cliff-forming unit between 40 and 50 m thick weathers yellow-brown or dark grey and comprises burrow-mottled, medium to thick-bedded, pale grey dolomites and sandy dolomites. Cross-bedding was observed locally. Accessible outcrop of this unit is scarce; in cliff section it appears to have a gradational base to the argillaceous dolomites beneath and often has a dark-light banded appearance, particularly in its lower part (Fig. 102). The upper beds in contrast appear poorly stratified in cliff section and the top of this unit is sharp, locally with irregular relief (Fig. 102); this surface is of inferred karstic origin.

The uppermost unit (c. 70 m thick) has a distinctive, well-stratified, pale fawn- or green-grey appearance (Fig. 102). In cliff section the unit locally shows undulating bedding or open folding (Fig. 102). This may reflect drape of, or collapse into, irregular depressions on the basal (karstic?) surface of the upper unit. In the type section, this unit comprises cross-bedded and bioturbated sandstones, interbedded locally with silty, microbially-laminated dolomites. Grey-



Fig. 104. Cross-bedded, fine-grained sandstones with occasional vertical burrows (*Monocraterion*). Koch Væg Formation, type section.

green silty mudstones form thin recessive interbeds and partings throughout. The fine- to medium-grained dolomitic sandstones show parallel lamination and tabular or trough cross-bedding in 2–10 cm sets (Fig. 104). They are commonly burrowed and are interbedded with mottled or structureless bioturbated dolomitic sandstones and sandy dolomites. Units of microbially-laminated dolomite, 0.2–1.5 m thick, occur more frequently towards the top of the formation. Planar or crinkly lamination is dominant, but small domal stromatolites are represented; desiccation cracks occur locally. The formation is capped by a pale weathering, massive, karstic breccia about 20 m thick, with an irregular base and hummocky top (Fig. 101A). It is composed of angular dolomite and sandstone clasts up to 30 cm across in a vuggy matrix of chert and coarse crystalline dolomite.

Boundaries. The Koch Væg Formation overlies the

Perssuaq Gletscher Formation with apparent conformity (Fig. 100A, 102). The boundary is sharp in cliff sections, but in outcrop the lithological change appears gradational, from pale ooidal dolomites of the Perssuaq Gletscher Formation into bioturbated, darker weathering dolomites of the Koch Væg Formation (Fig. 101B). It should be noted, however, that exposure is poor at this level in the reference section and the marked boundary observed in cliff sections was not located at outcrop. At the type section, the boundary is placed at the first appearance of grey, burrow-mottled, fine to medium crystalline dolomites (Fig. 101A).

The Koch Væg Formation is unconformably overlain by upper Lower – Middle Ordovician dolomites of the Wandel Valley Formation (Peel, 1979; Peel & Smith, 1988). The unconformity is planar on a regional scale (Figs 100A, 102) and bedding is typically sub-parallel. At the type section, the upper beds of the Koch Væg

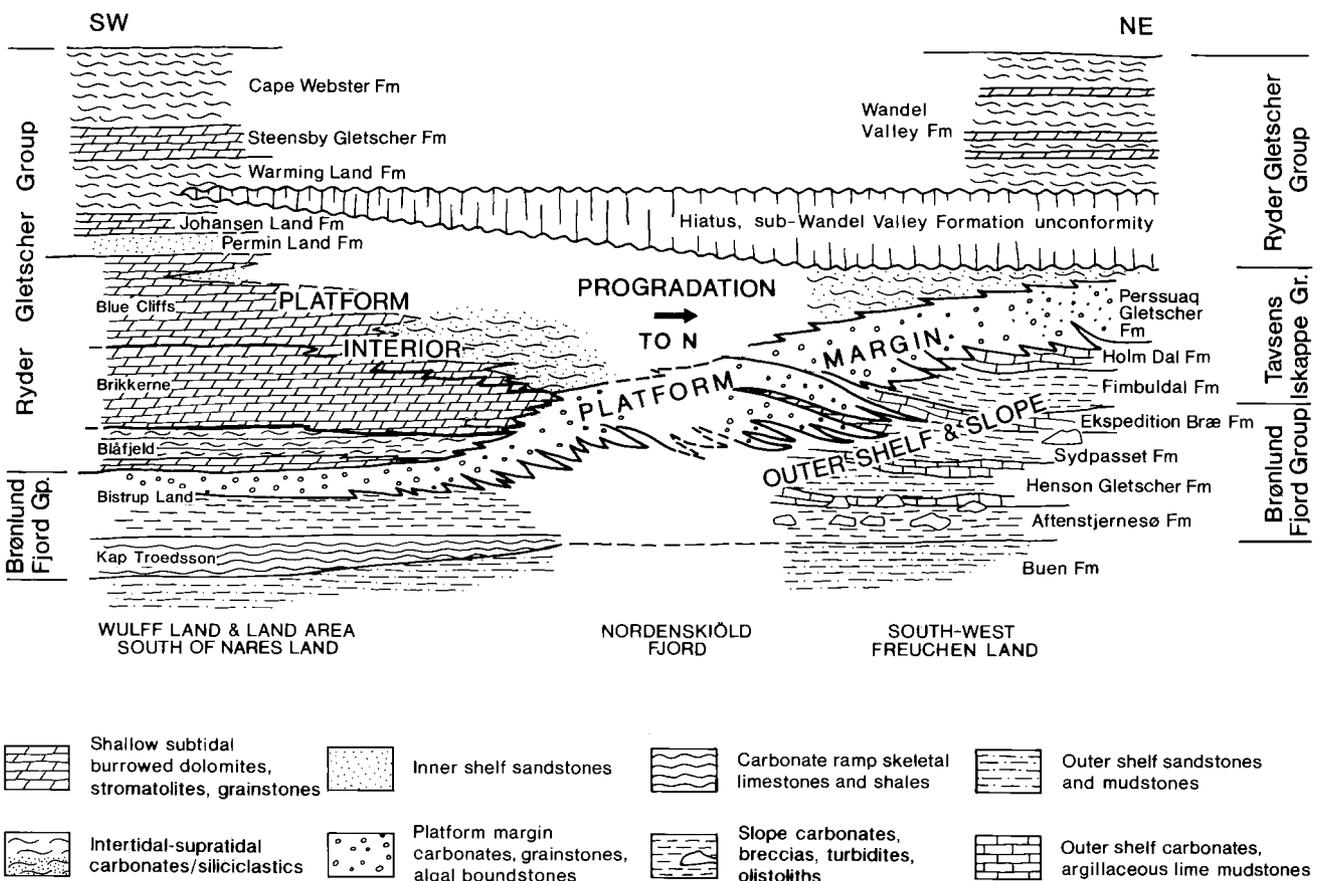


Fig. 105. Schematic diagram showing the stratigraphic relationships between the platform interior strata of the Ryder Gletscher Group and the platform margin, slope and deep shelf sediments of the Brønlund Fjord and Tavsens Iskappe Groups in the vicinity of Nordenskiöld Fjord, central North Greenland. Note that adjacent to the fjord, the Blue Cliffs Formation rests directly on massive platform margin dolomites assigned to the Bistrup Land Formation (see Fig. 85). Exposure of the upper Perssuaq Gletscher Formation is poor in this immediate area so its contact with the Bistrup Land Formation is not observed and the presence of platform interior facies above the Perssuaq Gletscher Formation is speculative. Modified from Higgins *et al.* (1991a).

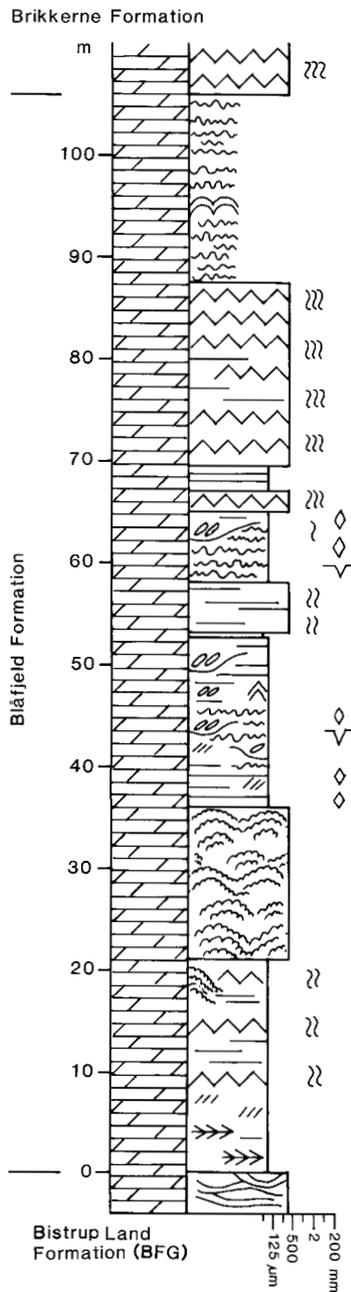


Fig. 106. Type section of the Blåfjeld Formation, south-west Wulff Land (Figs 78, 100B). The succession is readily subdivided into a lower uniform dark-weathering unit (0-36 m) and an upper banded succession of interbedded dark subtidal and light peritidal dolomites (36-106 m). See Fig. 14 for legend.

margin of Hans Tavsens Iskappe. The formation is well exposed along the east wall of the glacier (Figs 100A, 102), but is only accessible at the northern and southern extremities of Koch Væg.

Fauna and age. Fossils have not been recovered. The formation conformably overlies the Perssuaq Gletscher Formation which is considered to be of Middle to Late Cambrian age in this area, and is unconformably overlain by the Wandel Valley Formation of late Early Ordovician – Middle Ordovician age. A late Middle – Late Cambrian age is thought most likely.

Nordenskiöld Fjord – Warming Land region

The Cambrian portion of the Ryder Gletscher Group in the region from Nordenskiöld Fjord in the east, to southern Warming Land in the west, is represented by the Blåfjeld, Brikkerne and Blue Cliffs Formations (Figs 5, 100B, 105).

Blåfjeld Formation

new formation

History. This formation was described informally as RG2 (in part) and RG3 of the Ryder Gletscher Group by Peel & Wright (1985) and equates to the redescribed informal formation RG3 of Ineson & Peel (1987, see discussion therein).

Name. After Blåfjeld, a hill on the western coast of Nares Land (Fig. 78). Composed of Ordovician–Silurian strata, Blåfjeld lies north of the broad outcrop of the Ryder Gletscher Group which extends east–west from Nordenskiöld Fjord to Victoria Fjord, in terrain with few named geographical features.

Type section. Fig. 106; east side of the prominent north–south valley, east of Ryder Gletscher, Wulff Land (Figs 78, 100B, 107).

Thickness. 106 m at the type section. A comparable thickness is maintained over much of its outcrop but the formation thins rapidly eastwards just west of Nordenskiöld Fjord (Fig. 105).

Lithology. The Blåfjeld Formation is composed wholly

Formation are intensely brecciated to a depth of 20 m below the unconformity and the plane of the unconformity is irregular and hummocky, with a relief of up to a few metres, draped by the pale grey, thin-bedded and laminated, cherty dolomites of the Wandel Valley Formation.

Distribution. The formation has a restricted distribution and is only recognised south of Troelsen’s Fault, west of Hans Tavsens Iskappe in south-west Peary Land (Fig. 23). It crops out from the east side of Henson Gletscher eastwards to Fimbuldal, near the western



Fig. 107. Typical development of the Blåfjeld (B1), Brikkerne (B2) and lowermost Blue Cliffs (B3) Formations in south-west Wulff Land. Note the cyclic alternation of dark subtidal dolomites and light intertidal-supratidal dolomites in the Blåfjeld Formation.

of dolomite and characteristically shows a distinctive banded outcrop pattern (Fig. 107). This results from an alternation of intervals of grey-brown weathering, medium-bedded to thick-bedded, dark grey dolomites and very pale, silvery-grey, thin-bedded dolomites.

In the type section (Fig. 106), the formation is readily subdivided into a lower homogeneous dark-weathering unit and a thicker, upper banded unit. The lower unit (36 m thick) comprises dark grey-brown weathering dolomite; medium to thick bedding is evident in the lower half of the unit but the upper levels are massive and show only subtle bedding structure. The lower bedded interval comprises burrow-mottled dolomites with subordinate thin (*c.* 10 cm thick) intraclastic grainstone beds that display trough or planar herring-bone cross-bedding. Oncoids become increasingly common up-section and form discrete oncolite packstone/grainstone beds towards the top of this interval. The uppermost 15 m of this basal dark unit of the Blåfjeld Formation comprises dark grey-brown, faintly mottled dolomite. Although overtly massive,

crude bedding defines large symmetrical to elongate mounds, 5–10 m across with relief of up to several metres (see Fig. 11E); these mounds are especially well-developed near the base of this massive interval. Stromatolitic lamination is rarely observed and these are best described as thrombolite mounds.

The upper unit (70 m thick) is a succession of pale silvery-grey, recessive-weathering dolomites alternating with prominent units of burrow-mottled, locally laminated grey-brown dolomites (Figs 106, 107). The former display planar or crinkly microbial lamination, domal stromatolites, bird's-eye fenestrae, desiccation cracks and wave-ripples (Fig. 108A). Lenticular flat-pebble conglomerate beds (10–20 cm thick) occur at regular intervals and thin dark burrow-mottled dolomite beds are locally present. The prominent thick grey-brown units are typically more massive and characterised by burrow-mottling (Fig. 108B). Faint lamination is discernable locally and thin (max. 1 m) light grey stromatolitic dolomite beds occur rarely.

Contacts between the pale stromatolitic dolomite

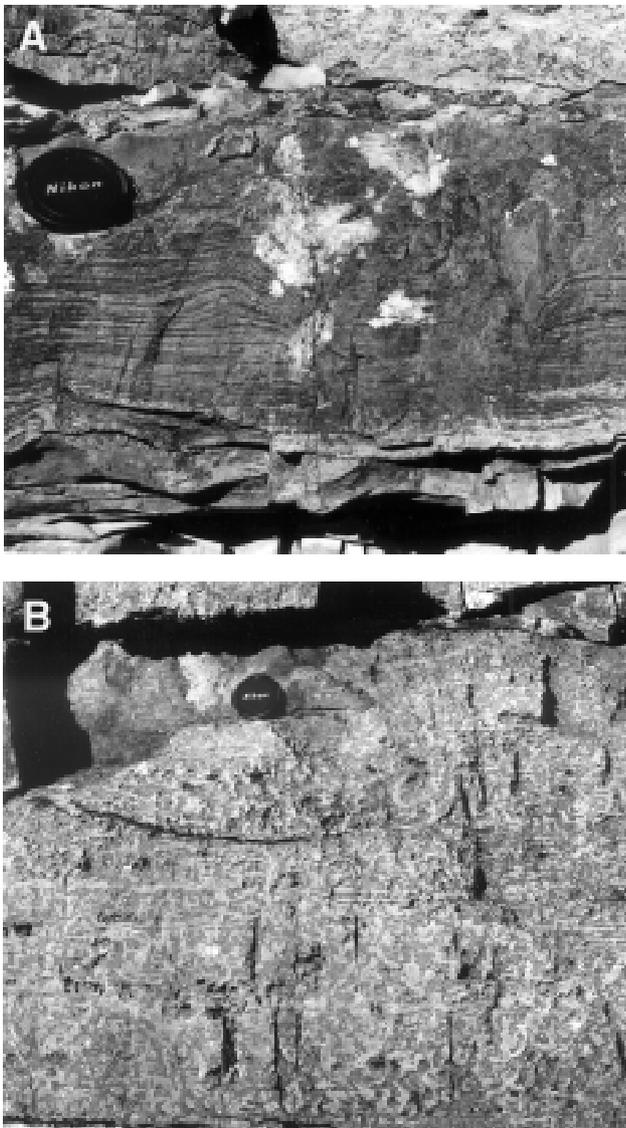


Fig. 108. **A.** Stromatolitic dolomites. **B.** Burrow-mottled dolomites; note local preservation of weak parallel stratification. Blåfjeld Formation, type section.

units and the succeeding burrow-mottled facies are typically sharp (see Fig. 11D); such dark-light couplets are laterally persistent and retain a constant thickness at outcrop scale (i.e. up to 10 km).

Boundaries. The Blåfjeld Formation conformably overlies the Bistrup Land Formation; the boundary is placed where dark, grey-brown weathering, mottled dolomites overlie mid-grey to light grey or cream bedded dolomites that commonly show relict grainstone textures and cross-bedding. This boundary is readily recognised in cliff sections (Fig. 100B). The top of the formation is defined at the base of the massive, cliff-forming, grey-brown dolomites of the Brikkerne Formation over-

lying the upper pale microbial dolomites of the Blåfjeld Formation (Fig. 107).

Distribution. The Blåfjeld Formation crops out in southern Wulff Land, Warming Land, and in the land area south of Nares Land (Fig. 78). The easternmost limit of the formation, a few kilometres west of the head of Nordenskiöld Fjord, is defined by the point where the well-bedded platform interior carbonates of the Blåfjeld Formation interdigitate with massive platform margin carbonates of the Bistrup Land Formation (Fig. 105).

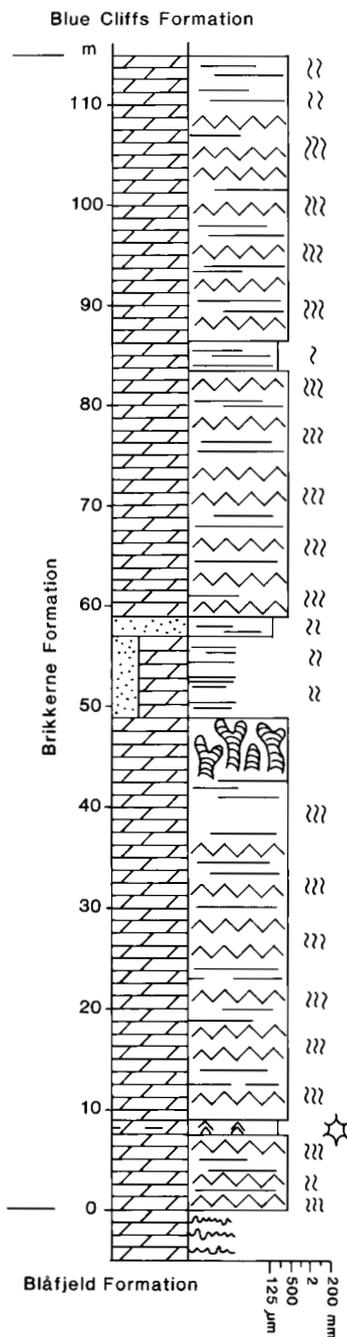


Fig. 109. Type section of the Brikkerne Formation, south-west Wulff Land (Figs 78, 100B). See Fig. 14 for legend.

Fig. 110. Microbial dolomites forming a low-relief mound within the Brikkerne Formation at the type section. The vertical and horizontal sections illustrate the complex linked columnar form of the stromatolitic framework (light component). From Higgins *et al.* (1991a).



Fauna and age. No fossils have been recovered from the dolomites of the Blåfjeld Formation. An Early to Middle Cambrian age is assumed on grounds of its stratigraphic position and correlation to deeper-water outer shelf strata assigned to the Brønlund Fjord Group.

Brikkerne Formation

new formation

History. Previously referred to informally as formation RG4 of the Ryder Gletscher Group (Peel & Wright, 1985; Ineson & Peel, 1987).

Name. After Brikkerne, a series of nunataks south of Nares Land, to the east of the head of Victoria Fjord (Fig. 78). Some uncertainty surrounds the geographical placement of the feature. The Army Map Series (AMS) 1:250 000 topographic map series and the 1:500 000 Geological Map Sheet 7 (Nyeboe Land) published by the Geological Survey of Greenland (1989) identify Brikkerne as a single dumbbell-shaped nunatak, but approved usage followed here indicates a string of hills and nunataks forming the southern margin of the land area south of Nares Land.

Type section. Fig. 109; east side of the major north-south valley, south-west Wulff Land.

Thickness. The Brikkerne Formation is 115 m thick at the type section. Although of relatively uniform thickness across Warming Land and south Wulff Land, the

formation thins eastwards in the vicinity of Norden-skiöld Fjord (see Fig. 105 and discussion below).

Lithology. The Brikkerne Formation characteristically forms prominent dark grey-brown weathering cliffs between the banded Blåfjeld Formation beneath and the light grey-green argillaceous carbonates of the Blue Cliffs Formation. The Brikkerne Formation is a uniform succession of thick-bedded unfossiliferous burrow-mottled dolomites. In the type section this monotonous succession of bioturbated, locally faintly laminated dolomites is interrupted at three levels by more varied facies. A 1 m thick unit of silty, sandy dolomites, 8 m above the base (Fig. 109), shows lamination of inferred microbial origin, wave ripples and desiccation cracks. A distinctive pale grey sucrosic dolomite unit at 43–49 m in the type section (Fig. 109) shows spectacular columnar stromatolites (Fig. 110). Laterally, such stromatolite units are seen to wedge out over several tens of metres within the more typical dark bioturbated facies and represent low-relief stromatolitic bioherms. In the type section a sandy glauconitic dolomite unit (c. 10 m thick) overlies the stromatolitic interval.

Boundaries. The base of the Brikkerne Formation is sharp and planar; it is placed where dark grey-brown, prominent weathering dolomites overlie pale silvery-grey stromatolitic dolomites of the upper Blåfjeld Formation (Fig. 107). The top of the formation is placed at the boundary between these cliff-forming dark dolomites and recessive-weathering, poorly-exposed, argillaceous lime mudstones assigned to the Blue Cliffs Formation.

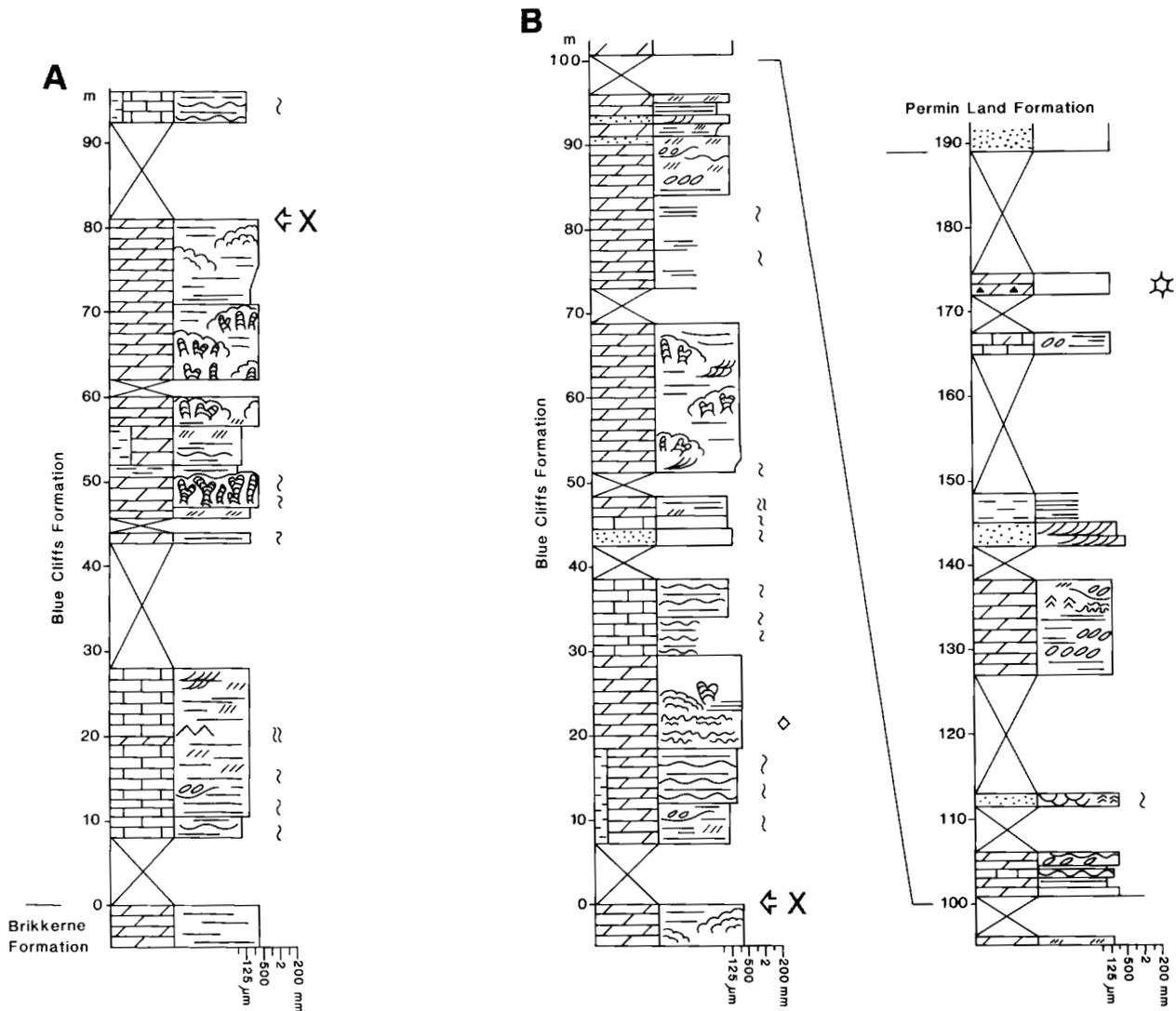


Fig. 111. **A.** Type section of the Blue Cliffs Formation, south-west Wulff Land (Fig. 78, locality C). **B.** Reference section of the Blue Cliffs Formation, south-west Wulff Land (Fig. 78, locality D). X marks the top of a marker bed that is recognised in both the type and reference sections. See Fig. 14 for legend.

Distribution. The Brikkerne Formation forms a distinctive dark weathering unit throughout Warming Land and southern Wulff Land and extends eastwards across the land area south of Nares Land to a point a few kilometres south-west of the head of Nordenskiöld Fjord where it interdigitates with pale carbonates of the Bistrup Land Formation (Brønlund Fjord Group, see Fig. 105).

Fauna and age. No fossils were recovered from the dolomites of the Brikkerne Formation; a Middle Cambrian age is assumed on the basis of its stratigraphic position above the ?Lower to Middle Cambrian Blåfjeld Formation and beneath the Blue Cliffs Formation which yields late Middle Cambrian faunas in its lower part (see below).

Blue Cliffs Formation

new formation

History. Previously referred to informally as formations RG5 and RG6 of the Ryder Gletscher Group (Peel & Wright 1985).

Name. After Blue Cliffs, the precipitous south-western margin of Wulff Land, along Ryder Gletscher (Fig. 78, see also Fig. 11C).

Type and reference sections. The Blue Cliffs Formation is defined on the basis of two incomplete sections in the prominent north-south valley in south-west Wulff Land (Fig. 78). The southernmost of these, on the eastern side of the valley (Fig. 78, locality C), illustrates

Fig. 112. Microbial dolomites forming part of a mound within the Blue Cliffs Formation in the type section, showing a distinctive narrow columnar stromatolite form.



the lower part of the formation and is here defined as the type section (Fig. 111A). The reference section (Fig. 111B), on the western side of the valley about 5 km to the north-west (Fig. 78, locality D), illustrates the upper two-thirds of the formation and the upper boundary.

Thickness. The total thickness of the Blue Cliffs Formation is approximately 270 m; the type section illustrates the lower 80 m and the reference section the upper 190 m of strata.

Lithology. The Blue Cliffs Formation is a varied succession of limestones, dolomites, sandstones and mudstones. The proportion of siliciclastic strata increases both stratigraphically upwards and eastwards in the formation (see Figs 105, 111). The formation typically forms recessive weathering light coloured slopes and is generally poorly exposed, particularly in its uppermost levels.

The lower 30 m of the formation in the type section are dominated by wavy to parallel thin-bedded lime mudstones with interbeds and partings of silty mud-

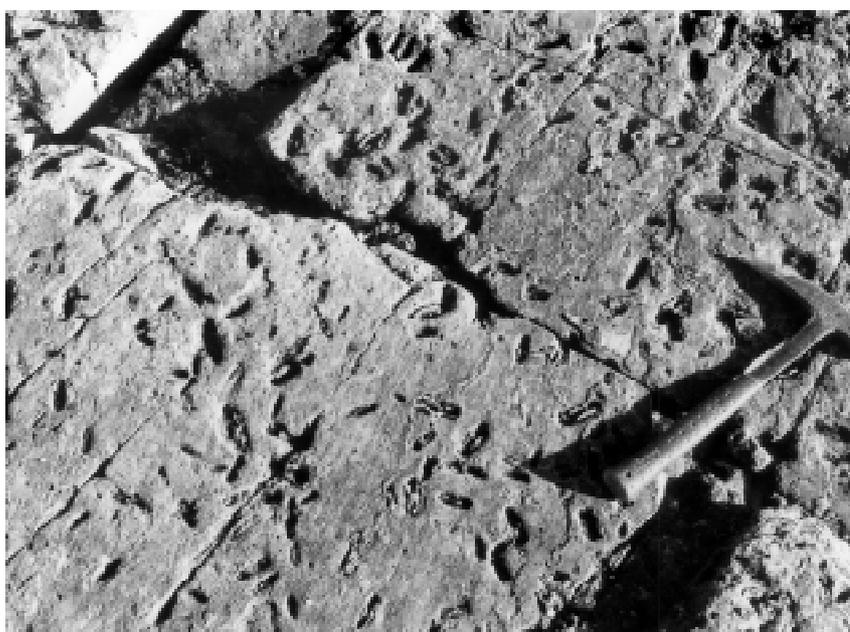


Fig. 113. Sandstone bedding plane showing characteristic cross-sections through *Diplocraterion* burrows. Blue Cliffs Formation, reference section.

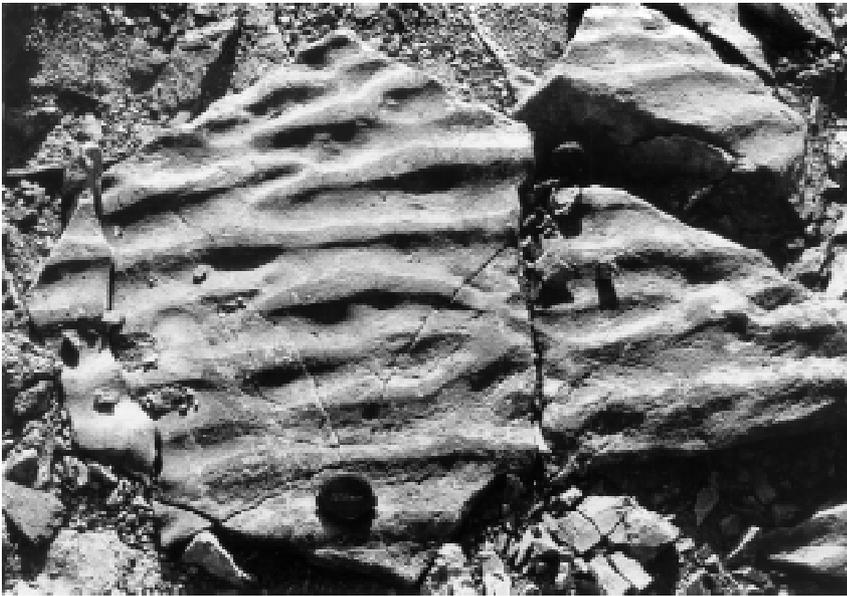


Fig. 114. Sandstone bedding plane showing flat-topped wave-ripples. Blue Cliffs Formation, south-west of Nordenskiöld Fjord.

stone that lend a green-grey colour to weathered slopes; the boundary between this green shaly facies and the dark brown weathering, cliff-forming dolomites of the Brikkerne Formation beneath is a distinctive mapping horizon. Rare fossiliferous lime packstone and grainstone beds show cross-lamination and small-scale cross-bedding; lenticular flat-pebble conglomerate beds are present in places. Bioturbation is common.

The upper half of the type section as well as the lower *c.* 70 m of the reference section comprise a cyclic succession of laminated and cross-laminated dolomites, stromatolitic biohermal dolomites and dolomitised grainstones. Typical cycles are 10–25 m thick and coarsen up from argillaceous lime mudstones or dolomites at the base to massive dolomite units comprising stromatolitic mounds (Fig. 112) interfingering laterally with carbonate grainstones. The units of mounds and grainstones are laterally continuous at the scale of outcrop, with individual mounds varying in diameter from about 1–10 m; the intervening grainstone facies commonly displays cross-bedding. Such bioherm-grainstone units typically form more resistant ledges and one such distinctive pale brown weathering massive unit (about 20 m thick) caps the type section and defined the top of the informal RG5 of the preliminary stratigraphic subdivision (Peel & Wright, 1985).

The upper 120 m of the Blue Cliffs Formation is typically poorly exposed (see Fig. 111B). It comprises a varied succession of light-coloured, recessive weathering dolomites, limestones, sandstones and silty mudstones. The proportion of siliciclastics increases up the succession and laterally from west to east. In the refer-

ence section, these upper beds of the Blue Cliffs Formation are parallel to wavy, thin-bedded dolomites and lime mudstones interbedded with cross-laminated carbonates and flat-pebble conglomerates. Wave-rippled surfaces are common and microbial lamination and desiccation cracks occur in places. Sandstones occur as thin interbeds and units up to several metres thick. They show small- to medium-scale trough and planar cross-bedding and wave-rippled bedding planes and are locally bioturbated (Fig. 113). Green and purple silty mudstones interbedded with pale dolomites form a conspicuous unit (about 10 m thick) at about 90 m below the top of the formation in the reference section.

The proportion of siliciclastic sediments increases eastwards and they dominate the upper half of the formation just west of Nordenskiöld Fjord. In this area, trough and planar cross-bedded, well-sorted fine to medium-grained sandstones form units up to 10 m thick; flat, low-angle lamination, herring-bone cross-bedding and wave-rippled, desiccation-cracked bedding surfaces occur locally (Fig. 114, see also Fig 11F). These sandstone packets alternate with stromatolitic dolomites, wave-rippled dolomites and flat-pebble conglomerates.

Boundaries. The base of the Blue Cliffs Formation is defined where greenish-grey, recessive weathering argillaceous lime mudstones overlie prominent dark grey-brown burrow-mottled dolomites assigned to the Brikkerne Formation. Approaching Nordenskiöld Fjord, in the land area south of Nares Land, the underlying



Fig. 115. Platform interior strata of the Ryder Gletscher Group east of the southern tip of Nares Land. The unconformity (u) separating the lower, gently folded strata from the upper, homoclinal strata becomes increasingly significant eastwards, correlating with the sub-Wandel Valley Formation unconformity that separates Cambrian from Ordovician strata over much of central North Greenland (see Figs 5, 6, 19, 54). The unconformity is not recognised farther west than this locality. These exposures exemplify, on a small-scale, the regional stratigraphic relationships at the top of the Blue Cliffs Formation. In its western outcrop, as on the flanks of this local fold structure, the Blue Cliffs Formation (B3) is conformably overlain by the siliciclastic Permin Land Formation (PL). In eastern areas, however, the Blue Cliffs Formation is unconformably overlain by Ordovician strata, as over the crest of this anticlinal structure. J, Johansen Land Formation; WA, Warming Land Formation; SG, Steensby Gletscher Formation; CW, Cape Webster Formation. The Permin Land Formation is 23 m thick. From Higgins *et al.* (1991a).

Blåfjeld and Brikkerne Formations pinch out into the massive carbonates of the Bistrup Land Formation such that the Blue Cliffs Formation is seen to ultimately rest conformably on the Bistrup Land Formation on either side of the fjord (Fig. 105). The boundary is placed where massive, structureless pale-coloured dolomites are succeeded by well-bedded dolomites and siliciclastic sediments.

The character and definition of the top of the Blue Cliffs Formation also varies from the west to the east. In Warming Land, southern Wulff Land and the land area south of Nares Land, the Blue Cliffs Formation is conformably overlain by Upper Cambrian – Lower Ordovician strata of the Permin Land Formation, form-

ing a conspicuous regional marker horizon (Figs 11C, 105, 115). The boundary is placed where recessive weathering microbially-laminated dolomites, flat-pebble conglomerates and subordinate thin-bedded sandstones are succeeded by massive cliff-forming white sandstones assigned to the Permin Land Formation. Bryant & Smith (1985) noted the possibility of confusion between the thin sandstones of the Blue Cliffs Formation and the sandstone-dominated Permin Land Formation and thus defined the boundary at the base of the first 10 m sandstone unit.

As shown in Fig. 105, the regional unconformity developed beneath the Wandel Valley Formation (late Early – Middle Ordovician) in central North Greenland

decreases in stratigraphic significance westwards such that the hiatus cannot be recognised west of Nares Land where it is seen within the Warming Land Formation (Fig. 115). The Permin Land Formation has been traced to about 20 km west of the head of Nordenskiöld Fjord and to the east of this point the top of the Blue Cliffs Formation is an unconformity; banded peritidal carbonates of the Wandel Valley Formation abruptly overlie the mixed siliciclastic sediments and carbonates of the upper Blue Cliffs Formation. Bedding in these two formations is typically parallel but along Nordenskiöld Fjord, gentle open folds locally deform the Blue Cliffs Formation and truncation may be observed at the unconformity.

Distribution. The Blue Cliffs Formation crops out from Warming Land in the west to just north-east of Nordenskiöld Fjord in southern Freuchen Land (Fig. 78).

Fauna and age. The Blue Cliffs Formation is only sparsely fossiliferous. Limestones near the base of the formation have yielded trilobites of late Middle Cambrian age, whereas forms near the middle of the formation include *Terranovella* sp., indicating a middle Dresbachian (Late Cambrian) age (Palmer *in* Peel, 1980). The upper levels of the formation are unfossiliferous but, on the basis of correlation to the Washington Land area of western North Greenland, Bryant & Smith (1985, 1990; Smith & Bjerreskov, 1994) suggested that the uppermost beds of the Blue Cliffs Formation approached the Cambrian–Ordovician boundary. The

Blue Cliffs Formation thus ranges in age from late Middle Cambrian to uppermost Late Cambrian or earliest Ordovician, at least in its western outcrop. Farther east, the upper beds of the formation are probably stratigraphically older due to truncation at the sub-Wandel Valley Formation unconformity.

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