Nares Strait Group

The Nares Strait Group represents the oldest strata of the central basin fill of the Thule Basin (Figs 2, 4, 120). It is subdivided into five formations, viz. Northumberland, Cape Combermere, Josephine Headland, Barden Bugt and Clarence Head Formations, in which eight members are formally recognised.

Nares Strait Group

new group

Composition. Koch (1926, 1929a; *in* Dawes & Haller, 1979, plate 1) included strata now referred to this group in his lower red sandstone of the Thule Formation, although some strata on Northumberland Ø are part of his upper sandstone unit. Seen regionally the group is part of the Wolstenholme Formation of Davies *et al.* (1963, fig. 2), although *not* part of the succession in the type area and environs studied by these authors, Kurtz & Wales (1951) and Fernald & Horowitz (1964). The group equates with the lower two members (a and b) of the Wolstenholme Formation as described by Dawes (1975) from Northumberland Ø and encompasses units I, II, III and IV of that formation in Canada (Frisch *et al.*, 1978; Frisch & Christie, 1982). It embraces the lower four units of the Wolstenholme Formation as defined by Dawes *et al.* (1982a) from both sides of Nares Strait.

Name. After Nares Strait, the narrow seaway separating Ellesmere Island and Greenland (Figs 2, 10).

Distribution. In Greenland, Prudhoe Land south-east of Sonntag Bugt, western Steensby Land and Northumberland Ø; in Canada, in all main exposures south of Johan Peninsula, viz. both sides of Cadogan Inlet, Goding Bay, Cape Combermere and Clarence Head (Fig. 2).

Type area. North-western Northumberland Ø, Greenland (Fig. 48).

Thickness. The maximum composite thickness reaches 1200 m. Individual sections vary from about 950 m on Northumberland Ø to about 700 m in northern Prudhoe Land and at Clarence Head to around 450 m in western Steensby Land, thinning east to 200 m at Granville Fjord (Figs 3, 12).

Dominant lithology. The Nares Strait Group is dominated by siliciclastic strata, with one main formation of basaltic extrusive and intrusive rocks, although basic sills occur throughout (Fig. 3). In ascending stratigraphic order the main lithologies are: quartz arenites with subordinate siltstone and shale (with basic sills) followed by a volcanic – red bed sequence composed of lavas, agglomerate, tuffs, sills and various clastic rocks, overlain by varicoloured carbonate and clastic rocks containing volcaniclastic elements, and topped by massive, nearly pure quartz arenites (Fig. 49).

Depositional environment. The group is taken to represent shallow water deposition in alluvial plain, littoral and offshore environments, as well as a period of terrestrial volcanism manifested mainly by outpouring of plateau basalts. Based in part on the interpretations of Frisch & Christie (1982) and Jackson (1986) the following history is suggested: early sandstone-dominated and sandstone-shale sequences of supratidal to subtidal environments ranging from alluvium of meandering rivers to possible prodelta or offshore muds, gave way to marine sand deposition with thick, highly reworked quartz sands probably representing extensive offshore bars.

Fossils. Stromatolites, algal laminites.

Boundaries and correlation. The Nares Strait Group lies between the crystalline shield and the Baffin Bay Group (Figs 3, 12, 75, 77). In the north, lack of exposure prevents factual information on the relationship to the Smith Sound Group, but the Nares Strait Group is assumed to be limited northwards around Sonntag Bugt by basin margin faults (Figs 1, 27). Coeval sediments probably are represented in the basal strata of the Smith Sound Group, i.e. the Cape Camperdown, Pandora Havn and Kap Alexander Formations (Figs 3, 4, 120).

Geological age. Neohelikian; an age based on isotopic age determinations of basaltic rock from flows and sills from Canada and Greenland. A $^{207}Pb/^{206}Pb$ baddeleyite age of 1268 Ma from the major sill in the Cape Combermere Formation at Goding Bay (section 28, Fig. 58) is the most reliable age available (LeCheminant & Heaman, 1991). The six most reliable whole-rock K-Ar age determinations of basaltic rock from Robertson Fjord, Northumberland Ø, Clarence Head and Gale

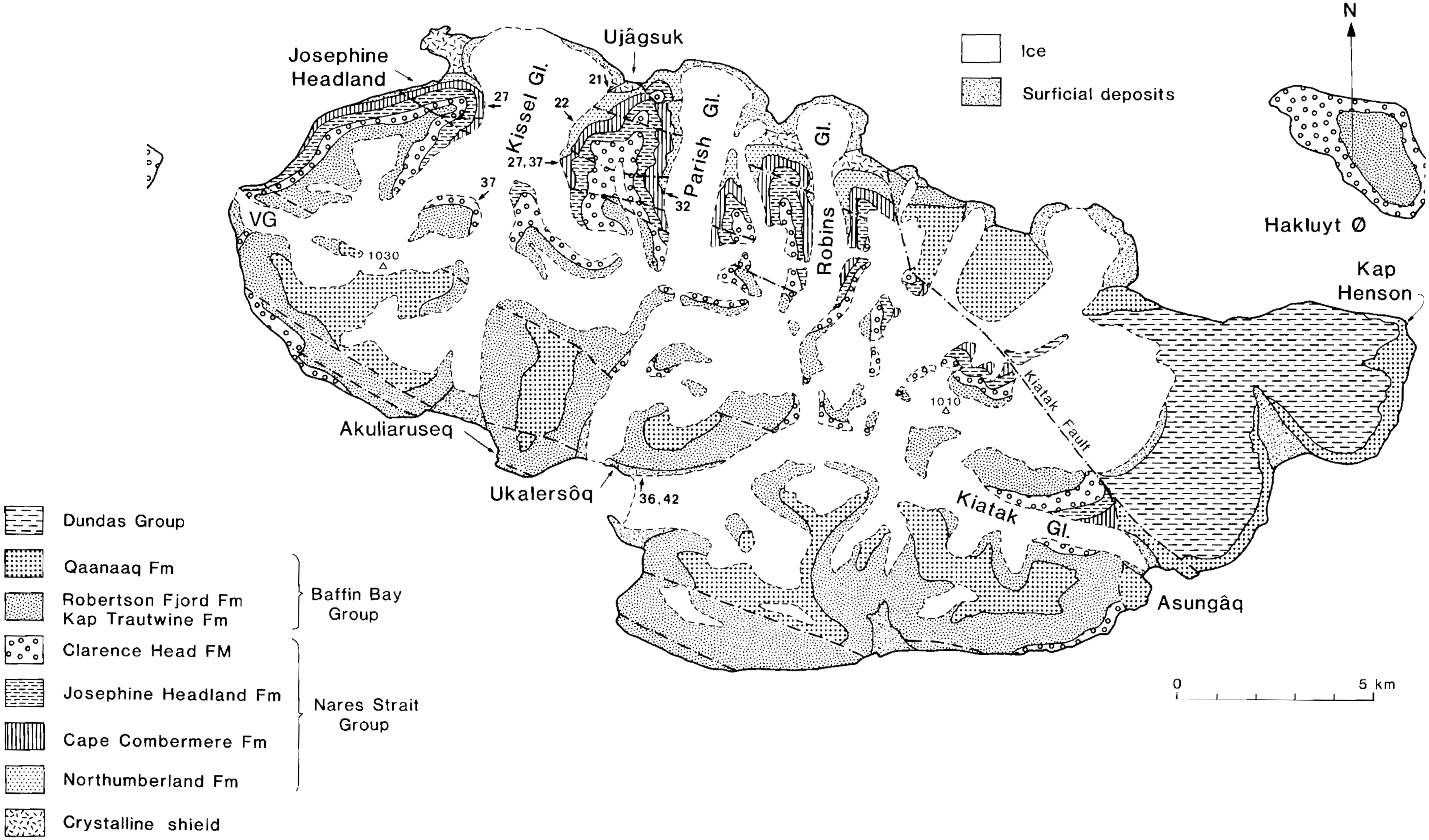


Fig. 48. Geological map of Northumberland Ø (Kiatak) and Hakluyt Ø, Greenland, showing the locations of sections 21, 22, 27, 32, 36, 37 and 42 (sections 27 and 37 are composite). Northumberland Ø proved to be a key area for the understanding of the Thule Basin stratigraphy. The island exposes a full section through the Nares Strait and Baffin Bay Groups, including the transition into the Dundas Group (Fig. 4). The north-western part of the island is the type area for the Nares Strait Group that represents the early siliciclastic-volcanic fill of the central basin. The initial recognition that the central basin succession also occurred in adjacent Canada, was based on the correlation between Northumberland Ø and Clarence Head on the coast of south-eastern Ellesmere Island. VG = Vestgletscher. Heights are in metres. For location, see Fig. 2.

Fig. 49. Nares Strait Group: Greenland and Canada. **A:** eastern side of Kissel Gletscher, Northumberland Ø; **B:** coast, south of Clarence Head, photo: T. Frisch. Ps = Precambrian crystalline shield, N = Northumberland Formation with basic sills, CC = Cape Combermere Formation, JH = Josephine Headland Formation with arrows marking dark carbonate bench of the Robins Gletscher Member, CH = Clarence Head Formation characterised by darker and banded strata in lower part. At Clarence Head, the Northumberland Formation is thin and in places tectonically cut out (see map, Fig. 75); on Northumberland Ø it is composed of the Kissel Gletscher (KG) and Kiatak (K) Members. The relief in both scenes is about 700 m. For location, see Figs 48 and 75.

Point fall in the range 1284 ± 37 and 1065 ± 73 Ma (Dawes *et al.*, 1973; Frisch & Christie, 1982; Dawes & Rex, 1986).

Subdivisions. The Nares Strait Group is subdivided into five formations: the Northumberland, Cape Combermere, Josephine Headland, Barden Bugt and Clarence Head Formations.

Northumberland Formation

new formation

Composition. The strata of this formation correspond to the basal unit of the Wolstenholme Formation as described on Northumberland Ø and in the Neqe–Siorapaluk area (Dawes, 1975, 1976a, b) and to units 1 to 10 as logged by Christie (1975) from Gale Point. It equates with unit I in the Clarence Head – Cape Combermere region as defined by Frisch *et al.* (1978) and

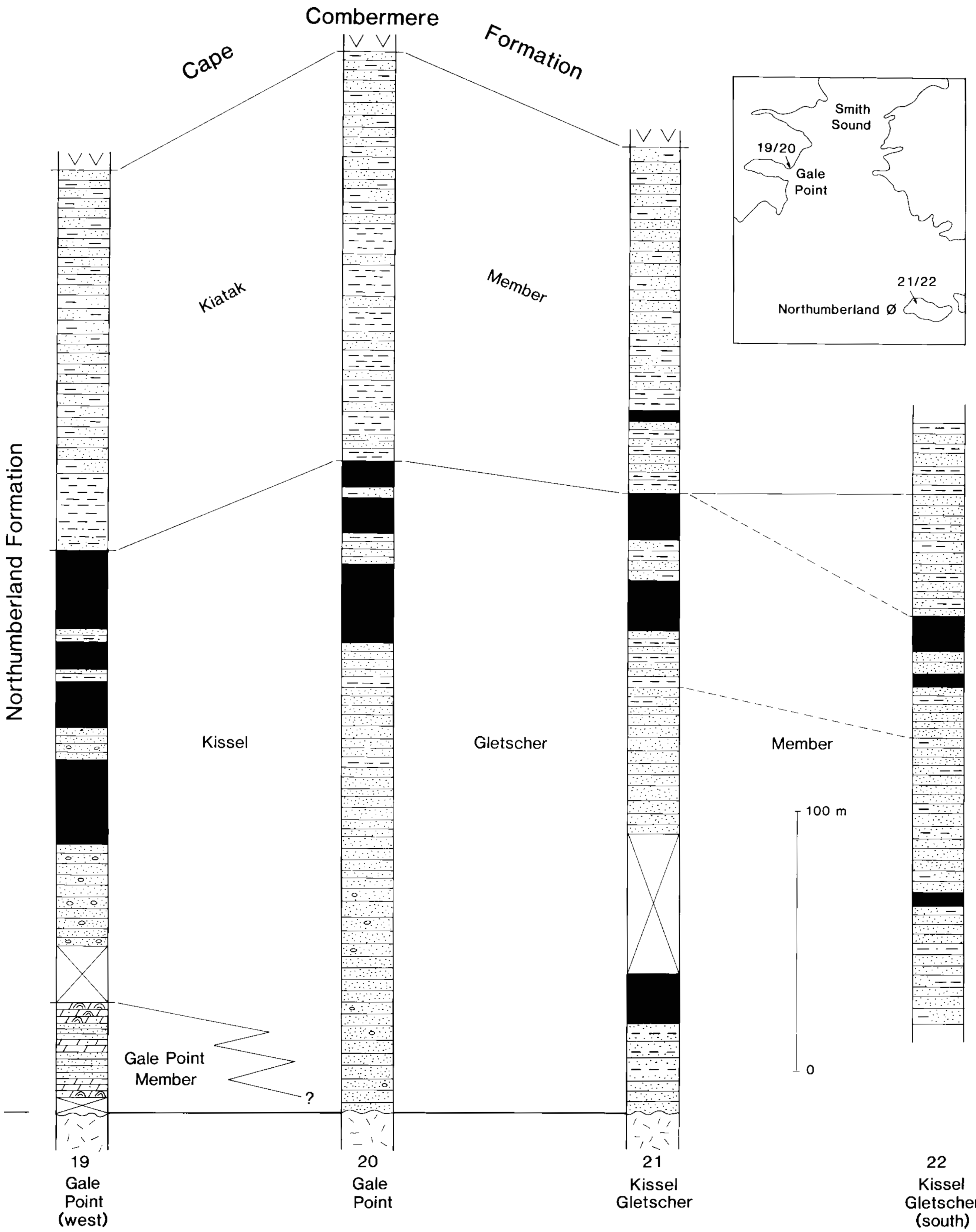


Fig. 50. Generalised sections of the Northumberland Formation from Northumberland Ø and Gale Point. Sections compiled from data in Frisch & Christie (1982; section 19), Christie (1975; section 20) and Jackson (1986; sections 21, 22); the latter with modification for thickness. Sections 21, the type section, and 22 are located in Fig. 48; Canadian sections are located in Fig. 54.

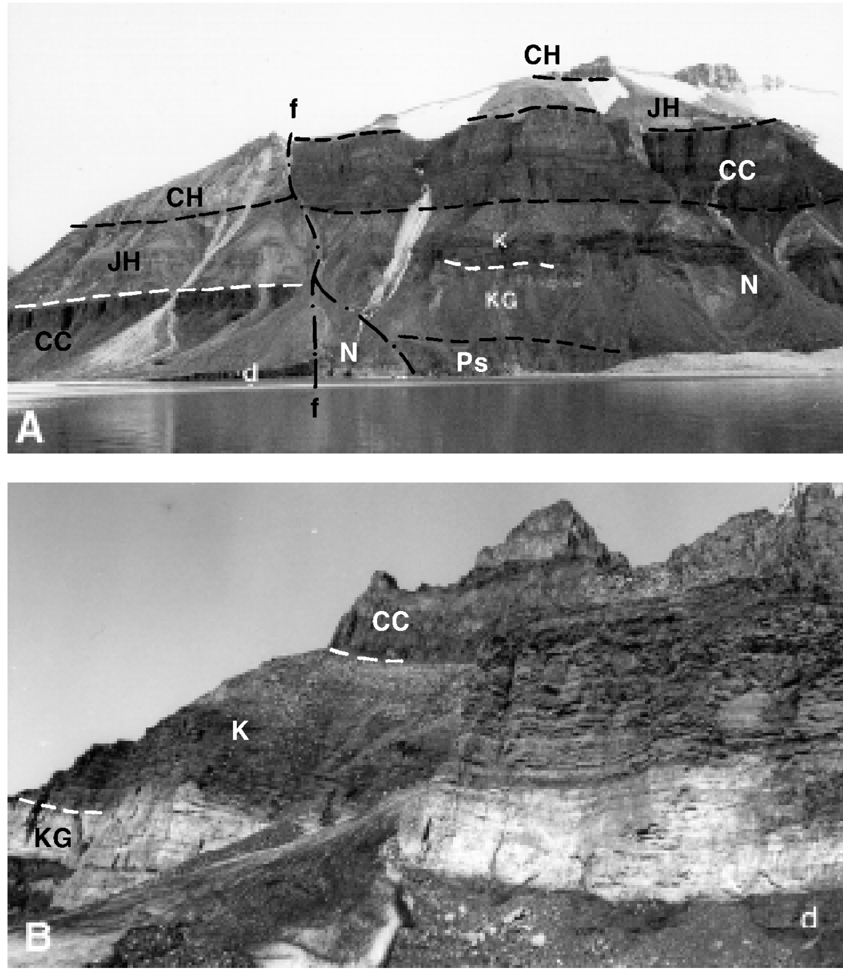


Fig. 51. Northumberland Formation (N) in the type area at western Ujâgsuk, Kissel Gletscher, Northumberland Ø. **A:** the type section above the cystalline shield (Ps) with moraine of Kissel Gletscher on the right; **B:** section to the south along Kissel Gletscher illustrating Kissel Gletscher (KG) and Kiatak (K) Members. CC = Cape Combermere Formation, JH = Josephine Headland Formation, CH = Clarence Head Formation, d = dolerite. Sections are given in Fig. 50; for map location, see Fig. 48.

Frisch & Christie (1982, fig. 2) but at Clarence Head includes the basal 15 m of strata of unit II, i.e. all sediments below the first major basaltic body. In the section at Clarence Head measured by Jackson (1986), the formation includes his unit 1 and the basal 60 m of unit 2. In the 6-unit scheme erected by Dawes *et al.* (1982a) for Ellesmere Island and Northumberland Ø, the strata correspond to the 'Basal Sandstone unit' (unit 1). However, it should be noted that at Gale Point, strata of overlying units, i.e. units 2 and 3 of Dawes *et al.* (1982a) and units II and III of Frisch & Christie (1982), are also referred to the Northumberland Formation, with the exception of a 39 m thick igneous unit that caps the section. This is regarded as the lowest strata of the Cape Combermere Formation.

Name. After Northumberland Ø, the middle and largest of three islands separating Murchison Sund and Hvalsund (Figs 2, 48).

Distribution. In Greenland, Prudhoe Land to the southeast of Diebitsch Gletscher, Northumberland Ø, and western Steensby Land; in Canada at Gale Point, south of Cadogan Inlet and at Clarence Head (Fig. 12). At Goding Bay the sections measured by Christie (1975), Frisch & Christie (1982) and Jackson (1986) are of strata stratigraphically higher than the Northumberland Formation. The one contact between Thule strata and crystalline shield in the area, north of Sparks Glacier, is interpreted as a fault boundary involving the Cape Combermere Formation (see Fig. 80).

Geomorphic expression and colour. Pale weathering, partly recessive and with resistant basic sills.

Type and reference sections. The type section is on the western side of Ujâgsuk, along Kissel Gletscher, Northumberland Ø (section 21, Figs 50, 51). (It should be noted that Jackson (1986) erroneously refers to the locality as 'Cadogan Glacier'.) Reference sections occur along Parish Gletscher and Robins Gletscher (e.g. fig. 7 *in* Dawes *et al.*, 1982a), at Barden Bugt (section 23, Fig. 52) and at Gale Point (sections 19, 20, Fig. 50).

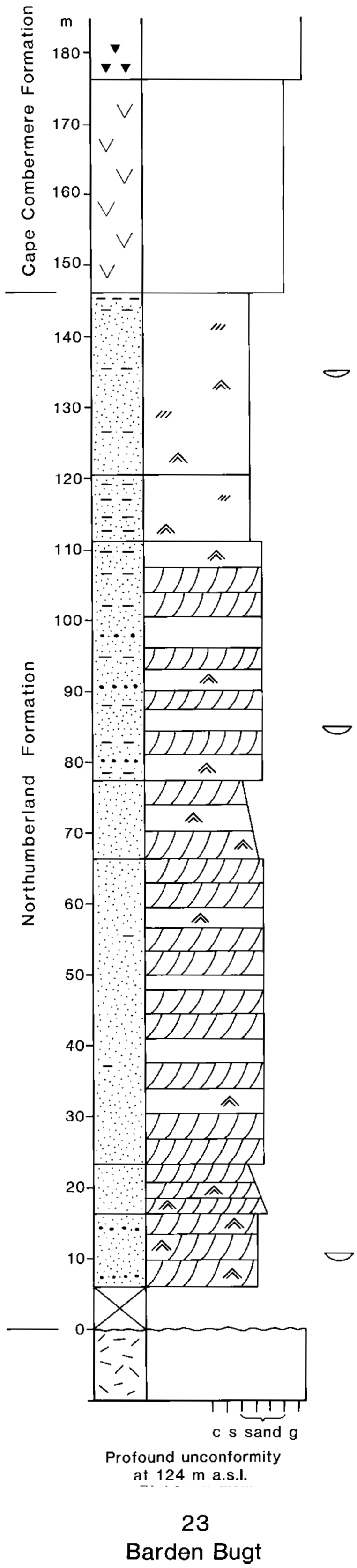


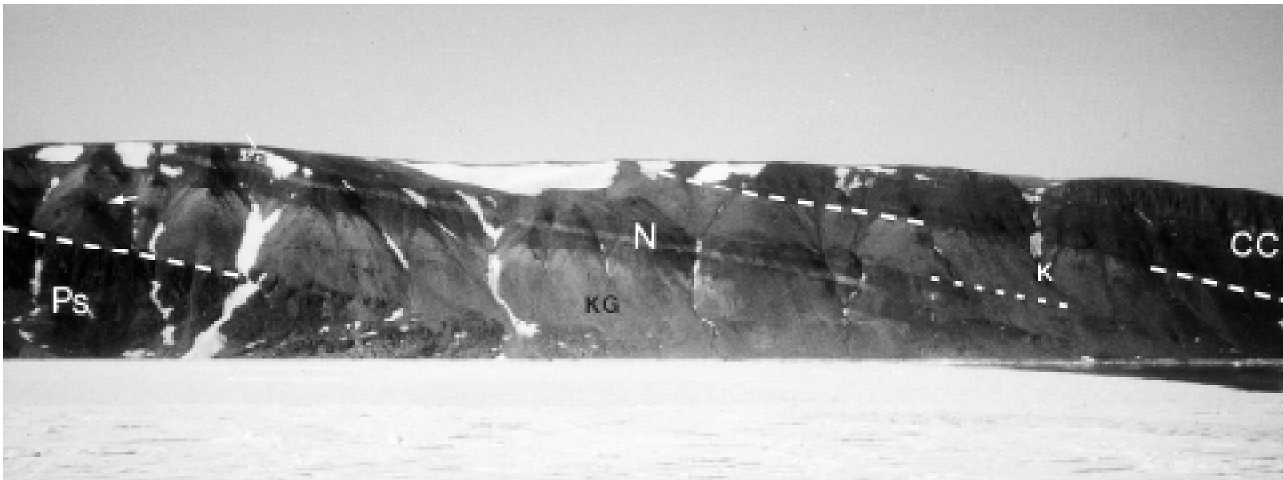
Fig. 52. Stratigraphic log of the Northumberland Formation from the south side of Barden Bugt; compiled mainly from data in O'Connor (1980). Section is located in Fig. 70.

Fig. 53. Basal strata of the Nares Strait Group. Thin-bedded, ripple-marked sandstones of the Northumberland Formation overlying biotite schists of the Precambrian shield. Only a thin weathering zone is present and no basal rudaceous rocks. East side of Bowdoin Fjord (Fig. 98).

Thickness. At Gale Point strata are between 265 and 350 m thick with up to 340 m on Northumberland Ø, thinning east to less than 50 m at Granville Fjord (Fig. 12). The thinnest section seen is in the Clarence Head – Cape Combermere area where between 10 and 75 m of strata are preserved, although tectonic disturbances have affected thicknesses (Frisch & Christie, 1982; Jackson, 1986; Figs 49B, 75).

Dominant lithology. Varicoloured sandstones, mainly quartz arenites, with red and green shale and siltstone units. At Gale Point additional lithologies in the lower part of the formation are calcareous sandstones and impure dolomites with stromatolites. Where examined basal beds rarely show rudaceous material (Fig. 53). Basic sills that both bifurcate and change stratigraphic level are prominent in the middle part; some basaltic bodies, for example the basic sill complex at Gale Point (Figs 54, 55), may contain effusive material.

Depositional environment. The formation is regarded



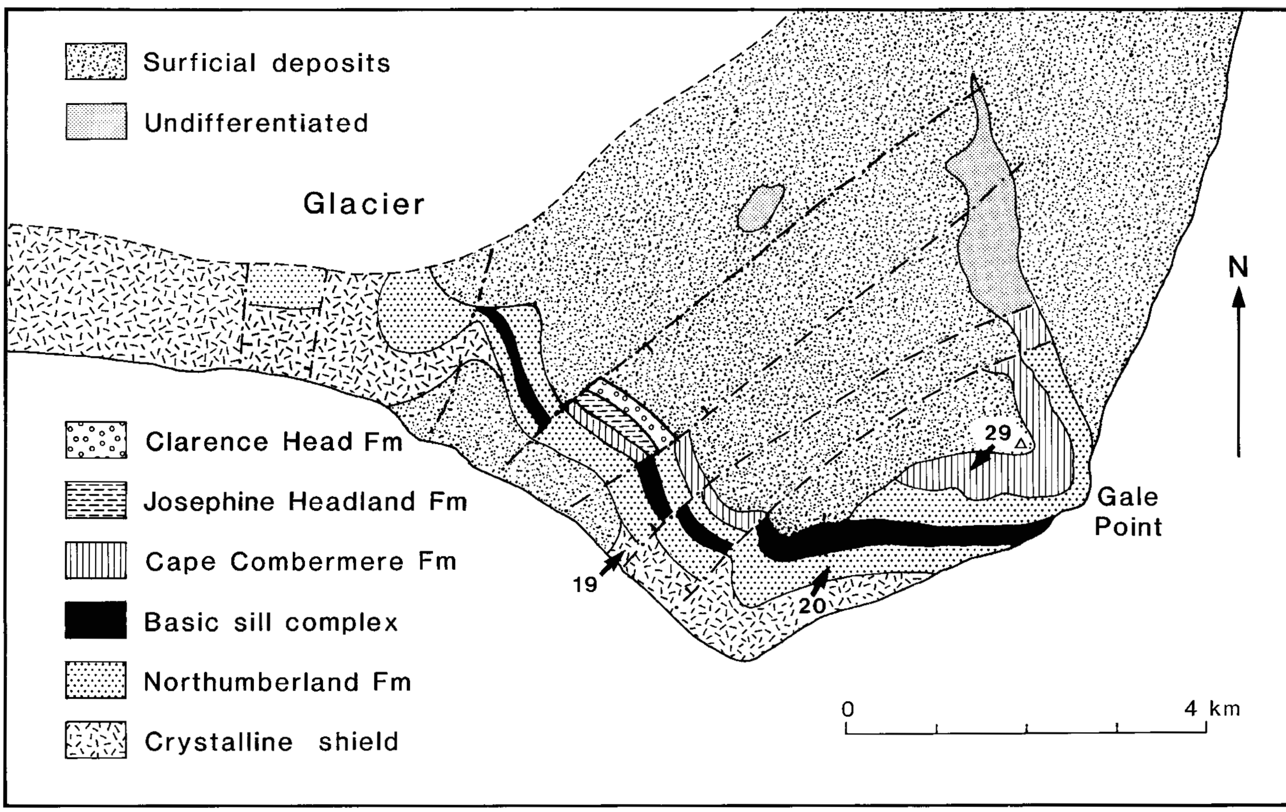


Fig. 54. Geology of the Gale Point area, Canada, showing the northernmost exposures of the Nares Strait Group overlying the Precambrian shield (Ps), and the location of sections 19, 20 and 29. Map and geology compiled from aerial photographs based on interpretation of data in Frisch & Christie (1982) and Frisch (1988); westernmost outcrops are reinterpreted as basal strata on shield rather than overlapping of the shield by 'upper beds' as in Frisch (1988). The photographic view of the coast south-west of Gale Point shows the Northumberland Formation (N) with dark basaltic units overlain by the Cape Combermere Formation (CC). The Kissel Gletscher (KG) and Kiatak (K) Members are shown. The dark rocks arrowed on left may represent dolomitic strata that farther west form the Gale Point Member of section 19 (see Fig. 50). The triangle marks summit at about 410 m a.s.l. Photo: G. D. Jackson. For location, see Fig. 2.

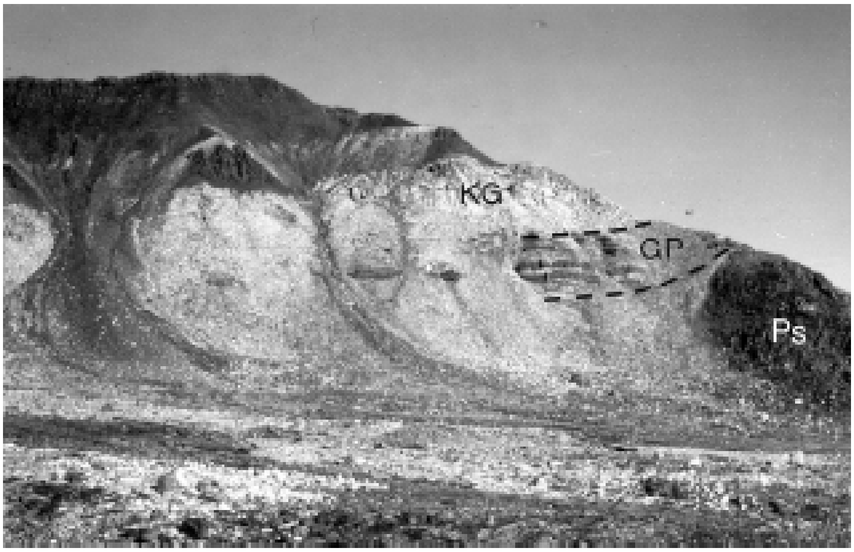


Fig. 55. Section west of Gale Point showing the Gale Point (GP) and Kissel Gletscher (KG) Members of the Northumberland Formation overlying the Precambrian shield (Ps). The dark basaltic units capping the hill form a sill complex (see Fig. 54) that may contain effusive rocks. This is the base of the type section of the Gale Point Member; section 19, Fig. 50; for map location see Fig. 54. Photo: T. Frisch.

as a mixture of subtidal to supratidal deposits; low-energy environments with stromatolites gave way to intertidal and floodplain deposits, reverting finally to shallow shelf deposition.

Fossils. Stromatolites.

Boundaries and correlation. The formation rests on crystalline rocks of the shield and it is overlain by the Cape Combermere Formation (Figs 49, 50, 51). The contact to the overlying formation is often with igneous rock but a regional conformable relationship is inferred. At Clarence Head the contact with crystalline basement is tectonised and Frisch & Christie (1982) regard the lower boundary as a fault (Figs 49B, 75).

There is no visible correlation with the Smith Sound Group of the northern platform but coeval strata may be present in the basal part of the Cape Camperdown Formation (Figs 11, 120).

Subdivisions. Where the formation is thickest, three members are recognised. The Kissel Gletscher and Kiatak Members are present on both sides of Nares Strait; the Gale Point Member appears to be restricted to Ellesmere Island.

Gale Point Member

new member

Composition. This member corresponds to unit I of Frisch & Christie (1982) as exposed west of Gale Point. A small outcrop at MacMillan Glacier some 40 km to the north, provisionally correlated with the Gale Point section by these authors, is referred to the Rensselaer Bay Formation (Smith Sound Group).

Name. After Gale Point at the northern entrance of Cadogan Inlet (Figs 2, 54).

Distribution. West of Gale Point. The member cannot be recognised in the section logged by Christie (1975) in the sea-cliffs immediately south-west of Gale Point (section 20, Fig. 50), although photographic interpretation suggests that dark dolomitic rocks, characteristic of the member, occur nearby (Fig. 54).

Geomorphic expression and colour. Pale weathering, moderately recessive and poorly exposed.

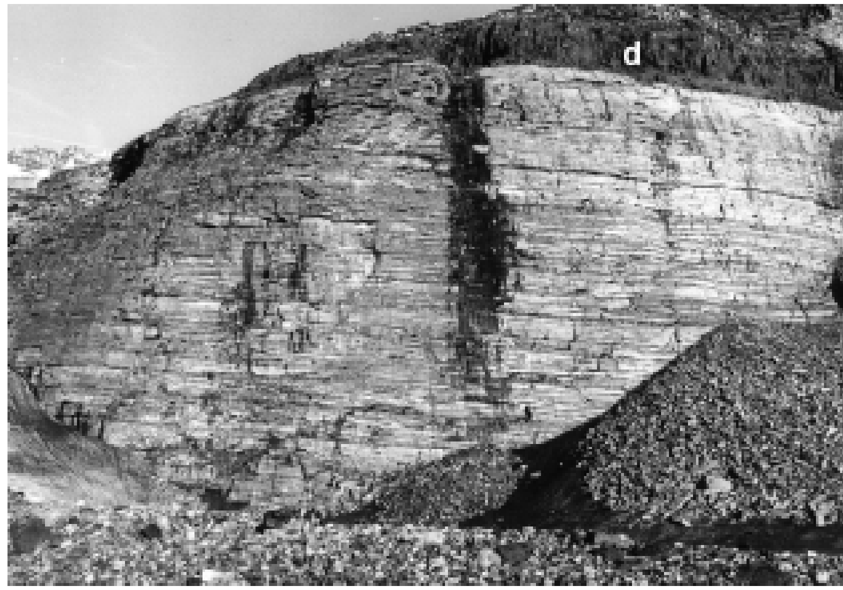
Type section. West of Gale Point (section 19, Figs 50, 55).

Thickness. Up to 40 m.

Lithology. The main lithologies are dolomitic sandstone, subarkose and stromatolitic dolomite. The sandstones are thin bedded, white, buff or pale green in colour, with cross-bedding and occasional ripple marks. The dolomites, which alternate with the sandstones in the bulk of the member, contain chert clasts, have shale and sandy partings and display domal stromatolites.

Depositional environment. Deposition was probably in an overall supratidal environment in which carbonate precipitation and algal growth were periodically

Fig. 56. Thin- to medium-bedded mottled sandstones in the upper part of the Kissel Gletscher Member of the Northumberland Formation. Low-angle cross-bedding is depicted by colour variation. A basaltic sill (d) caps about 60 m of strata. Eastern side of Kissel Gletscher, Northumberland Ø.



stifled by influx of detrital material. According to Frisch & Christie (1982) the lack of interstitial clastics, relatively steep walls and absence of lateral linkage favour the stromatolites having formed in a rapidly subsiding or sediment starved region, such as a lagoon or supradeltaic lake.

Fossils. Domal stromatolites up to 15 cm high (see Frisch & Christie, 1982; fig. 14).

Boundaries and correlation. The upper and lower contacts are poorly exposed, but the Gale Point Member probably directly overlies crystalline basement and in the type section it has a conformable contact with the Kissel Gletscher Member above (Fig. 55). The relationship to the Kissel Gletscher Member away from the type section is unknown; possibly the two members interdigitate.

Kissel Gletscher Member

new member

Composition. This member corresponds to the basal strata of unit 1 of Northumberland Ø of Dawes (1976b) and is grossly equivalent to sub-units 1A and 1B as described by Jackson (1986). At Gale Point it comprises units 1 to 7 of Christie (1975) and all but the uppermost 25 m of unit II of Frisch & Christie (1982).

Name. After Kissel Gletscher, north-west Northumberland Ø (Figs 2, 48).

Distribution. Northumberland Ø, western Steensby Land, Gale Point, Cape Combermere and probably Prudhoe Land. The light-coloured lower part of the thin and faulted section at Clarence Head (Frisch & Christie, 1982, fig. 5) is referred to this member (Fig. 49B).

Geomorphic expression and colour. Buff to orange weathering, partly recessive with distinct cliff-forming beds and resistant basic sills mainly in the upper part (Figs 49A, 54).

Type and reference sections. The type section is the same as for the formation, viz. western side of Ujâsuk, along Kissel Gletscher, Northumberland Ø (section 21, Figs 50, 51). Reference sections are at Gale Point (sections 19, 20, Fig. 50).

Thickness. About 200 m at Kissel Gletscher and Gale Point, thinning to the south and east; at Kap Trautwine about 70 m. Jackson (1986) records a southward thickening of 36 m over about 1.5 km in the upper beds at Kissel Gletscher (Fig. 50).

Lithology. The member is typified by planar, generally medium-bedded, fine- to medium-grained, massive to laminated multicoloured quartz arenites characterised by varying degrees of mottling (Fig. 56). Some units are distinctly thin bedded and platy (~ 10 cm), others thick to very thick bedded. Lenticular beds characterise some outcrops. Cross-bedding and symmetrical ripple marks occur throughout; at Kissel Gletscher some units are characterised by strong bimodal cross-beds (Jackson, 1986). At the base of some beds there are scours, as well as occasional, thin, coarse to very coarse layers commonly showing minor channels. At Gale Point sandstones are locally conglomeratic with quartz granules and pebbles, occasionally subangular, occurring in small diffuse concentrations. In the upper part of the member mud flakes are common in some beds. At Kissel Gletscher and Barden Bugt upward-fining cycles up to a couple of metres occur.

Thin interbeds of green, red and purple shale occur sporadically and these show profuse mudcracks. Shale increases in abundance in the upper part, and in the upper 20 m Jackson (1986) describes wavy to lumpy beds containing shale chips and balls.

The arenites are composed of rounded to subrounded, locally subangular, quartz that often shows dusty borders; some rocks approach subarkose. Sericite may be present interstitially and in some rocks forms a sparse matrix, very occasionally with carbonate.

Much of the Kissel Gletscher Member is composed of pale sandstones – grey, pink, pale green, buff and even white – but particularly in the lower part units vary from purple and maroon to orange and brownish colours. Reduction spots and irregular colour patterns are common. Reduction of iron is a widespread feature and it appears to have taken place on a large scale; some pale sandstones contain only small relict patches of red coloration.

On Northumberland Ø and at Gale Point the uppermost part of the member contains prominent igneous bodies up to 30 m thick, and in the Gale Point west section igneous rocks form at least 50% of the member (section 19, Fig. 50). Where examined in Greenland the basaltic rocks are sills. At Gale Point, Christie (1975) suggests that some may be effusive; Frisch & Christie (1982) state that at least three of the four igneous bodies in the Gale Point west section are sills.

Depositional environment. The Kissel Gletscher Member probably represents a marine transgression and the incoming of major detrital sedimentation that terminated the protected low-energy environment of the Gale Point Member. Bimodal cross-beds indicate a tidal environment. According to Jackson (1986) the nature and abundance of compound cross-beds suggest deposition in sand ridges and waves in a shallow shelf, while the incoming of shale in the upper part may represent relatively protected deposition behind a barrier island or in a lagoon.

Fossils. None known.

Boundaries. The lower boundary is the formational boundary except in the Gale Point west section where the member is underlain by the Gale Point Member. Where basaltic material is absent the upper boundary to the Kiatak Member is gradational and taken at the incoming of abundant thin red beds; it is often seen as a distinct colour change (Fig. 51). At Gale Point and in places on Northumberland Ø the uppermost rock is basalt taken to be intrusive.

Kiatak Member

new member

Composition. On Northumberland Ø the Kiatak Member corresponds to the middle and upper strata of unit 1 of Dawes (1976b), being equivalent to sub-units 1C and 1D as described by Jackson (1986). At Gale Point it comprises units 8–10 of Christie (1975), and the upper 25 m of unit II and all but the upper igneous part of unit III of Frisch & Christie (1982).

Name. After Kiatak, the Eskimo name for Northumberland Ø (Figs 2, 48).

Distribution. Northumberland Ø, western Steensby Land and Gale Point. The red beds in the upper part of the faulted section at Clarence Head may belong to the member.

Geomorphic expression and colour. A generally recessive unit, with lower part dark weathering and locally cliff-forming; upper part is pale weathering and often scree covered (Fig. 51).

Type and reference sections. The type section is the same as for the formation, i.e. western side of Ujâgsuk, along Kissel Gletscher (section 21, Figs 50, 51). Reference sections are at Gale Point (sections 19, 20, Fig. 50).

Thickness. In Greenland up to about 135 m; at Gale Point between 85 and 210 m of strata are referred to the member.

Lithology. The member is an interbedded sandstone-siltstone-shale sequence. In Greenland it shows variable lithology. The lower part is composed of purple, red to brownish red, very thin- to medium-bedded sandstones, with red and green siltstone and shale (Fig. 51); the upper part contains much less argillaceous material and fewer red beds. In the upper part sandstones are mainly buff to pale pink, in places white, and they are planar to lenticular, medium to thick bedded. There are also some pink sandstone beds in the lower part of the member; these have an irregular, rather lenticular form. At Gale Point the member is dominated by fine-grained lithologies: interbedded, red, green and buff, often banded variably silty and micaceous sandstone, siltstone and shale.

The sandstones are fine to medium grained, composed of subrounded to subangular quartz with up to 10% feldspar and with mica flakes and disseminated hematite. They are often finely laminated and frequently have green shale partings that show mudcracks. Cross-bedding and ripple marks occur but they vary markedly in frequency at different levels of the member. Some sandstone beds contain intraformational conglomerates with shale flakes and clasts.

In Greenland purple and green shale beds are up to 35 cm thick, usually containing thin sandstone and siltstone horizons. Jackson (1986) notes that some red and green beds are composed of mud balls 6 cm in diameter. At Gale Point shale and siltstone form thicker beds; in the western section Frisch & Christie (1982) report a 20 m unit of green shale.

Depositional environment. This sandstone-siltstone-shale succession is thought to represent a complex of intertidal to supratidal deposits, more specifically to a flood plain environment. According to Jackson (1986) basal strata contain beach deposits, while the lower part of the member in the type section is dominated by meandering stream channel and overbank deposits formed in a low-energy environment. The uppermost strata of relatively clean sands are taken to represent intertidal shelf deposition.

Fossils. None known.

Boundaries. The lower boundary of the member is generally with sill rock of the Kissel Gletscher Member; on Northumberland Ø, as described above, where a sedimentary contact is preserved, it is gradational. The upper boundary is that of the formation, viz. sharp contact with igneous rock of the Cape Combermere Formation.

Cape Combermere Formation

new formation

Composition. Volcanic strata with interbedded red beds, first recognised on Ellesmere Island, form part of Christie's (1962a, b) 'little disturbed formation 2'; in Greenland on Northumberland Ø the strata were placed by Dawes (1975) as part of the lowest member of the Wolstenholme Formation being later defined as unit 2 (Dawes, 1976b). The formation equates with unit II of the Wolstenholme Formation of Frisch *et al.* (1978) and Frisch & Christie (1982) as described between Clarence Head and Goding Bay, although at Clarence Head basal sediments beneath the first major igneous body (12–15 m thick) are herein referred to the Northumberland Formation. In the 6-unit scheme erected by Dawes *et al.* (1982a) the formation equates with the 'Basalt – Red Bed unit' except that only the uppermost 39 m of the section west of Gale Point described by Frisch & Christie (1982, fig. 2) are included in this formation, the underlying strata of units 1, 2 and 3 being referred to the Northumberland Formation. In the section measured by Christie (1975) farther east at Gale Point, the formation corresponds to units 11 to 19.

Name. After Cape Combermere, the prominent eastern cape of Smith Bay (Figs 2, 57).

Distribution. In Greenland, Prudhoe Land south-east of Sonntag Bugt, Northumberland Ø and western Steensby Land; in Canada, in all main sections between Gale Point and Clarence Head that expose the lower Nares Strait Group (Fig. 12).

Geomorphic expression and colour. Dark-weathering cliff-forming unit differentiated into dark grey to black precipitous cliffs (igneous rocks) punctuated by purple to brown recessive intervals (sediments).

Type and reference sections. The type section is at Cape Combermere (section 26, Figs 57, 58); good reference sections occur on Northumberland Ø (section 27, Fig. 58, and at Robins Gletscher), and at Clarence Head, Goding Bay and at Gale Point (sections 24, 25, 28, 29, Fig. 58).

Thickness. Basaltic sills, the largest of which is nearly 140 m thick, form an uncertain and varying thickness. Although all sills may not be contemporaneous and coeval with the extrusive strata (i.e. sills occur in the

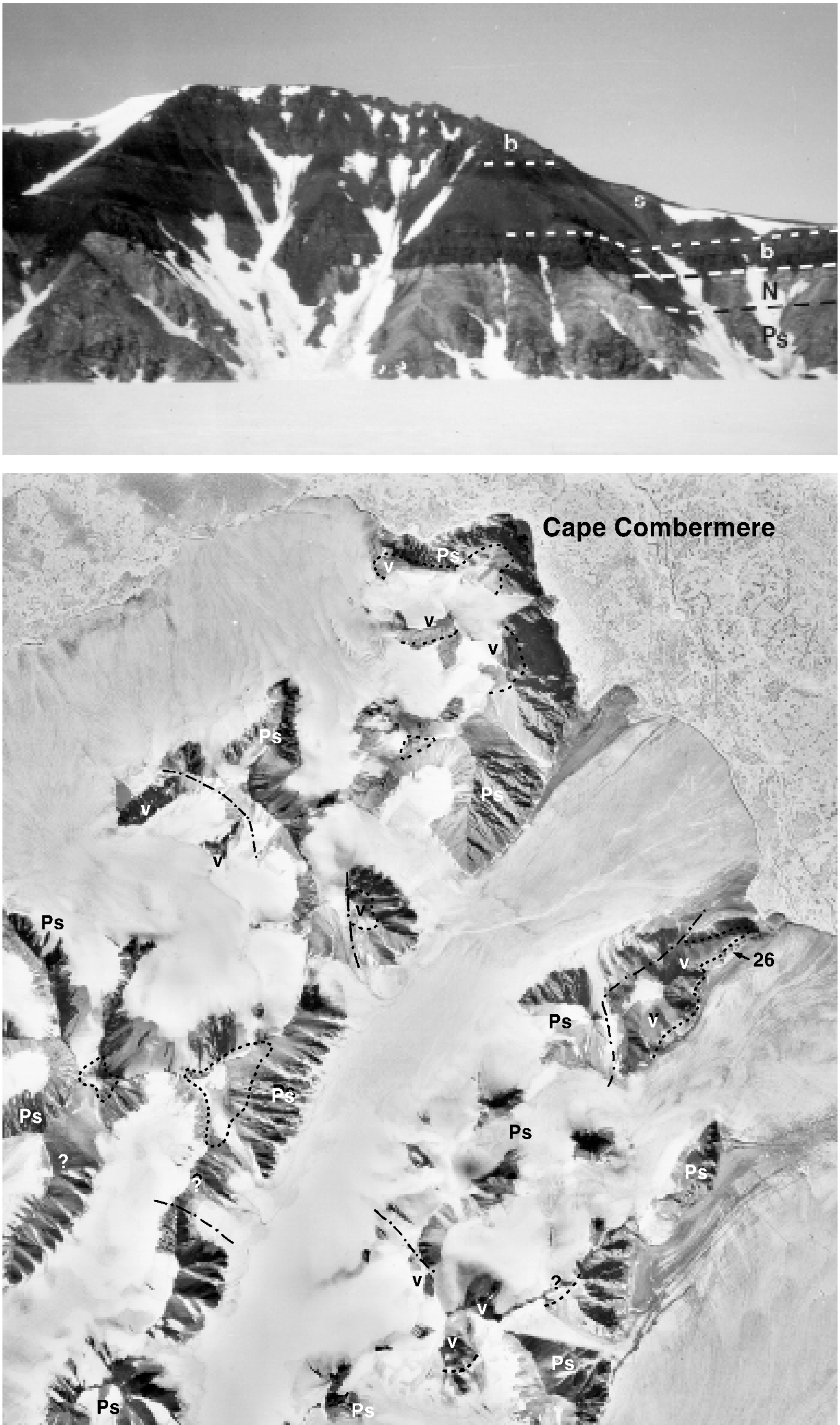


Fig. 57. Geology of the Cape Combermere area, Canada, showing the location of the type section of the Cape Combermere Formation (section 26).
Coastal view, above: Dark Cape Combermere Formation capping cliffs with sedimentary member (s) separating lower and upper basalt members (b). Height of section above the glacier is about 300 m. Section 26, given in Fig. 58, was measured on the lower slopes on the right. Photo: W. C. Morgan.
Aerial view, below: small outliers of Northumberland Formation (light coloured) and Cape Combermere Formation (dark, also marked v) on the Precambrian shield (Ps). Compilation and interpretation are by the author from data supplied by T. Frisch. East–west field of view is about 10 km; highest nunatak is above 760 m. A ground view of this nunatak country is given in Fig. 13B. Photo: E31-124, National Air Photo Library, Ottawa.
For location, see Fig. 2.

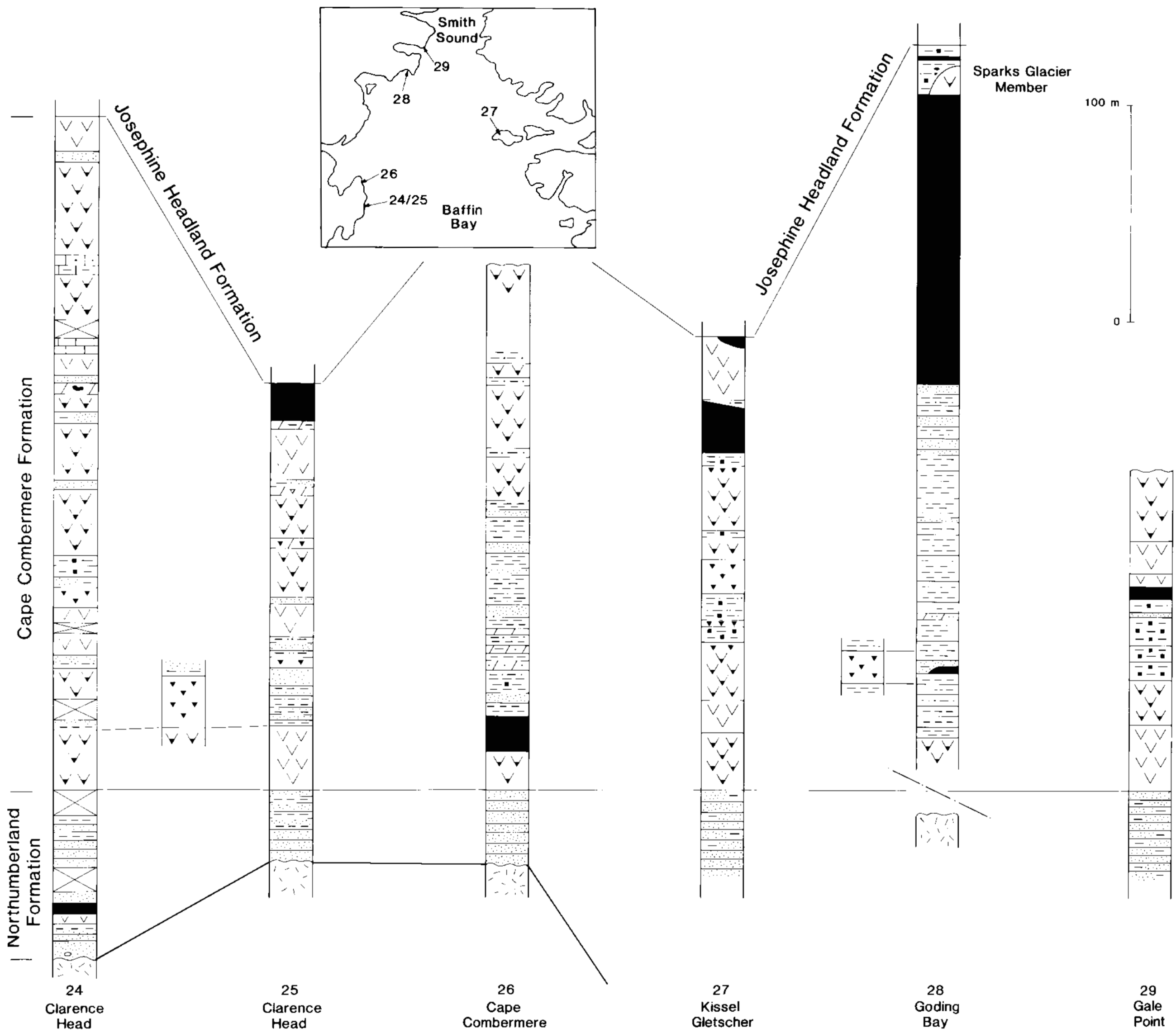


Fig. 58. Generalised sections of the Cape Combermere Formation. Canadian geology compiled from following sources: section 24 from Jackson (1986), sections 25, 26, 28 and 29 from data in Christie (1975) with some modification in section 28 from Frisch & Christie (1982) and Jackson (1986). Section 27 is a composite section from both sides of Kissel Gletscher. Dykes and low-angle sills are not shown. Part sections illustrate volcanic breccia units in nearby sections. Section locations: 24 and 25, Fig. 75; 26, Fig. 57; 27, Fig. 48; 28, Fig. 80; 29, Fig. 54.

overlying Baffin Bay Group and younger strata), thicknesses given here include all concordant sheets of basalt. So defined the formation varies in thickness from more than 340 m at Goding Bay (base not seen) and 310 m at Clarence Head to about 200 m on Northumberland Ø to less than 100 m in Prudhoe Land (Fig. 12). At Bowdoin Fjord and Granville Fjord a single basic sheet of uncertain origin with a minimum thickness of 15 m is taken to represent the distal edge of the formation in the east (see Figs 87, 98).

The thickness difference of 120 m between sections spaced about 1 km apart at Clarence Head (sections 24, 25, Fig. 58) may not reflect true stratal variation. These sections, as elsewhere, include precipitous units the thicknesses of which are estimates (Frisch & Christie, 1982, p. 3; R. L. Christie, personal communication, 1975).

Lithology. The formation consists of a complex suite of effusive, hypabyssal and pyroclastic basaltic rocks with interbedded water-lain volcaniclastic and clastic sediments and subordinate siliciclastic carbonate rocks.

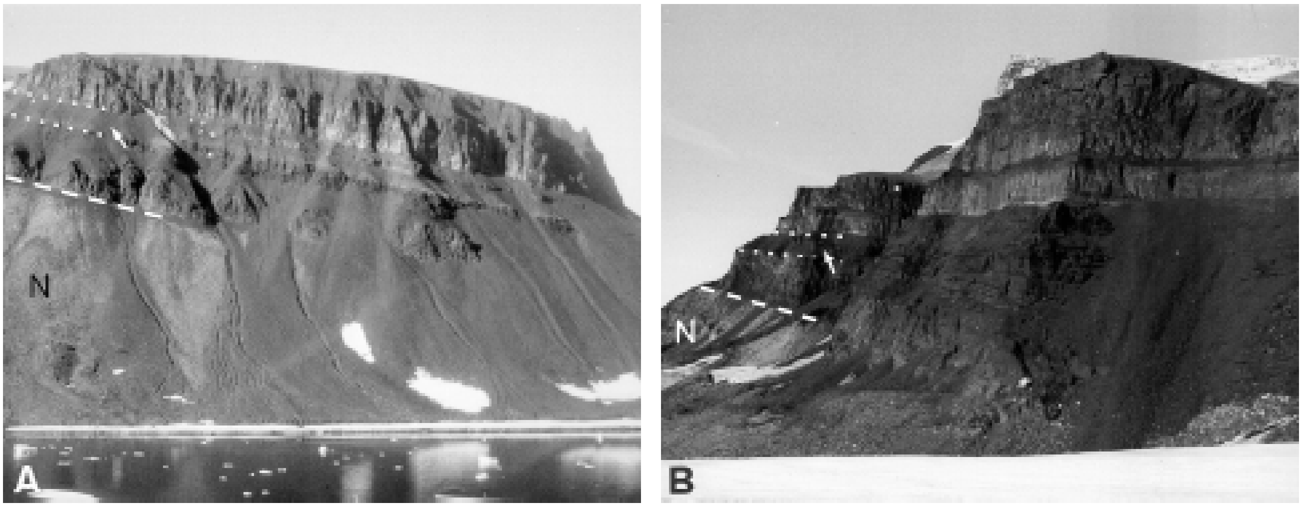


Fig. 59. Cape Combermere Formation, Canada and Greenland, illustrating lower and upper resistant basalt units separated by bedded volcaniclastic unit (arrowed). N = Northumberland Formation. **A:** Gale Point seen from the south, photo: K. W. Christie; **B:** eastern Kissel Gletscher, Northumberland Ø, viewed to the north. For location, see Figs 48 and 54.

Throughout much of its exposure the formation shows a tripartite division: a varied unit of recessive sandstone, siltstone and shale with diverse volcanic, pyroclastic and volcaniclastic rocks separates upper and lower massive units of lava and sill rock (Figs 57, 59, 71). At Clarence Head the formation is composed of at least 12 basaltic bodies separated rather regularly by sediments (Fig. 58).

Igneous rocks generally constitute between 60 and 80% of the formation. At Goding Bay igneous and sedimentary rocks make up about equal volumes of the incompletely exposed section. Pyroclastic rocks are a notable component of main Greenland exposures and at Gale Point; in contrast such rocks are less common at Clarence Head and Cape Combermere and they have not been recognised in the section at Goding Bay studied by Frisch & Christie (1982) and Jackson (1986).

Distinguishing between flows and sills can be extremely difficult, particularly where contacts with host rock are not exposed. Based on the complete sections effusives appear to dominate over intrusives. Observations taken at face value can be conflicting; thus at a single locality good amygdaloidal texture may suggest a flow top, elsewhere basalt of the same body can appear to be intrusive. Such relationships are taken to indicate the near-surface origin of some of the sills with perhaps lava being intruded down-slope into older strata.

Lavas and sills. Flow and sill rock are very similar in appearance, weathering dark grey to greenish-grey. Some lavas have a purplish hue on fresh surfaces and commonly a purplish-brown, even reddish, weathering colour. Some have red tops. All flows examined show some degree of vesicular or amygdaloidal structure. Confirmed sill rock, with chilled contacts, may also contain amygdules. Petrographically both lava and sill rock are similar; microporphyritic, sub-ophitic clinopyroxene basalt with or without olivine as a phenocryst phase. Olivine typically shows alteration to semi-opaque oxides. Textures may be hyalo-ophitic, intersertal or intergranular; the lavas show a wider range of textural variation than the sills with transitions to vesicular basalt and in places with stellate aggregates of feldspar laths.

Individual sills range from less than a metre thick to the gabbro at Goding Bay 130 to 140 m thick (Frisch & Christie, 1982; Jackson, 1986). This sill has baked the adjacent sediment; it shows columnar jointing throughout suggesting that it represents a single cooling unit. Many sills are between 10 and 25 m thick. Flows range from 2 m thick to the 43 m flow near the top of section 24 at Clarence Head (Fig. 58).

Typical flows are characterised by heterogeneous tops that show upward increasing abundance and size of vesicles and amygdules or the presence of a fragmental or brecciated zone. Vesicular basalt also occurs at the base of some flows but appears impersistent along strike. Amygdules are more common than crystal-free vesicles; mineral infillings are calcite, siderite, zeolites and silica minerals; the latter often shows spherulitic texture. Some lavas are locally vuggy and they can contain reddish-brown agates; at Robertson Fjord, Robins Gletscher and Gale Point agates are up

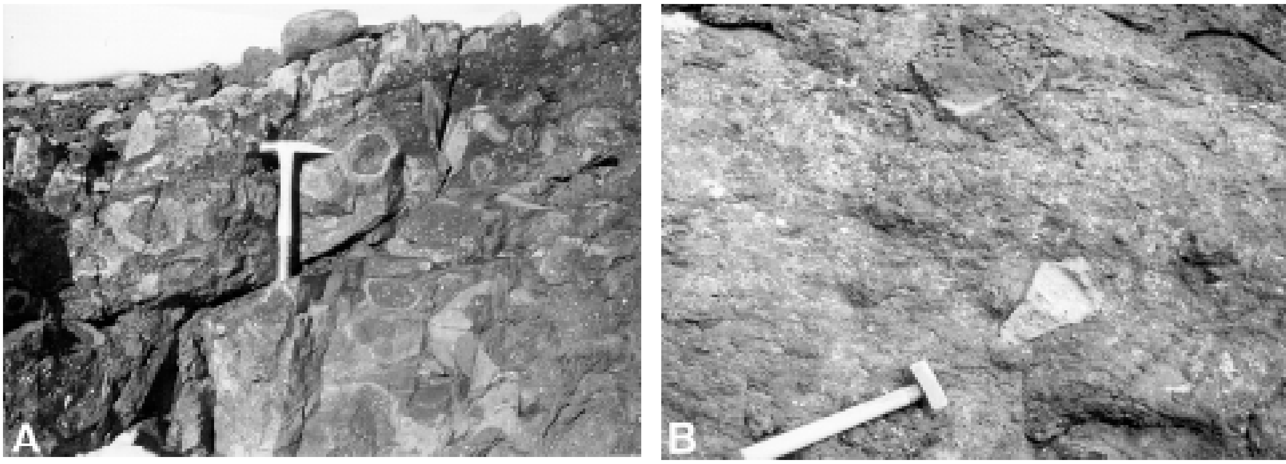


Fig. 60. Volcanic agglomerates with carbonate-rich matrices from the Cape Combermere Formation. **A:** bombs of amygdaloidal basalt containing tuffaceous fragments with rims of concentric carbonate laminae. Clarence Head, section 25, photo: R. L. Christie; **B:** subangular to rounded fragments of varying composition and up to several decimetres in size. Josephine Headland, section 27.

to 10 × 30 cm in size. Some vugs contain ornamental quality chalcedony and quartz crystals.

The fragmental flow tops have a rubbly to blocky appearance and are commonly brecciated and agglomeratic; some tops have tuffaceous material between blocks. Such rocks commonly are enriched in carbonate, both in the matrix or cavity-fill and in small irregular veins. Flow-top breccia may contain a variety of pyroclast composition, volcanic as well as volcaniclastic. Pillow-like structures have been recognised at several localities, for example at Clarence Head and on Northumberland Ø; loose material from Robins Gletscher shows the unmistakable chilled dense to glassy margins characteristic of water-lain pillow lava. Flows display a variable degree of vertical columnar jointing but it is not a particularly conspicuous feature.

Volcanic breccia and agglomerate. Discrete units of pyroclastic rocks up to 25 m thick occur; the thickest are in the lower part of the formation (Fig. 58). Breccias are dark grey to purplish-red weathering and cliff-forming and contain a variety of angular to rounded volcanic and sediment enclaves. At Kissel Gletscher these are composed of diverse basaltic rocks, many of which are vesicular and carbonate-rich, pumice, some light coloured to brownish altered volcanic rocks, some of which are quartz porphyries, yellow and red quartzite and baked siltstone, together with volcaniclastic rocks that are characterised by angular to subrounded quartz grains. Phenocrysts of quartz and feldspar in the porphyries may be badly corroded in an altered fine-grained cryptocrystalline matrix.

Enclave sizes are centimetre to metre scales. Vol-

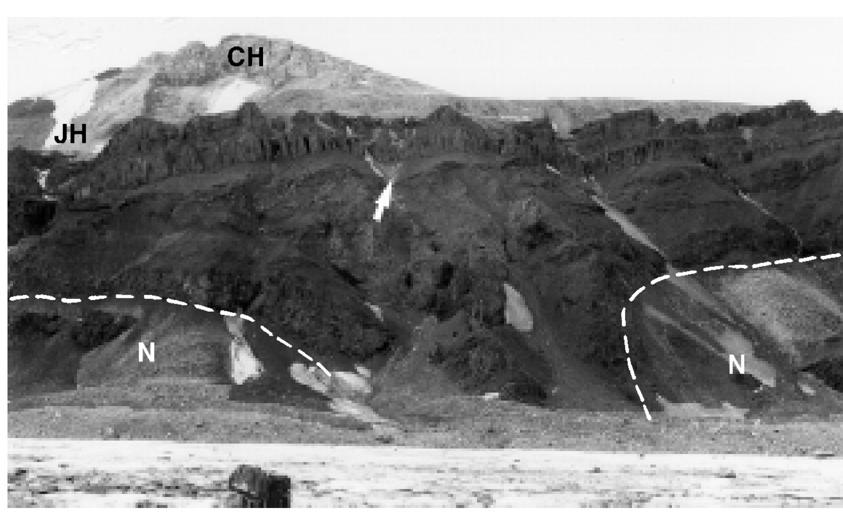


Fig. 61. A volcanic vent in the Cape Combermere Formation on the western side of Robins Gletscher, Northumberland Ø. For location, see Fig. 48. The vent feeds the lower part of the formation since the sedimentary unit (arrowed) and the uppermost columnar-jointed basalt continue uninterrupted above the vent. N = Northumberland Formation with basalt sills, JH = Josephine Headland Formation, CH = Clarence Head Formation. Height of basalt section at vent about 300 m.

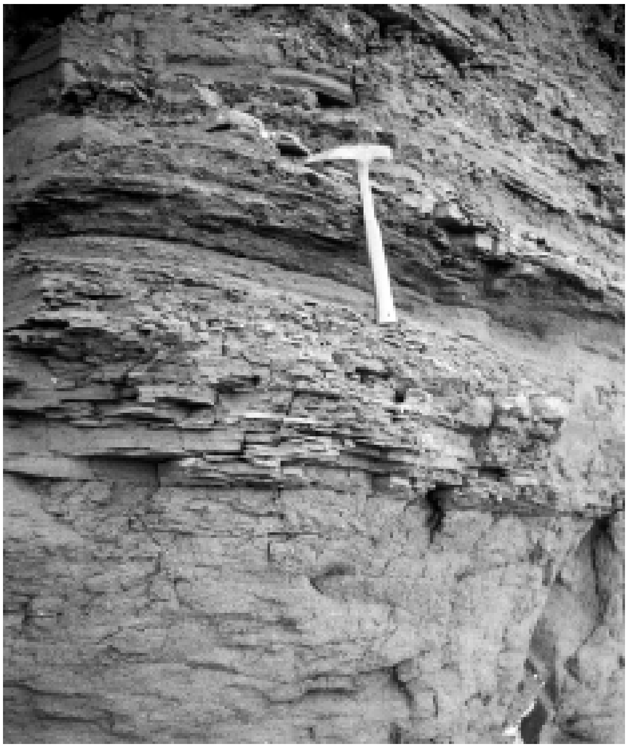


Fig. 62. Bedding characteristics of clastic and volcaniclastic sediments of the Cape Combermere Formation at Barden Bugt (Fig. 70). Red to brown, interbedded fine to very coarse sands with occasional pebble beds. Photo: B. O'Connor.

canic bombs are smooth-surfaced and pitted, mainly composed of black to dark grey amydaloidal basalt with calcite fillings. Some show distinct rimming. At Clarence Head, a 3 m thick carbonate-matrix agglomerate has volcanic bombs up to 25 cm that have well developed rims of carbonate (Fig. 60). At Robins Gletscher an irregular mass of rubbly agglomerate, composed mainly of rounded to subrounded basalt blocks up to 50 cm long, occurs in association with a possible volcanic feeder (Fig. 61).

Sedimentary rocks. Sediments are of wide diversity dominated by sandstone-siltstone-shale sequences with minor carbonate and volcaniclastic rocks. Volcaniclastic rocks are best developed on Northumberland Ø and at Gale Point where they characterise the middle unit of the formation; in more eastern outcrops and in southern sections in Ellesmere Island, sediment packages apparently contain less pyroclastic material. For example, at Cape Combermere only "a few centimetres of basaltic tuff" have been noted (Frisch & Christie, 1982, p. 7).

Clastic rocks are characteristically red to brown, thin-bedded and recessive, dominantly fine to medium grained and often have hematitic laminae. At the type section at Clarence Head, clastic rocks form interflow packages up to 15 m thick of arkosic sandstones, commonly with red or green shale partings, interbedded with shale and siltstone. Ripple marks and desiccation cracks occur; cross-beds are very rare. Buff, orange and green sandstones occur occasionally; Jackson (1986) mentions fining-up sequences in the basal strata. At Goding Bay a 160 m section contains conspicuous red shale units and is topped by a dark, concretionary shale unit (see below, Sparks Glacier Member). Christie (1975) noted coarse-grained, green glauconitic sandstones in upper strata at Goding Bay, while at Cape Combermere grading from red sandstone to fine-grained silts in 20 cm beds was noted by W. C. Morgan (personal communication, 1990).

In eastern outcrops, e.g. in Prudhoe Land and western Steensby Land, coarser clastic material comes in, and red to brown and purple interbedded fine to coarse sandstones with occasional pebble beds, have minor red siltstone and shale (Fig. 62). Mudcracks are common, ripple marks and cross beds rare. Reduction mottling and fish-eye spots occur in some places. At Barden Bugt the sandstones have angular to subrounded quartz and occasional feldspar grains in a carbonate-rich matrix.

Carbonate strata form a minor lithology occurring as thin, brownish, less often green and grey-weathering thin limestone or dolomite beds that are variously laminated, fragmented, arenaceous and argillaceous. Jackson (1986) noted limestone-clast granule conglomerate beds, cryptalgal laminites and gypsum nodules at Clarence Head.

Volcaniclastic strata are concentrated within a very distinctive, deep red and maroon to tan succession up to 25 m thick on Northumberland Ø and up to 38 m at Gale Point (Figs 58, 59). Main rock types are fine-grained, variably silty sandstone, siltstone and shale with lithic tuff, tuff breccia and ash flow units. The silty sandstones have rounded to angular quartz grains in a very fine-grained siliciclastic matrix with occasional microscopic volcanic clasts. The rocks are irregularly thin bedded and commonly severe fracturing obscures bedding. Desiccation cracks occur on the muddy tops of some beds.

Sandstones and shales grade into lithic tuffs with increase of rock fragments, which are generally up to 5 mm in size, but occasionally larger. Fragments are fine grained and mostly volcanic but some are shale or quartzite. Main volcanic types are basaltic, quartz porphyry and glass, with some elongated carbonate-rich clasts. A similar clast suite is found in tuff breccia which forms discrete beds on Northumberland Ø. Clasts are angular to subrounded and normally below 3 cm in length.

Some chocolate-brown strata on Northumberland Ø are characterised by accretionary lapilli which are rounded to slightly ellipsoidal, generaly less than 1 cm in diameter. Normally the lapilli are densely scattered throughout the rock, but particularly in upper parts of beds; however, isolated spheroids also occur. They are characterised by a thin, dense outer shell of ash around an unstructured central part that corresponds to the tuff matrix. The spheroids are identical to rim-type lapilli described as indicative of ash-flow deposits by Schumacher & Schmincke (1991). At Clarence Head the upper parts of thin beds are described by Jackson (1986) as being "full of small spherical bodies (pisolites or concretions?)". These have an internal structure very similar to the Northumberland Ø lapilli (G. D. Jackson, personal communication, 1992).

Volcanic and sedimentary environments. The Cape Combermere Formation represents rift volcanicity in the axial parts of the basin, with contemporaneous sedimentary deposition in shallow water to terrestrial environments.

The similar chemistry of flows and sills suggests that both effusive and hypabyssal basalts belong to the same magmatic regime: a continental flood basalt province. Chemical analyses of Canadian material judged nearest to original composition fall mainly in the tholeiitic field in alkali-silica and AFM diagrams (Frisch & Christie, 1982); Greenland results plot similarly. However, some lavas tend towards andesites, and, the presence in Greenland of pyroclastic rocks with quartz porphyry clasts indicates that rock types other than 'typical' plateau tholeiitic basalts occur.

The flows, some with reddish weathering tops, are typical terrestrial effusives while local pillow structure indicates proximity of a shoreline. The sills, commonly amygdaloidal, are regarded as near-surface intrusions, an interpretation supported by dual contact relationships (extrusive-intrusive) shown by the same basaltic body. The rim-type accretionary lapilli in bedded tuffs are typical proximal deposits indicating a nearby source (within a few kilometres). One vent or feeder has been recognised on Northumberland Ø (Fig. 61).

Biogenic carbonates associated with the interflow sequences indicate prolonged association of lava extrusion and intermittent shallow water. Fining-upward cycles in lower strata suggest early fluvial deposition (Jackson, 1986) while marine conditions are thought to have prevailed in at least one area of Ellesmere Island at the end of deposition of the formation (see Sparks Glacier Member below).

Fossils. Algal laminites.

Boundaries. The Cape Combermere Formation overlies the Northumberland Formation and is overlain by the Josephine Headland Formation, and in Greenland, in eastern outcrops, by the Barden Bugt Formation (Figs 49, 58, 71).

In most outcrops lower and upper boundaries are sharp involving igneous rock, either lava or sill. On a regional scale such contacts are conformable; locally and in detail discordant relationships exist. The lower boundary is transgressive reaching different levels of the underlying Northumberland Formation; at Robins Gletscher it plunges inwards towards a vent structure. The upper boundary consistently marks the same stratigraphic level. Where the upper contact involves igneous rock in contact with the Josephine Headland Formation, the contact in detail may be very irregular (see later under Robins Gletscher Member). Where the boundary is a sediment-sediment contact, as at Goding Bay, it is conformable and well defined.

Subdivision. A regional tripartite subdivision is mentioned under *Lithology*. The similarity of sections at Cape Combermere, Gale Point and main exposures in Greenland is striking, and direct correlation is suggested between upper and lower basalt units and the middle sedimentary unit (Figs 57, 59, 61, 71). At Gale Point and Northumberland Ø, the middle unit is characterised by tuffaceous rocks. With stratigraphic logging, aided by unit by unit geochemistry, detailed regional correlation of flows may well be achieved. Pending such investigations the tripartite subdivision is not formalised. Only a peculiar concretionary shale unit, forming the uppermost strata, is separated out and described here as a formal member.

Sparks Glacier Member

new member

Composition. This member corresponds to the uppermost subunit of unit II of Frisch *et al.* (1978) and Frisch & Christie (1982) and of unit 2 of Jackson (1986), as exposed at Goding Bay, equating with unit 12 in the section measured by Christie (1975).

Fig. 63. Contact of the Cape Combermere Formation (CC) with the Josephine Headland Formation (JH). **A:** Clarence Head, calcite-veined basalt overlain by brown dolomites of the Robins Gletscher Member; **B:** Goding Bay, black shales with concretions and basaltic components of the Sparks Glacier Member (SG) overlying a diabase sill (d) and being overlain by the Robins Gletscher Member (scree covered) and interbedded sandstones and shales of the Cape Dunsterville Member. Photos: T. Frisch.

Name. After Sparks Glacier, a broad glacier reaching the sea at the head of Goding Bay (Figs 1, 2, 80).

Distribution. In all sections at Goding Bay exposing the uppermost part of the Cape Combermere Formation.

Geomorphic expression and colour. Dark weathering, generally recessive, with more resistant ribs of basaltic material (Fig. 63).

Type section. The type section is that measured by Jackson (1986) at the head of Goding Bay, close to the sections studied by Christie (1975) and Frisch & Christie (1982) (section 28, Figs 58, 80).

Thickness. Complete stratal thickness varies from 12 to 23 m. Where encroached by effusive basalt, the thickness is reduced to 9 m.

Lithology. A complex unit of sedimentary and igneous rocks dominated by dark shale. The sediments are laminated to very thin bedded, mostly black to dark green-grey to olivine green shale, slate and fine-grained siltstone. Minor, reddish quartz arenite and tuffaceous rocks are cross-bedded. Shales in the upper part of the member have a reddish hue. Rare siliceous stromatolitic dolomites are recorded by Jackson (1986).

Numerous thin basalt layers, both sills and flows, between 10 and 30 cm thick but occasionally thicker, occur parallel with bedding; Jackson (1986) also notes small dykelets. The igneous bodies often show altered margins.

Peculiar to the member are abundant iron-rich siliceous concretions, 25–30 cm in diameter, that occur mainly in the shales but also in the tuffs. These vary from spheroidal and ellipsoidal to nodular in form, are coarser grained and greener in colour than their host, and are composed of siliceous material with siderite, chlorite and hematite.

Fossils. Rare stromatolites.

Depositional environment. The presence of hematite and siderite in siliceous concretions in the black shale indicates oxidizing conditions during shallow water sedimentation. Jackson (1986), noting rare turbidite-like quartz arenite beds, suggests an origin as prodelta or offshore muds, with the associated tuffs and basaltic elements as the effects of landward volcanism in the west.

Boundaries. The lower boundary of the Sparks Glacier Member is generally planar and abrupt defined by the intrusive contact of the 130–140 m thick basic sill (Fig. 63B). This body has caused conspicuous baking of the basal strata. At one section seen by Jackson (1986), the member has a transgressive contact to a basaltic flow and only the upper part of the member is present. The upper boundary of the member is everywhere that of the formation, viz. a conformable contact with the Josephine Headland Formation (Robins Gletscher Member, Fig. 63A).

The Sparks Glacier Member, with shales and rare stromatolitic dolomites, shows a link to the overlying Josephine Headland Formation and its positioning within that formation is arguable. However, the member is placed in the Cape Combermere Formation on account of its intimate association with basalt flows, a practise also followed by Frisch & Christie (1982) and Jackson (1986).

Josephine Headland Formation

new formation

Composition. The formation equates with the uppermost part of the lower member of the Wolstenholme Formation as described by Dawes (1975) and on Northumberland Ø subsequently defined as unit 3 (Dawes, 1976b). It corresponds to unit III of the Wolstenholme Formation as defined on Ellesmere Island by Frisch *et al.* (1978) and Frisch & Christie (1982), but with the exception of Gale Point where the greater part of that unit is referred to the Northumberland Formation. In the 6-unit division pertaining to both sides of Nares Strait, the formation corresponds to the 'Dolomite–Shale unit' (Dawes *et al.*, 1982a) with the exception of the therein described strata from Gale Point.

Name. After Josephine Headland, a prominent coastal mountain in north-western Northumberland Ø (Figs 2, 48, 77).

Distribution. In Greenland, Prudhoe Land between Sonntag Bugt and Morris Jesup Gletscher, and Northumberland Ø; in Canada, in the main outcrop areas between Cadogan Inlet and Clarence Head (Fig. 12). The formation is deemed present north of Cadogan Inlet in a down-faulted block (Fig. 54) but it not represented in the sections measured farther east by Christie (1975) and Frisch & Christie (1982).

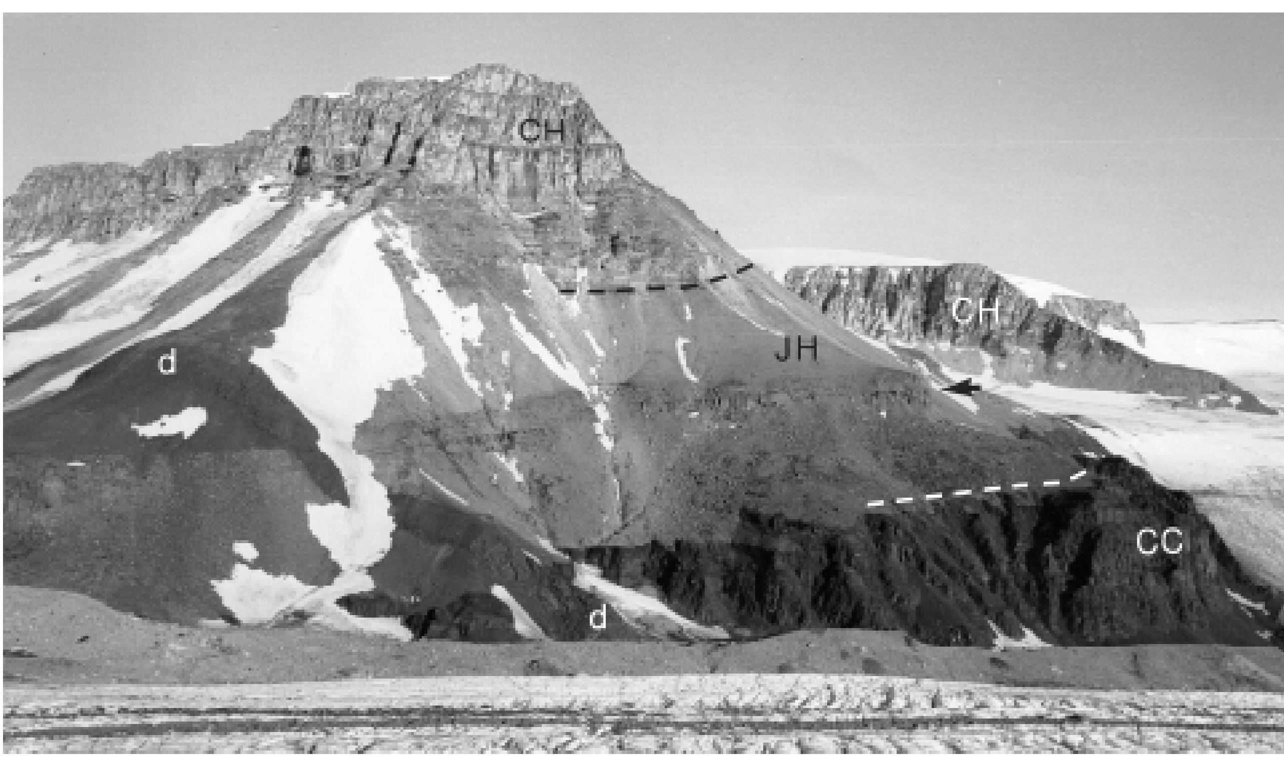


Fig. 64. Nunatak on the south side of Bamse Gletscher, northern Prudhoe Land showing the recessive Josephine Headland Formation (JH) with the intertonguing, cliff-forming unit (arrowed) as the Bamse Gletscher Member of the Barden Bugt Formation. Subdivision of Clarence Head Formation (CH) into lower thinner bedded and upper cliff-forming units is apparent. The sedimentary section, about 450 m thick, is cut by a late Hadrynian basic dyke (d). CC = Cape Combermere Formation. For regional view, see Fig. 1; for map location, see Fig. 27.

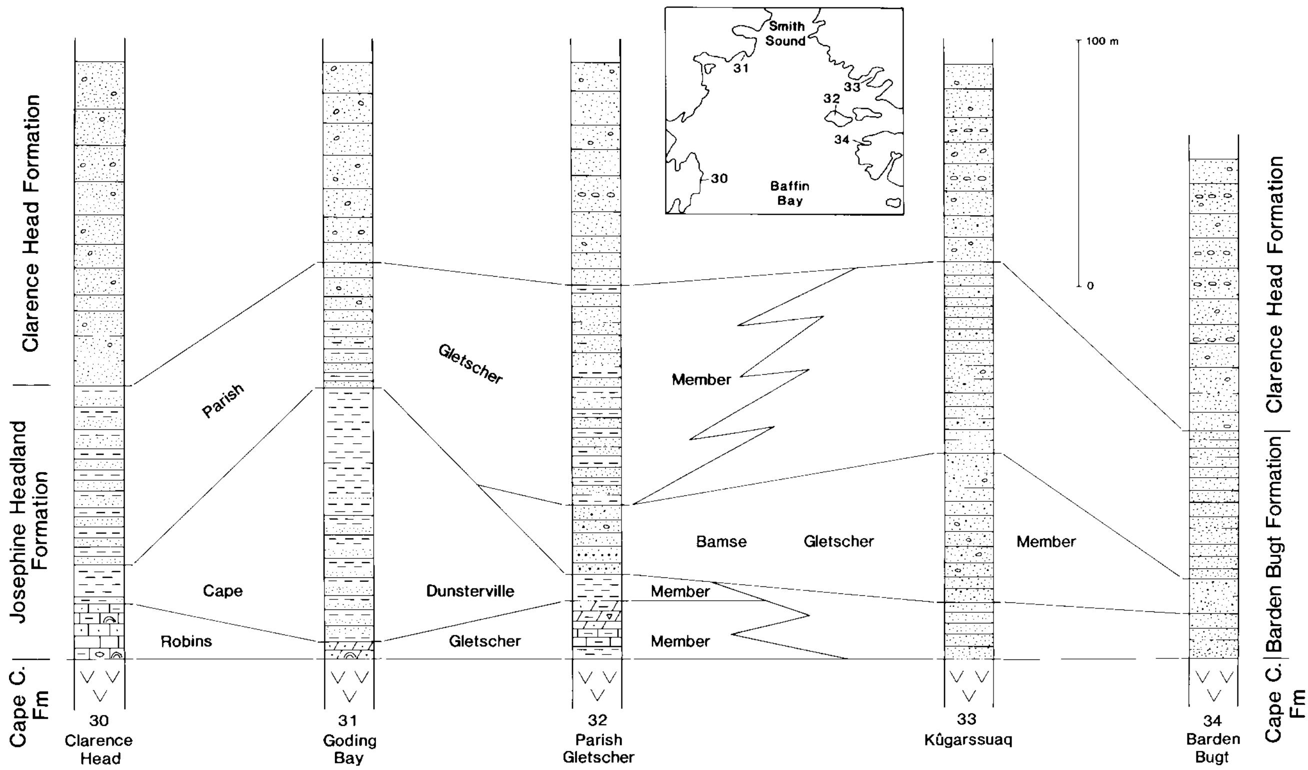


Fig. 65. Generalised sections of the Josephine Headland, Barden Bugt and Clarence Head Formations. Sections 30 and 31 are compiled from Jackson (1986); sections 33 and 34 partly based on data in O'Connor (1980). A stratigraphic log of section 32, the type section of the Josephine Headland Formation, is given in Fig. 66. Section locations: 30, Fig. 75; 31, Fig. 80; 32, Fig. 48; 33, Fig. 83; 34, Fig. 70.

Geomorphic expression and colour. A pale reddish weathering, generally recessive unit, often poorly exposed, with some prominent resistant benches (Figs 49, 64).

Type and reference sections. The type section is on the west side of Parish Gletscher, Northumberland Ø (section 32, Figs 65, 66); reference sections are at Clarence Head and Goding Bay (sections 30, 31, Fig. 65), cliffs on both sides of Kissel Gletscher (Figs 48, 49A) and at Bamse Gletscher (Fig. 64).

Thickness. Ranges from about 107 m at Clarence Head to 160 m at Goding Bay, possibly a little more in northern Prudhoe Land (Fig. 12).

Dominant lithology. Wide lithological variation exemplified by three members (Fig. 65). From base upwards main rock types are: limestone, dolomite and shale with a minor volcaniclastic bed, interbedded sandstone and shale with prominent red shale units and alternating sandstone-shale sequence with possible volcaniclastic elements.

Depositional environment. The Josephine Headland Formation marks a marine transgression across the volcanic landscape of the Cape Combermere Formation. A shallow shelf is seen as the overall depositional environment, basal carbonates being deposited initially when the input of detrital clastics was at a minimum, followed by clastic-dominated intertidal to fluvially influenced supratidal deposits (Jackson, 1986). Nearby volcanic activity prevailed for at least part of the time interval recorded by the formation.

Fossils. Stromatolites and algal laminites in basal beds.

Boundaries and correlation. The Josephine Headland Formation overlies, apparently conformably, strata of the Cape Combermere Formation; in places the contact is with a basic sill referred to that formation (Fig. 58). It is overlain conformably by the Clarence Head Formation and in Greenland the formation interdigitates with the Barden Bugt Formation (Figs 64, 65).

The relationship to strata of the Smith Sound Group is not exposed but the Pandora Havn Formation of that group is a possible correlative to the Josephine Headland Formation over the basin margin (Fig. 120).

Subdivisions. The Josephine Headland Formation is subdivided into three formal units: from below, the Robins Gletscher, Cape Dunsterville and Parish Gletscher Members.

Robins Gletscher Member

new member

Composition. The member equates with the lower subunit of the Dolomite-Shale unit of the Wolstenholme Formation as described from Clarence Head, Goding Bay and Northumberland Ø by Dawes *et al.* (1982a), and with sub-unit 3A of Jackson (1986).

Name. After Robins Gletscher, northern Northumberland Ø (Figs 2, 48).

Distribution. Same as the formation although its presence in northern Prudhoe Land, south-east of Bamse Gletscher, has not been ascertained.

Geomorphic expression and overall colour. Rather dark, brownish-weathering, resistant unit often forming a small bench (Fig. 49).

Type and reference sections. The type section of the Robins Gletscher Member is the same as for the formation at Parish Gletscher (section 32, Figs. 65, 66); reference sections are on both sides of Kissel Gletscher (Figs 48, 49A) and at Clarence Head and Goding Bay (sections 30, 31, Fig. 65).

Thickness. Variable in both Greenland and Canada: 5–6 m at Goding Bay, 9–22 m at Clarence Head and 20–35 m on Northumberland Ø. Thickness at Bamse Gletscher is obscured by scree.

Lithology. Thin- to medium-bedded, variously laminated, cryptocrystalline dolomite and limestone, with red and green shale with arenaceous carbonates and subordinate fine-grained sandstone. Shale usually forms interbeds with much thicker carbonate beds but in the type section red shale forms a discrete unit up to 5 m thick containing rare 3–6 cm thick limestone beds (Fig. 67). Both at Clarence Head and Northumberland Ø the carbonates in the upper part are variously argillaceous and siliceous with occasional thin sandstone beds.

The carbonates are typically brown to reddish brown weathering; some limestones weather light grey to

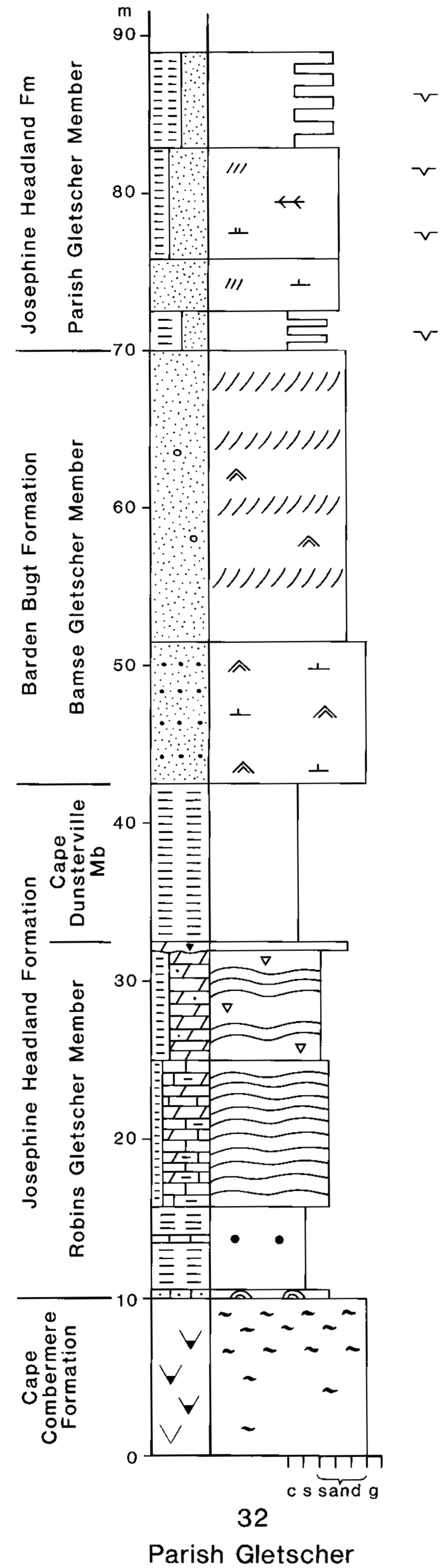


Fig. 66. Stratigraphic log of lower part of Josephine Headland Formation at Parish Gletscher, Northumberland Ø. For location, see Fig. 48.

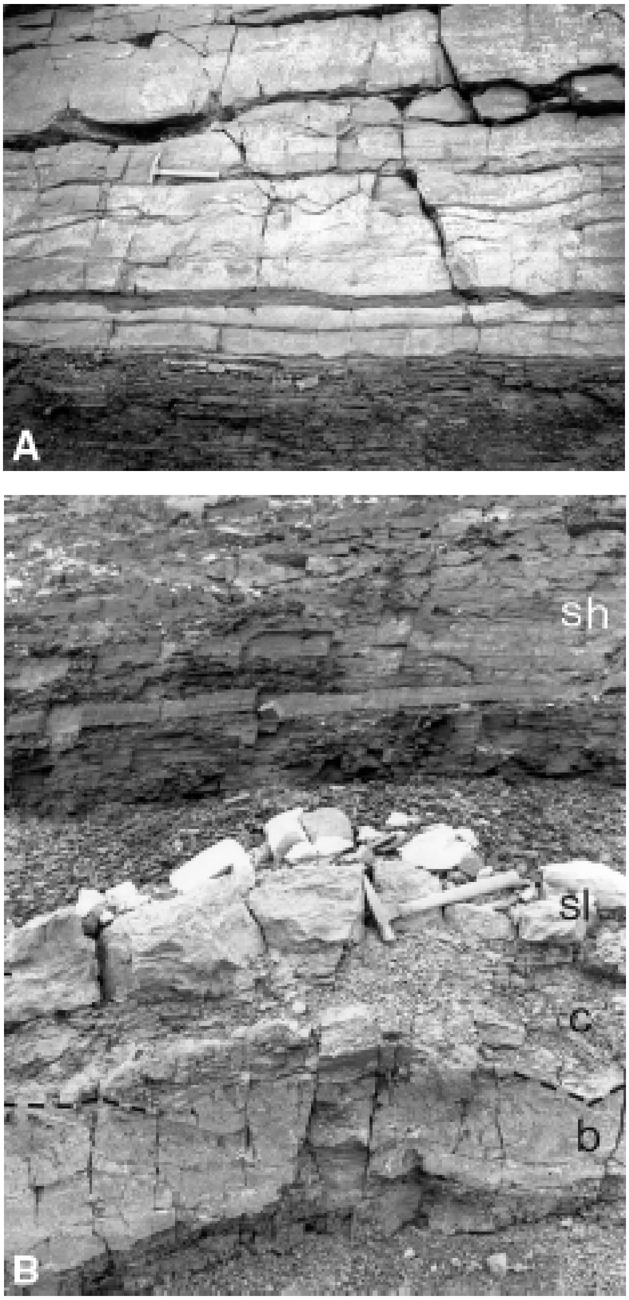


Fig. 67. Robins Gletscher Member of the Josephine Headland Formation, west side of Parish Gletscher, Northumberland Ø. **A:** brown dolomite with thin interbeds of red shale, some of which are preserved as wavy laminations; **B:** carbonate-rich rubbly material (c), stromatolitic limestone (sl) and maroon shales (sh) overlying basalt (b) of the Cape Combermere Formation.

green grey. Red to brown shaly partings show mudcracks and Jackson (1986) mentions tepee structures 15 cm high. Wavy bedding and thin lamination are common and, in the lower part particularly, algal laminites occur together with low-relief, laterally linked stromatolite columns. Some carbonates are oolitic and pisolitic. Some thin carbonate breccia and conglomerate beds contain siltstone and shale clasts with occasional volcanic pebbles.

The basal bed is commonly a stromatolitic carbonate; red to maroon shales locally underlie it, and in some localities a thin carbonate-rich breccia or conglomerate occurs at the contact. At Robins Gletscher such carbonate breccia rock contains subangular to angular, commonly irregular inclusions of basalt and cryptocrystalline quartz up to 2 cm long; at Clarence Head the carbonate granule conglomerate is only some 10 cm thick. In the type section basal red shales are very arenaceous, at intervals containing rounded quartz with some feldspar grains. Some show tuffaceous components: rounded to elongated granules to irregular fragments of cryptocrystalline quartz and glass up to 2 mm long set in a brown streaky matrix.

A breccia bed about 40 cm thick caps the Robins Gletscher Member at the type section (Fig. 66). In addition to angular sedimentary clasts the breccia contains what appears to be volcanic debris. The bed has a very irregular, scoured contact to the underlying dolomite and is taken to represent a flow breccia.

Depositional environment. The banks of low amplitude stromatolitic carbonates characterising the Robins Gletscher Member are taken to record the initial deposition of a marine transgression when the supply of terrigenous clastic material was at a minimum. Noting the presence of overlying beach deposits, Jackson (1986) interpreted the carbonates to represent intertidal to supratidal environments. Pyroclastic elements indicate contemporaneous volcanism nearby.

Fossils. Stromatolites, algal laminites.

Boundaries. The lower boundary of the Robins Gletscher Member is that of the formation. Where the member is in contact with sediments of the Cape Combermere Formation, as for example at Goding Bay, the boundary is conformable, planar and sharp; in contact with effusive rocks the contact may be sinuous to very irregular with the lower surface of the basal carbonate mirroring the top of the underlying flow (Figs 67, 68). In places in contact with intrusive rock there has been mixing of carbonate and basalt due to carbonate remobilisation. The upper boundary is conformable and drawn above the last carbonate or argillaceous dolomite bed, or, as at the type section at Parish Gletscher, above a volcanic breccia bed.

Fig. 68. Detail of stromatolitic dolomite of the Robins Gletscher Member of the Josephine Headland Formation in contact with vesicular basalt (b) of the underlying Cape Combermere Formation. Irregular cuspate contact has dark inclusions within the carbonate. West side of Robins Gletscher, Northumberland Ø. Hand-lens as scale.

Cape Dunsterville Member

new member

Composition. This member corresponds to beds in the lower to middle part of the Dolomite–Shale unit of the Wolstenholme Formation as defined by Dawes *et al.* (1982a) from Clarence Head, Goding Bay and Northumberland Ø; in Ellesmere Island it equates with subunit 3B of Jackson (1986).

Name. After Cape Dunsterville, the southern part of the peninsula limiting Goding Bay eastwards (Figs 1, 2, 80).

Distribution. On Northumberland Ø and at Bamse Gletscher in Greenland; at Clarence Head and Goding Bay in Canada. Its presence in Prudhoe Land, south-east of Bamse Gletscher, is not ascertained.

Geomorphic expression and colour. A pale red weathering, rather recessive unit, with main shale units commonly scree covered.

Type and reference sections. The type section is at Goding Bay (section 31, Figs 65, 80); thinner reference sections are at Clarence Head and Parish Gletscher (sections 30, 32, Fig. 65).

Thickness. Thinner in Greenland, varying from 5–10 m on Northumberland Ø to 15 m at Clarence Head and 102 m at Goding Bay.

Lithology. Thinly bedded, multicoloured sandstones and shales with units of reddish coloured shale (Fig. 63B). In Canada at Goding Bay, brownish red shale forms the upper half of the member while at Clarence Head and on Northumberland Ø shales predominate. Thus at Clarence Head a red shale unit 12 m thick dominates the 15 m section while on Northumberland Ø the member is mainly in shale (Fig. 65).

At the thickest development of the Cape Dunsterville Member at Goding Bay, Jackson (1986) describes a 7 m thick basal coarsening-upwards cycle involving green shale beds that decrease in thickness upwards from 80 cm to 2 cm, interbedded with thin to medium size beds of grey green, planar to wavy-bedded, in places cross-bedded subarkose. The middle 44 m of the member are dominated by fining-upward cycles of red-green sandstone (in beds 1 m to 60 cm thick) and red shale (7 m to less than 1 m thick). Basal sandstones have sharp contacts and display shallow channels; mudcracks occur on top surfaces of sandstone and shale beds. Cross-bedding and symmetrical ripple marks are common. Some sandstones contain carbonate-rich lamellae and shale fragments. Shale beds contain sandstone clasts, and Frisch & Christie (1982) mention hematitic mud or sand balls up to 3 cm in diameter.

Possible ball and pillow structures occur in the interbedded sandstone-shale section at Bamse Gletscher where certain shales of deep brownish-red colour contain rounded to disc-shaped sandstone concretions, the largest of which reach 10 cm in diameter. These balls and discs are fine to very fine grained and where sectioned are of siliceous dolomite. Some of the purplish-green sandstones at Bamse Gletscher are glauconite-bearing and carbonate-cemented, typically with subangular quartz grains.

Depositional environment. The Cape Dunsterville Member is taken to represent deposition in an overall shore zone environment with encroaching fluvial deposition. Basal coarsening-upwards strata overlain by fining-upwards cycles, fully developed at Goding Bay, are interpreted by Jackson (1986) as regressive beach deposits and meandering stream and overbank deposits, respectively, with the upper red argillites as vertical accretion muds.

Fossils. None known.

Boundaries. The conformable lower and upper boundaries are well demarcated. The lower contact is with the Robins Gletscher Member; the upper contact in Canada is with the Parish Gletscher Member. As a function of the interdigitation between the Josephine Headland and Barden Bugt Formations, in Greenland the Cape Dunsterville Member is overlain by the Bamse Gletscher Member (Fig. 65). The contact is drawn where red shales are abruptly overlain by the resistant sandstones of the Bamse Gletscher Member.

Parish Gletscher Member

new member

Composition. This member corresponds to the uppermost part of the Dolomite–Shale unit of the Wolstenholme Formation of Dawes *et al.* (1982a) from Northumberland Ø and Ellesmere Island (except Gale Point). At Clarence Head and Goding Bay it equates with subunit 3C of Jackson (1986); at Cape Dunsterville with unit 1 of Christie (1975).

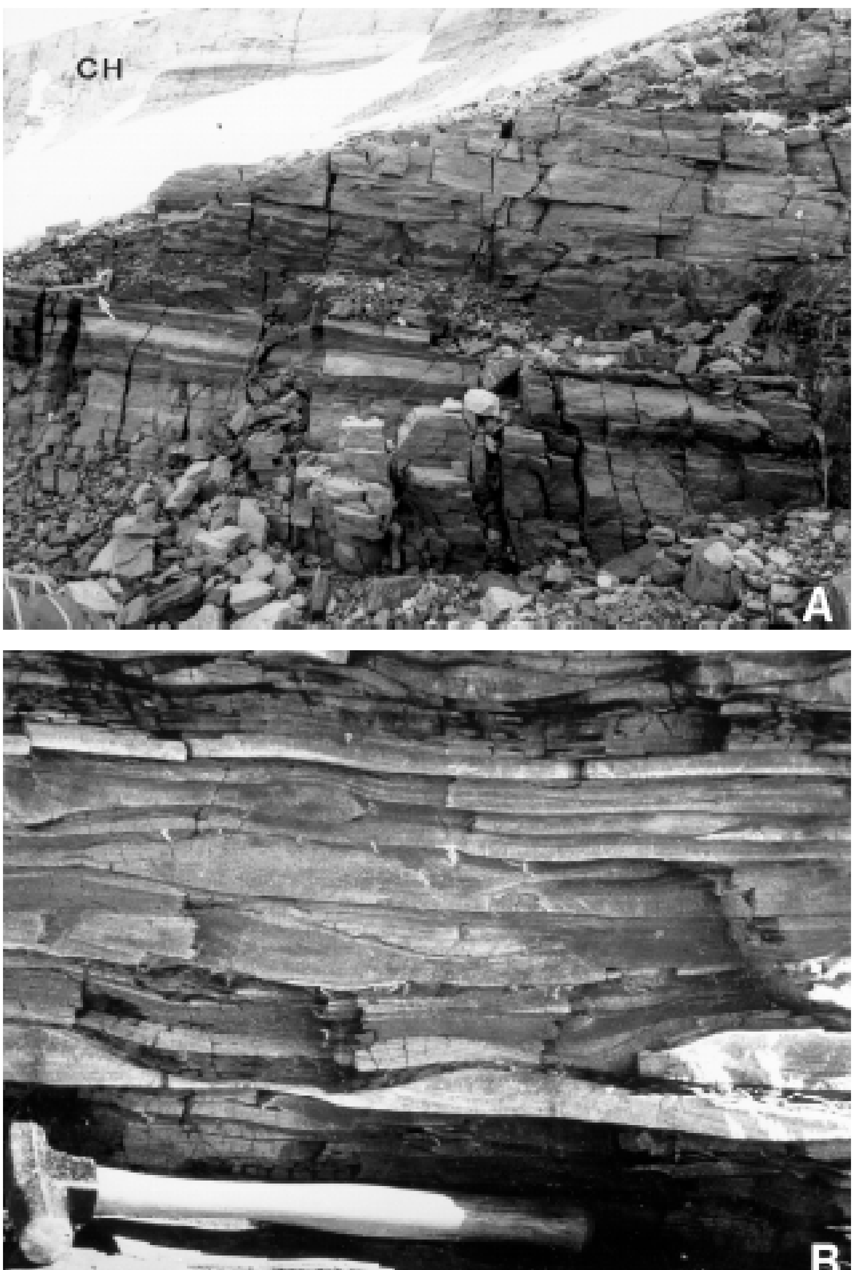


Fig. 69. Bedding characteristics of the Parish Gletscher Member of the Josephine Headland Formation.
A: variously mottled and laminated sandstone interbedded with shales on the western side of Parish Gletscher, Northumberland Ø; hammer (arrowed) as scale. Clarence Head Formation (CH) in background;
B: lenticular bedded, variously laminated sandstones with thin shale intercalations. The lenticular bedding is of probable wave ripple origin. Clarence Head. Photo: T. Frisch.

Name. After Parish Gletscher, northern Northumberland Ø (Figs 2, 48).

Distribution. Northumberland Ø and northern Prudhoe Land, and in all sections of the Josephine Headland Formation in Ellesmere Island.

Geomorphic expression and colour. A pale reddish-weathering, generally recessive unit with moderate scree cover.

Type and reference sections. The type section is that of the formation at Parish Gletscher (section 32, Figs 65, 66); reference sections are on both sides of Kissel Gletscher (Figs 48, 49A) and at Clarence Head and Goding Bay (sections 30, 31, Fig. 65).

Thickness. From 50–75 m in Canada to 90 m, possibly more, in Greenland.

Lithology. The main lithology is multicoloured, thin- to medium-bedded, alternating sandstones and shales; at one section in Parish Gletscher possible volcaniclastic strata occur in the middle part.

The sandstones, mostly medium grained, show colour variation along strike. Thus at Northumberland Ø and Goding Bay they have predominantly red, pink, purple and lilac hues with some pale green, white to buff beds; at Clarence Head, according to Jackson (1986), the sandstones are mainly grey and white with local red beds. At Robins Gletscher the sandstones show a colour mottling of reduction spots and irregular patterns with purple to brownish red sandstone reduced to buff colour. The shales are mostly green and red-maroon.

Sandstone and shale are thin to medium bedded (Fig. 69). Certain buff to yellow beds in the upper part are up to 1 m thick and on Northumberland Ø the section is topped by a 2–5 m thick red shale bed. Generally sandstone increases upwards relative to shale, and Jackson (1986) notes an upward change in composition at Goding Bay from subarkose to quartz arenite with red granular to pebbly sandstone in the uppermost part. Locally, both in Greenland and Canada, carbonate-cemented sandstones occur. The sandstones range from massive to laminated with common shale partings and laminae. Wavy to lenticular-bedded sandstones are common (Fig. 69). Cross-bedding, in places of herringbone type, and mudcracks are common throughout; asymmetrical ripples, minor channels and shale-flake conglomerate are seen locally.

At one section on the west side of Parish Gletscher a sequence of sandstones and shales at least 20 m thick are darker hued than normal: shales are deep purple to black, sandstones are dark grey, brown or deep purple. The rocks are variously laminated and many are characterised by disrupted laminae and bedding. Mudcracks are common. The rocks show wide textural variation from quartz arenites to varieties in which quartz grains are scattered throughout a brown, tuffaceous? cryptocrystalline matrix of clay minerals. Clasts up to 1 mm may represent volcanic rock. This analogous section is adjacent to a basic dyke that may have baked the strata to some extent and the effect is accentuated by basalt injection parallel to bedding. The section was only cursorily examined but the impression remains that certain darker strata represent volcaniclastic rocks.

Depositional environment. Wave ripples, bidirectional cross-bedding and lenticular bedding suggest that tide-dominated deposition in the intertidal to supratidal environment existed for at least the main part of the member (Frisch & Christie, 1982). Jackson (1986) suggests alternating tidal flat shale and intertidal sandstone deposition or a general estuarine environment. The appearance of granule and pebble beds in the uppermost part at Goding Bay may suggest tidal channel or fluvial influence. In Greenland the member records waning volcanism.

Fossils. None known.

Boundaries. The lower boundary of the Parish Gletscher Member is conformable, well demarcated and drawn at the top of red shales of the Cape Dunsterville Member and, in Greenland, above the massive quartz arenites of the Bamse Gletscher Member of the Barden Bugt Formation (Fig. 65). The upper contact is the formational boundary marked by the incoming of quartz arenites of the Clarence Head Formation (Fig. 49).

Barden Bugt Formation

new formation

Composition. Strata of this formation are part of the lower red sandstone of Koch (1929a) and the lower beds of the Wolstenholme Formation of Dawes (1976a).

Name. After Barden Bugt, a prominent bay in western Steensby Land (Figs 2, 70).

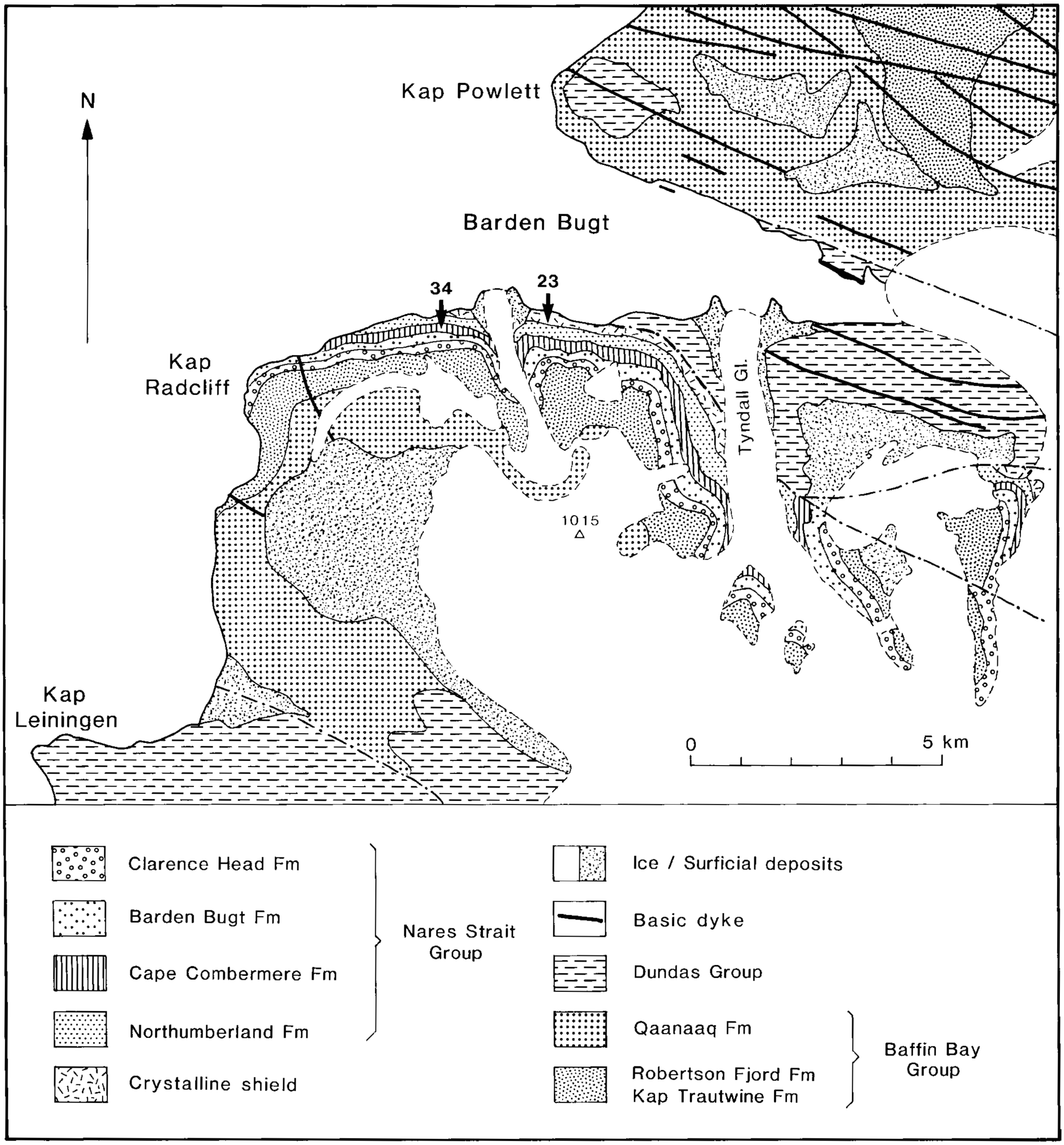


Fig. 70. Geological map of the Barden Bugt area, Steensby Land, Greenland, showing locations of sections 23 and 34. The area exposes a continuous succession from the Nares Strait Group into the Baffin Bay Group with, to the north of the bay, the passage into the more argillaceous strata marking the transition to the Dundas Group. The bay itself is etched from a down-faulted block that juxtaposes on the south the Dundas Group and the Precambrian shield, preserving the less-resistant Dundas lithologies as a WNW-trending belt across Steensby Land (Fig. 2). This faulted belt, that also forms the head of Granville Fjord (Fig. 87), is parallel to other regional faults (e.g. Fig. 109) and to a major swarm of Hadrynian basic dykes. Height of 1015 is in metres. For location, see Fig. 2.

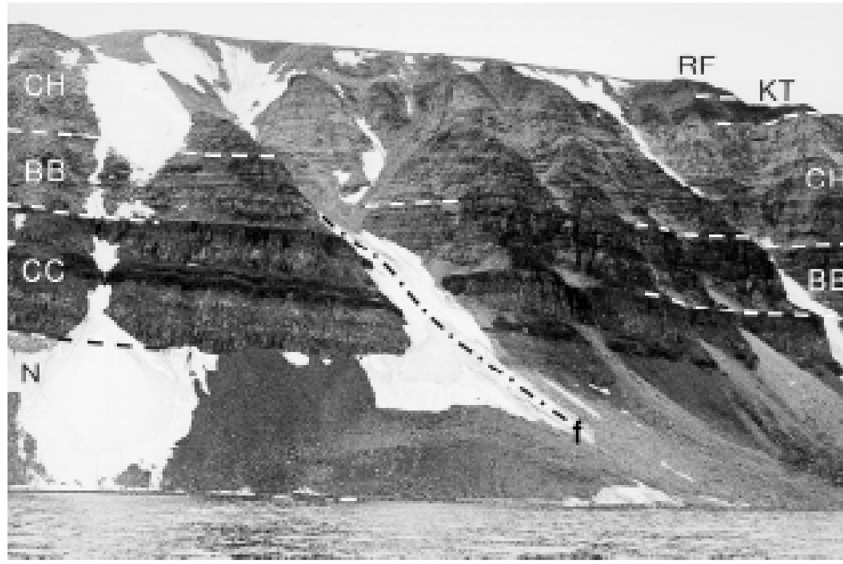


Fig. 71. Southern cliffs of Barden Bugt about 600 m high showing the Barden Bugt Formation (BB) divisible into a pale lower unit and a darker striped upper unit, flanked by the Clarence Head (CH) and Cape Combermere (CC) Formations. The tripartite division of the latter formation, viz. upper and lower basalt units separated by a bedded sedimentary unit, is well seen, as is the subdivision of the Clarence Head Formation into a lower dark, and upper, more massive, pale unit.
N = Northumberland Formation,
KT = Kap Trautwine Formation,
RF = Robertson Fjord Formation.
Sections 23 and 34 are of these cliffs but located farther east (see Fig. 70).

Distribution. Prudhoe Land between Robertson Fjord and Bowdoin Fjord, and western Steensby Land (Fig. 12).

Geomorphic expression and colour. A generally cliff-forming purple to pale red weathering unit. In western Steensby Land the lower part is pink to orange-buff weathering and moderately recessive; the upper part has a characteristic striped or banded appearance (Fig. 71).

Type and reference sections. The type section is on the south side of Barden Bugt to the west of an unnamed glacier (section 34, Figs 65, 72); a measured reference section is on the south-eastern side of Robertson Fjord at Kûgarssuaq (section 33, Figs 65, 72).

Thickness. Ranges from a maximum of about 160 m in Robertson Fjord to at least 90 m at Barden Bugt to less than 60 m in Granville Fjord (Fig. 12).

Lithology. Pink, pale purple to reddish brown quartz arenites ranging from fine to very coarse grained and from thin to thick bedded (Fig. 73). Cross-bedding and ripples are generally common but they may be locally absent. Quartz grains are generally well rounded but some rocks have subangular grains, others show secondary silica growth on rounded grains. Occasional feldspar and rounded quartzose rock fragments occur.

At Barden Bugt, basal beds are an upward coarsening and thickening sequence of pink to brown sandstone with cross-bedding prominent in thicker beds up to 1.5 m thick and absent in thinner beds down to 15 cm. At higher levels pale sandstones are interbedded with thinner red beds that show prominent ripples; this lithology produces the striped to banded appearance of the upper part of the formation in western Steensby Land (Fig. 71). The upper part is typically thin, often lenticularly bedded; sandstones show low-angle cross-bedding and mudcracks. Near the top are several deep purple, laminated beds. In addition to well-rounded quartz grains these contain an abundance of cryptocrystalline silica grains and fragments up to 2 mm long characterised by serrated borders and set in a brown matrix. These are possible volcaniclastic deposits.

A resistant unit in the middle part of the formation is composed of pale, planar cross-bedded quartz arenite (see Bamse Gletscher Member below). Pale purple sandstones, some planar bedded with small-scale channels, others with large-scale channelled cross-beds in a variety of directions, form the upper part of the formation.

Depositional environment. The Barden Bugt Formation is thought to have been deposited in an intertidal to dominantly supratidal environment. Lower coarsening-upwards beds with wave ripples may represent a regressive littoral deposit; the strata characterised by prominent cross-bedding, channelling and current ripples could be fluvial, possibly braided sandy stream deposits. Nearby volcanism is suggested.

Fossils. None known.

Boundaries and correlation. The formation overlies,

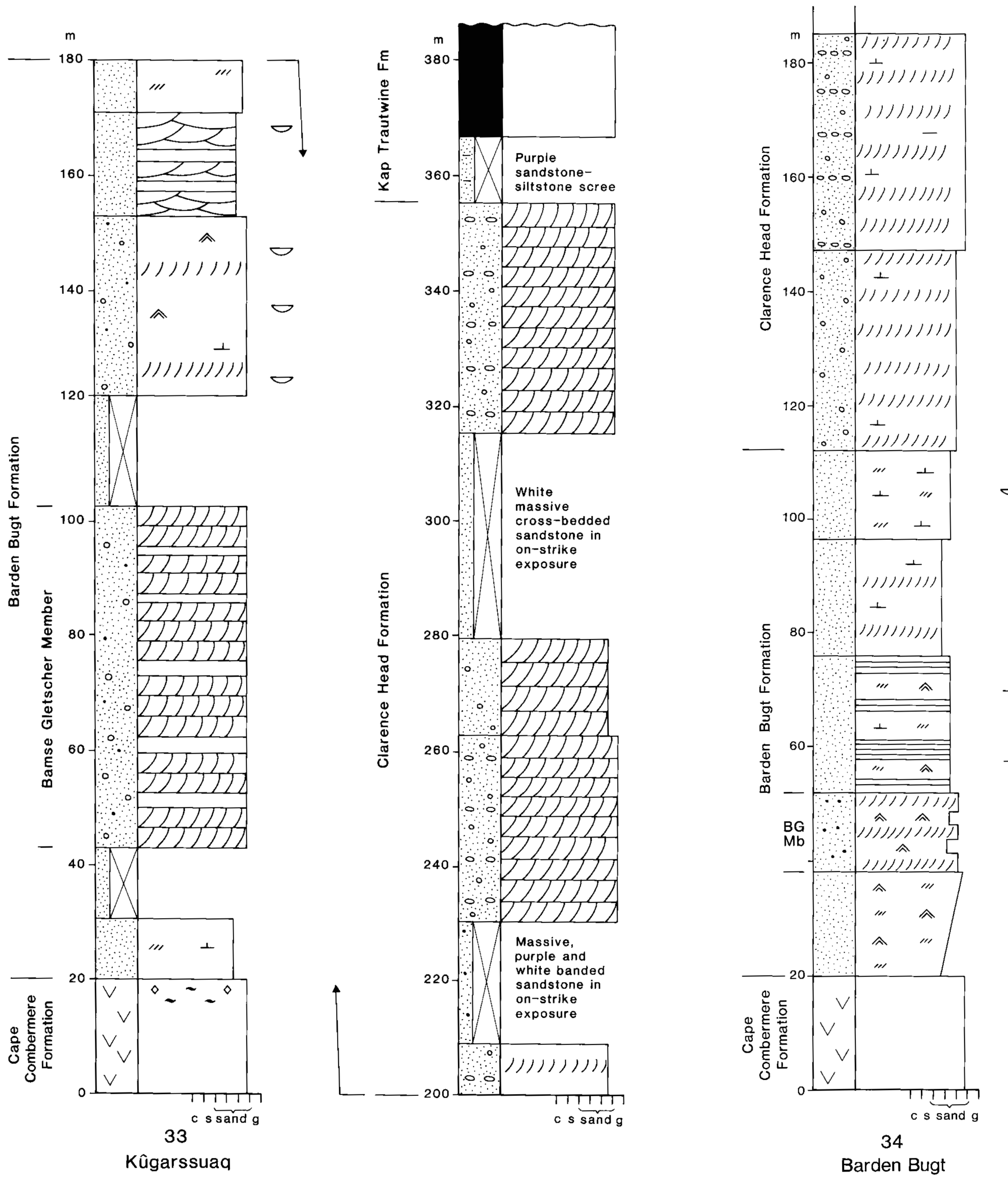


Fig. 72. Stratigraphic logs of the Barden Bugt and Clarence Head Formations from Kûgarssuaq, Robertson Fjord, and Barden Bugt, Steensby Land; the latter compiled from data in O'Connor (1980). These are the type sections of the Barden Bugt Formation (section 34) and the Bamse Gletscher Member (section 33). Map locations are given in Figs 70 and 83; the Kûgarssuaq section is shown in Fig. 74.

apparently conformably, the effusive strata of the Cape Combermere Formation; at Bowdoin Fjord its lower contact is with a basaltic (?)sill. The upper boundary is conformable to the Clarence Head Formation being drawn at the first appearance of clean quartz arenites.

The Barden Bugt Formation is a lateral equivalent of the Josephine Headland Formation with which it interfingers.

Subdivisions. The conspicuous cliff-forming, pale unit in the middle part of the formation in Prudhoe Land is defined as the Bamse Gletscher Member.

Bamse Gletscher Member

new member

Composition. This member is part of the Dolomite–Shale unit of the Wolstenholme Formation in Greenland as defined by Dawes *et al.* (1982a).

Name. After Bamse Gletscher, northern Prudhoe Land (Figs 1, 2, 27).

Distribution. Prudhoe Land between Sonntag Bugt and MacCormick Fjord, Steensby Land and Northumberland Ø.

Geomorphic expression and colour. Pale weathering, cliff-forming unit forming a prominent bench (Fig. 64).

Type and reference sections. The type section is at Kûgarssuaq on the south-eastern coast of Robertson Fjord (section 33, Figs 65, 74); reference sections are at Parish Gletscher, Northumberland Ø (section 32, Figs 65, 66) and at Bamse Gletscher (Fig. 64).

Thickness. About 20–30 m on Northumberland Ø and up to 60 m in Prudhoe Land.

Lithology. Pink, lilac and purple, medium- to thick-bedded quartz arenites that are medium to very coarse grained. Pebbly sandstone is common and granule beds up to 15 cm thick have sharp bases and display small-scale channelling. Planar cross-bedding in sets from 40 cm to 1 m is common; symmetrical ripple marks occur. Thinner bedded basal strata have purple shale partings and exhibit mudcracks.

The sandstones vary from massive and homogeneous type with sugary texture to weakly laminated finer grained varieties. Quartz is rounded to subangular; pebbles and granules are extremely well rounded and often with well-developed dusty borders. Occasional rounded rock fragments; some rocks have a sparse yellow-brown glauconitic matrix.

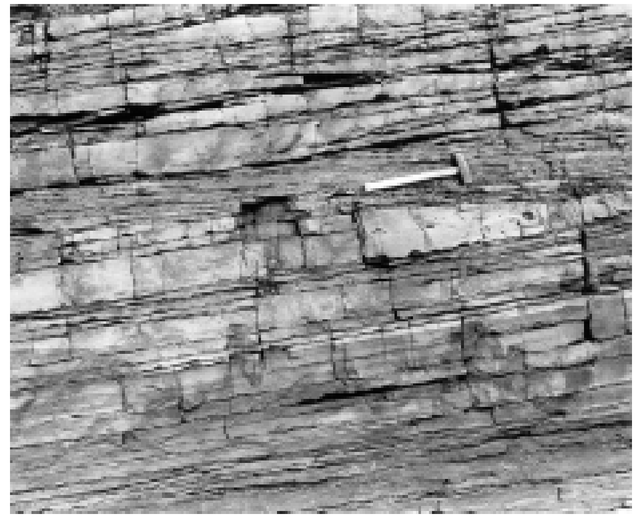


Fig. 73. Bedding characteristics of the Barden Bugt Formation: thin- to medium-bedded sandstones showing lenticularity, low-angle cross-bedding and ripple marks. West side of Bowdoin Fjord (Fig. 98).

Depositional environment. Sedimentary features provide no specific evidence on depositional environment within the intertidal to supratidal regime of the Barden Bugt Formation. One possibility is that the cross-bedded, wave-rippled sands represent an offshore bar.

Fossils. None known.

Boundaries. The Bamse Gletscher Member has conformable and well-demarcated upper and lower boundaries to unnamed strata of the Barden Bugt Formation. Where the member interfingers with strata of the Josephine Headland Formation, it has sharp contacts to both the shales of the Cape Dunsterville Member and the interbedded sandstones and shales of the Parish Gletscher Member.

Clarence Head Formation

new formation

Composition. Strata of this formation on Northumberland Ø were called member (b), subsequently unit 4, of the Wolstenholme Formation (Dawes, 1975, 1976b). At Clarence Head and Goding Bay the formation corresponds to unit IV of Frisch *et al.* (1978) and Frisch &

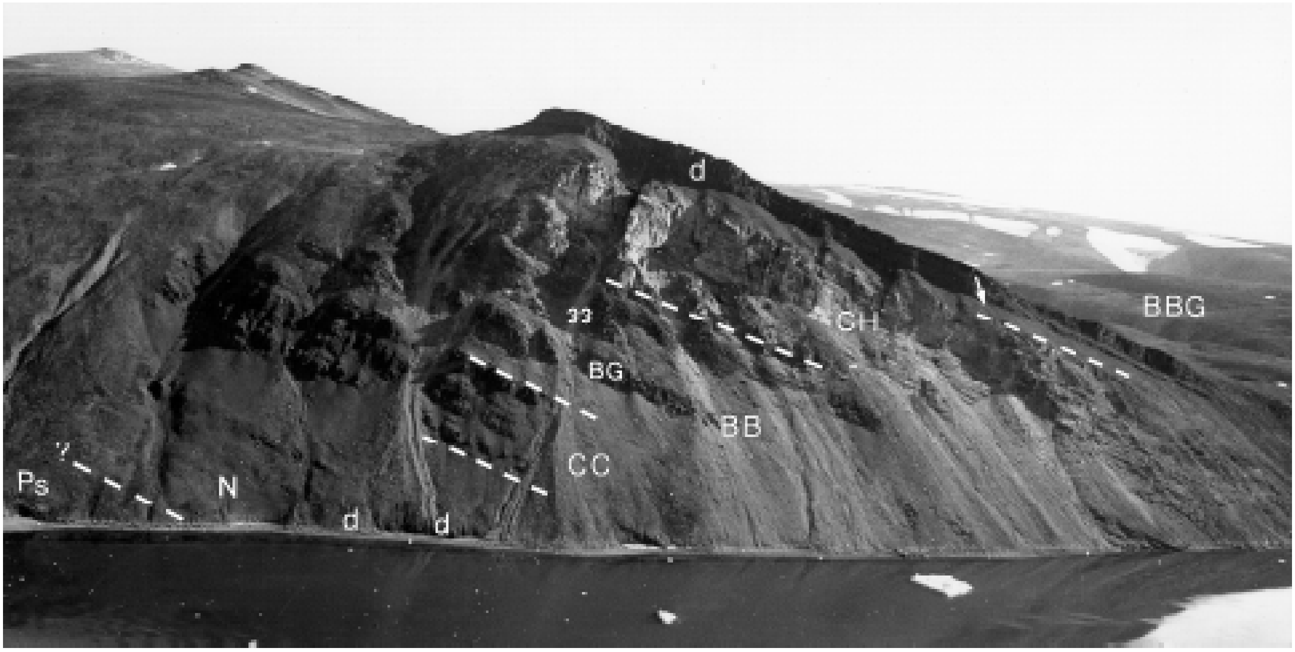


Fig. 74. Sea-cliff Kûgarssuaq, Robertson Fjord, about 400 m high, showing location of section 33 up central gully. Ps = Precambrian shield, N = Northumberland Formation with basaltic sills or ?flows (d), CC = Cape Combermere Formation, BB = Barden Bugt Formation with resistant Bamse Gletscher Member (BG), CH = Clarence Head Formation. Bipartite division of CH into lower more recessive and upper cliff-forming units is apparent. The dark recessive, unexposed strata (arrowed) under the capping basic sill (d) are the basal beds (Kap Trautwine Formation) of the Baffin Bay Group (BBG). This basic sill occurs throughout Prudhoe Land near the contact between the Nares Strait and Baffin Bay Groups. For map location, see Fig. 83.

Christie (1982) and unit 4 of Jackson, with the exception that at Goding Bay it includes 15 m of strata (units 4 and 5 of Christie, 1975) referred by Frisch & Christie (1982, p. 8) to the overlying unit V. At Cape Dunsterville units 2 and 3 of Christie (1975) are referred to this formation. In the 6-unit scheme of Dawes *et al.* (1982a) for both sides of Nares Strait the formation equates with the 'White Sandstone unit'.

Name. After Clarence Head, a prominent coastal cliff in south-eastern Ellesmere Island (Figs 2, 75).

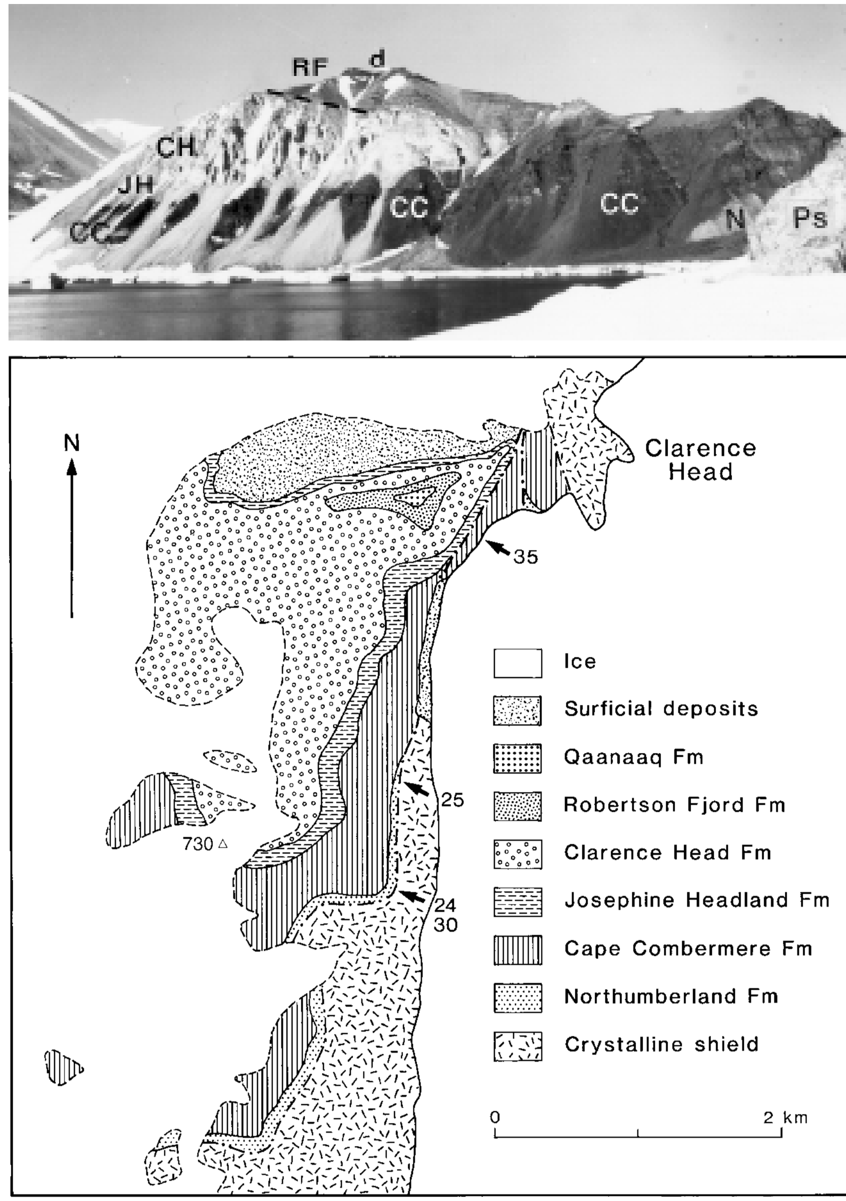
Distribution. In Greenland, Prudhoe Land, western Steensby Land, Northumberland Ø and Hakluyt Ø; in Canada, west of Gale Point, south of Cadogan Inlet, and at Goding Bay and Clarence Head (Fig. 12).

Geomorphic expression and colour. Monotonous in colour and appearance; a light-weathering and very resistant unit forming prominent massive bluffs and towering cliffs. The lower part, that is in many places more recessive, has a white/buff – mauve/purple, striped to banded appearance (Figs. 64, 74, 76).

Type and reference sections. Complete accessible sections are rare because of precipitous outcrops. The type section is at Clarence Head (section 35, Figs 75, 79). Accessible reference sections in Canada are at the head of Goding Bay and at Paine Bluff (sections 39 and 40, Fig. 79), and in Greenland at Kûgarssuaq in Robertson Fjord and at Barden Bugt (sections 33, 34, Figs 72, 79). Other partly accessible sections exposing both lower and upper boundaries occur on Northumberland Ø and in northern Prudhoe Land between Bamse Gletscher and Diebtisch Gletscher.

Thickness. In its maximum development at Paine Bluff in Goding Bay, the formation is at least 280 m thick; on Northumberland Ø and Hakluyt Ø it reaches 250 m, possibly more, varying to less than 100 m in parts of western Steensby Land and south-eastern Prudhoe Land (Fig. 12). At Castle Cliff, Bowdoin Fjord (Fig. 98), a tapering body provisionally referred to the formation is estimated to range in thickness from 75 to 20 m. The wedge-shaped nature of the formation is also seen at Goding Bay where it is from 165 to 280 m thick and at Clarence Head where it ranges from less than 100 to over 200 m (Frisch & Christie, 1982).

Fig. 75. Geology of the Clarence Head area, Canada. The geological map, showing the locations of sections 24, 25, 30 and 35, is compiled from aerial photographs based on interpretation of data in Frisch & Christie (1982) and Frisch (1988) and from T. Frisch (personal communication). View of the coast south of Clarence Head (section 35) shows the prominent white cliffs of the type section of the Clarence Head Formation (CH) above scree-covered Josephine Headland Formation (JH) and Cape Combermere Formation (CC), with red beds of the Robertson Fjord Formation (RF) of the Baffin Bay Group capping the section. The dark craggy summit at about 600 m a.s.l., is a basic sill (d), above which (out of sight) are pale sandstones of the Qaanaaq Formation. The contact with the Precambrian shield (Ps) is tectonised and the Northumberland Formation (N) is in places cut out. Height of *c.* 730 is in metres. Photo: T. Frisch. For location, see Fig. 2.



Dominant lithology. Pale weathering, white, buff, light grey and pink, medium- to coarse-grained, medium- to very thick-bedded sandstones, with quartz-pebble conglomerates, in which cross stratification and symmetrical ripple marks are common. The lower part is often characterised by purple to mauve, pale brown to orange and red interbedded sandstones (Fig. 76) in which colour striping and banding are caused by hematite laminae and partings, reduction, and discoloration layering. Brown to lilac liesegang rings, often developed as pseudo-bedding, occur throughout the formation. Thin, laminated red sandstones occur in the lower strata, as well as minor subarkoses. The main thickness of the formation is particularly uniform and homogeneous, so that very rare, thin red beds in the uppermost strata at Paine Bluff (see Fig. 82) and at Bowdoin Fjord (see Fig. 78) appear conspicuous.

Cross-bedding, abundant throughout the formation, occurs mostly in sets between 0.5 and 1.5 m thick. At Goding Bay cross-beds are slightly bimodal (Jackson, 1986), while at Clarence Head abrupt reversals in current direction are recorded by Frisch & Christie (1982). Grits, pebbly sandstone and quartz-pebble conglomerates are irregularly distributed; such lithologies may be local and sporadic, common elsewhere. Well-rounded quartz pebbles are generally below 3 cm long; pebbles twice that size are sporadic. The rudaceous layers, discontinuous along strike, form discrete beds but more commonly, conglomerate beds have irregular diffuse borders grading to sandstone.

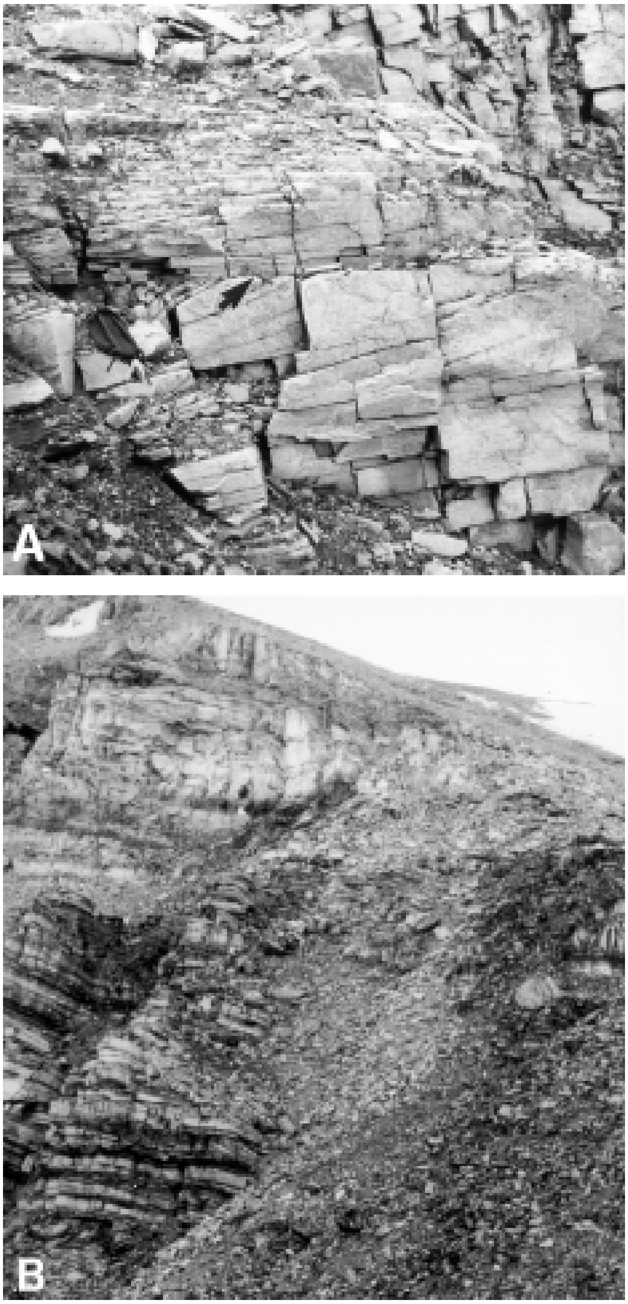


Fig. 76. Bedding characteristics of the Clarence Head Formation. **A:** large-scale planar cross-bedding, with hammer (arrowed) as scale. Upper part of the formation at Barden Bugt; **B:** banded, purple and white sandstones overlain by more homogeneous and thicker bedded white quartz arenites. Clarence Head, section 35. Photo: T. Frisch.

The majority of the sandstones are very clean quartz arenites that show a varying degree of authigenic silica overgrowth. There is a textural range from a rock having well-rounded quartz and an interstitial matrix of finer quartz, hematite-limonite dust and sericite, to a well-cemented rock in which quartz shows subrounded to subangular form due to heavy overgrowth. Some well-rounded quartzite fragments occur but feldspar grains are rare.

The two red beds at the top of the Paine Bluff section (see Figs 79, 82) have different lithologies. The lower bed, up to 2 m thick, is a cross-bedded pink to white sandstone with shaly partings; the upper, 3 m thick, is interbedded micaceous siltstone and cross-bedded sandstone with minor intraformational breccia (Christie, 1975). Red beds of similar appearance and stratigraphic position elsewhere, e.g. Bowdoin Bugt (see Fig. 78), have not been examined.

Depositional environment. The white, very clean sands, a reflection of distance from source and substantial reworking, and the thick, abundant cross-beds, in places bimodal, suggest a shallow marine depositional environment in the tidal zone. Deposition as offshore sand bars could account for the fairly abrupt thickness variations. Reversals of palaeocurrent directions are suggested to be related to longshore or tidal currents (Frisch & Christie, 1982; Jackson, 1986).

Fossils. None known.

Boundaries and correlation. The formation rests conformably on underlying strata – the Josephine Headland and Barden Bugt Formations (Figs 49, 71). If outcrop would allow, it might be shown to overlap onto crystalline basement at the basin margin in the south-east. The upper boundary is a regional marker representing the incoming of red bed sedimentation of the Baffin Bay Group (Figs 75, 77). Over the main part of the Thule Basin it is overlain with sharp contact by the Kap Trautwine Formation (in places the contact is with a basic sill); in the Goding Bay – Cape Dunsterville area it is overlain by the Goding Bay Formation.

Although stratigraphical relationships are not preserved in northernmost Prudhoe Land, the Clarence Head Formation is regarded as a lateral equivalent of the Kap Alexander Formation of the Smith Sound Group (see Fig. 120).

Subdivisions. In many sections in both Greenland and Canada, a bipartite division into lower, more recessive and banded, and upper, more massive and cliff-forming, units is apparent (Figs 49, 64, 74, 76) but no formal recognition is made here.