a specific phase of late Precambrian sedimentation in North and North-East Greenland – the so-called pre-Carolinidian (orogeny) cycle. The strata were subdivided into a Lower and an Upper Thule Group and informally referred to as 'Thulean beds'. Although these rocks have age equivalents in the Thule Basin, the Carolinidian orogeny was not demonstrable in North-West Greenland and has since been disputed even in the type area of Kronprins Christian Land (Jepsen & Kalsbeek, 1981; Haller, 1983).

For a detailed history of the use of Thule Formation/Group in North and North-East Greenland, the reader is referred to the papers cited above and to the discussion in Adams & Cowie (1953, pp. 16–17), Berthelsen & Noe-Nygaard (1965, p. 227), Jepsen (1971, pp. 7–10) and Dawes (1971, pp. 204–210, 1976a, pp. 265–267). More recently Collinson (1980) has introduced the Independence Fjord Group to cover sediments of Koch's Thule Formation as defined in Peary Land and areas to the south-east. In Haller (1983) Thule Group is retained although it is placed in inverted commas.

Selected nomenclatorial practice

This bulletin raises the Thule Group to supergroup status and drastically restricts its geographical distribution. Paradoxically, however, the supergroup includes only *part* of *one* of three formations that compose the initial Thule Group of the Smith Sound area; a part that has been referred to another stratigraphical unit, viz. the Ellesmere Group of Kerr (1967b). These facts plus the considerable nomenclatorial confusion that has surrounded the Thule Group constitute a case for the abandonment of the name Thule in any definitive revision. However, the name is considered to be so entrenched in the literature that its replacement would be confusing.

There is also a case for reuniting nomenclatorially Proterozoic successions across northern Greenland. Investigations in eastern North Greenland (Collinson, 1980; Jepsen *et al.*, 1980; Kalsbeek & Jepsen, 1984), reviewed by Sønderholm & Jepsen (1991), confirm that clastic and basaltic rocks, originally part of Koch's (1929a) Thule Formation, are of the same age and type as the lower Thule Supergroup. Koch's initial correlation across northern Greenland can be maintained. Thus, the Independence Group of Collinson (1980) and the Zig-Zag Dal Basalt Formation of Jepsen *et al.* (1980) might be referred to the lower Thule Supergroup, with the overlying Hagen Fjord Group (Clemmensen & Jepsen, 1992) as part of the upper Thule Supergroup. This is not done here, however, since direct links between exposures in North and North-West Greenland are lacking and the Thule Basin is regarded as a discrete depocenter, one of several on the northern margin of the North Atlantic craton (Dawes *et al.*, 1982a). Present practice tends to restrict nomenclatorial names to successions that can be correlated within individual depocentres, rather than between the separate basins (see Young, 1979; Campbell, 1981).

Lithostratigraphy

The formal units of the lithostratigraphic scheme are discussed in general ascending stratigraphic order and starting with the relatively thin northern platform and basin margin succession. Lithostratigraphic schemes of the Thule Supergroup are given in Figs 4 and 11; regional stratigraphy is summarised in Fig. 3. Generalised stratigraphic sections for 26 stations through the lower Thule Supergroup are displayed in Fig. 12 and the stratigraphical relationships of the groups and formations are illustrated in a schematised cross-section given in the last chapter (see Fig. 120).

Stratigraphic sections. The stratigraphic sections presented have been compiled from data of variable detail; some are based on detailed logs; elsewhere, only qualitative reconnaissance sections are available. The precise thickness of the Thule Supergroup is unknown. The sheer extent of the succession (seen in relation to the scope of the field work) and in many places the steepness of slope, have prevented systematic measurement. Some unit measurements are estimates based on partially measured sections. As far as possible the material has been standardised and it is presented both

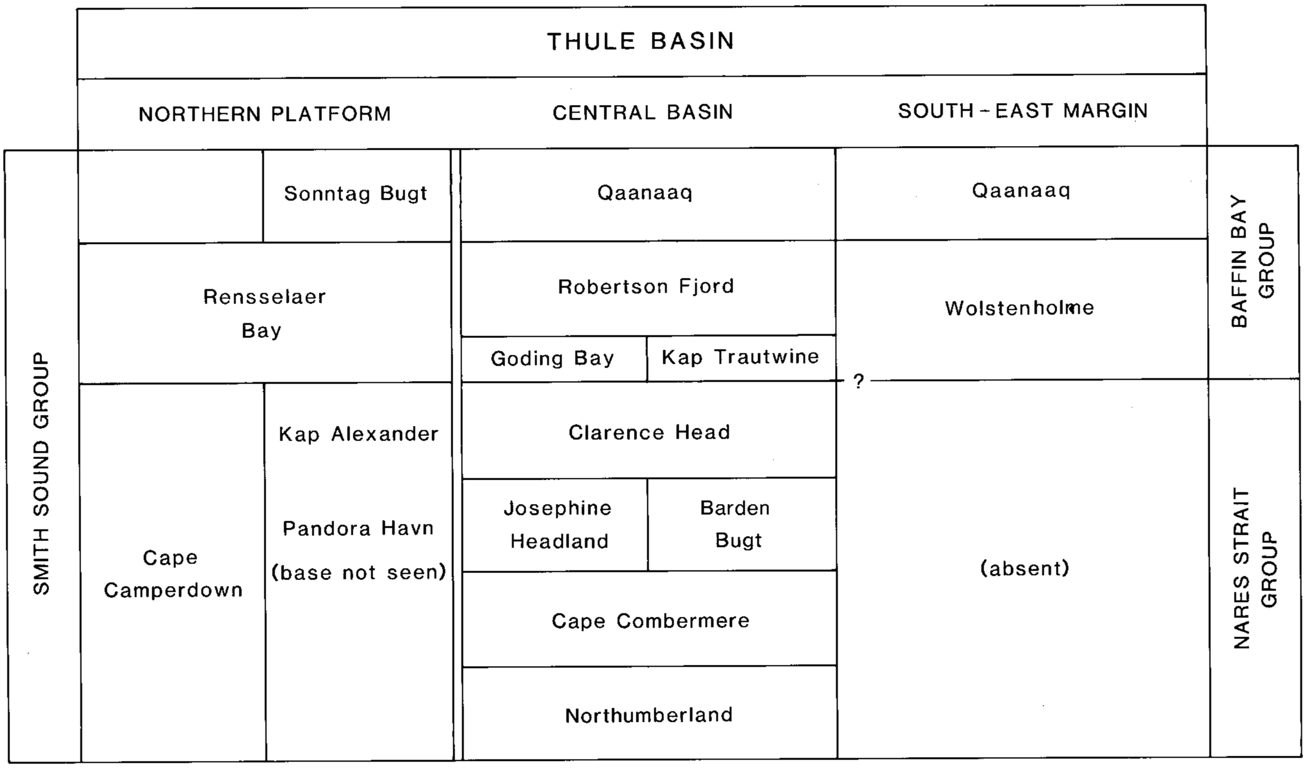


Fig. 11. Lithostratigraphic scheme of the lower Thule Supergroup showing groups and formations.

as stratigraphic logs and generalised sections with a common legend (see Plate 1 at rear). Sections of Canadian outcrops are compiled by the author from data in Christie (1967, 1975), Frisch & Christie (1982) and Jackson (1986) and these are presented in matching form.

Unit descriptions. To meet formal lithostratigraphic procedure, each unit description has a section on depositional environment. Determination of the depositional milieu of Precambrian successions is notably problematic; in the absence of systematic sedimentological analysis, it is tentative. The interpretations offered here, based on variable sedimentological detail taken from both published (e.g. Frisch & Christie, 1982; Strother *et al.*, 1983; Jackson, 1986) and unpublished data in Survey files, are in places necessarily speculative.

Names: spelling and derivation. Lithostratigraphic names for Thule strata have hitherto been of mixed derivation, based both on English and Greenlandic spelling of geographical localities. Authorised place names in Greenland have now Greenlandic or Danish spelling, and formal stratigraphic names in this paper are so derived. Likewise all stratigraphic names from Ellesmere Island are based on authorised Canadian (English) spelling. Where Greenlandic names are introduced as stratigraphical terms, the new spelling form is used, e.g. Qaanaaq Formation (rather than Qânâq). Following the guidelines of stratigraphic nomenclature (e.g. Holland *et al.*, 1978; Salvador, 1994), the initial spelling of stratigraphic units should be preserved even when redefined. Hence, the English form, Rensselaer Bay Formation, is adhered to although the type area is Rensselaer Bugt – the authorised Danish form.

The scarcity of geographical names in Canada has dictated that two non-geographical names have been used for new lithostratigraphic units. To accord with the guidelines of formal designation (Hedburg, 1976; Salvador, 1994) the proper names used (Bentham and Troelsen, deceased geologists who studied Thule strata) are unique, relevant and convenient to use.

Three names, Smith Sound, Nares Strait and Baffin Bay, refer to international waters. Fittingly and also because the names cover strata in both Canada and Greenland, the English spelling is used.

One stratigraphic name has been spelt inconsistently in the literature: the Narssârssuk Group of this paper is derived from the Narssarssuk formation of Kurtz and Wales (1951) who, like Davies (1957), did not use a circumflex accent. Davies *et al.* (1963) used the then authorised spelling of Narssârssuk, the form followed here.

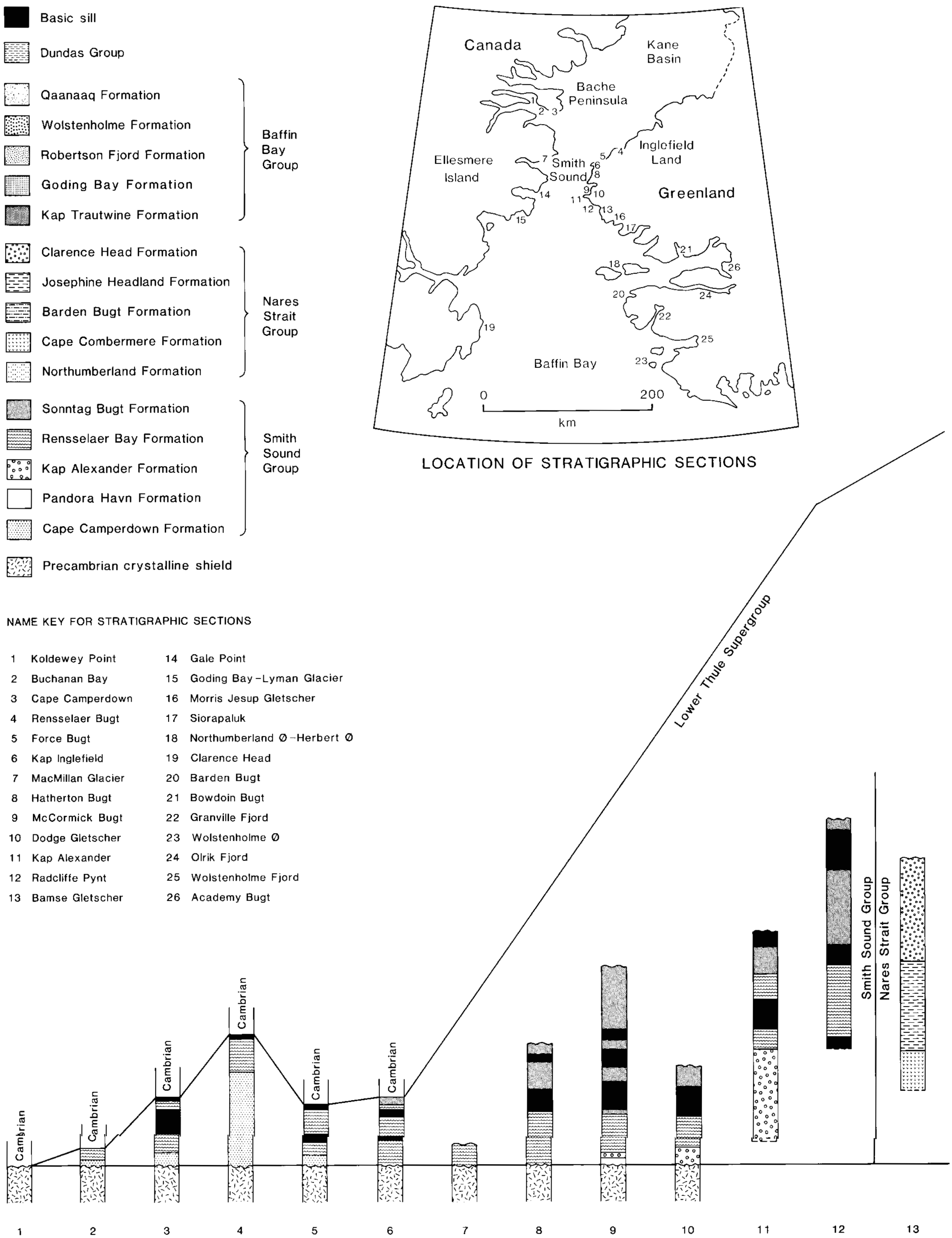
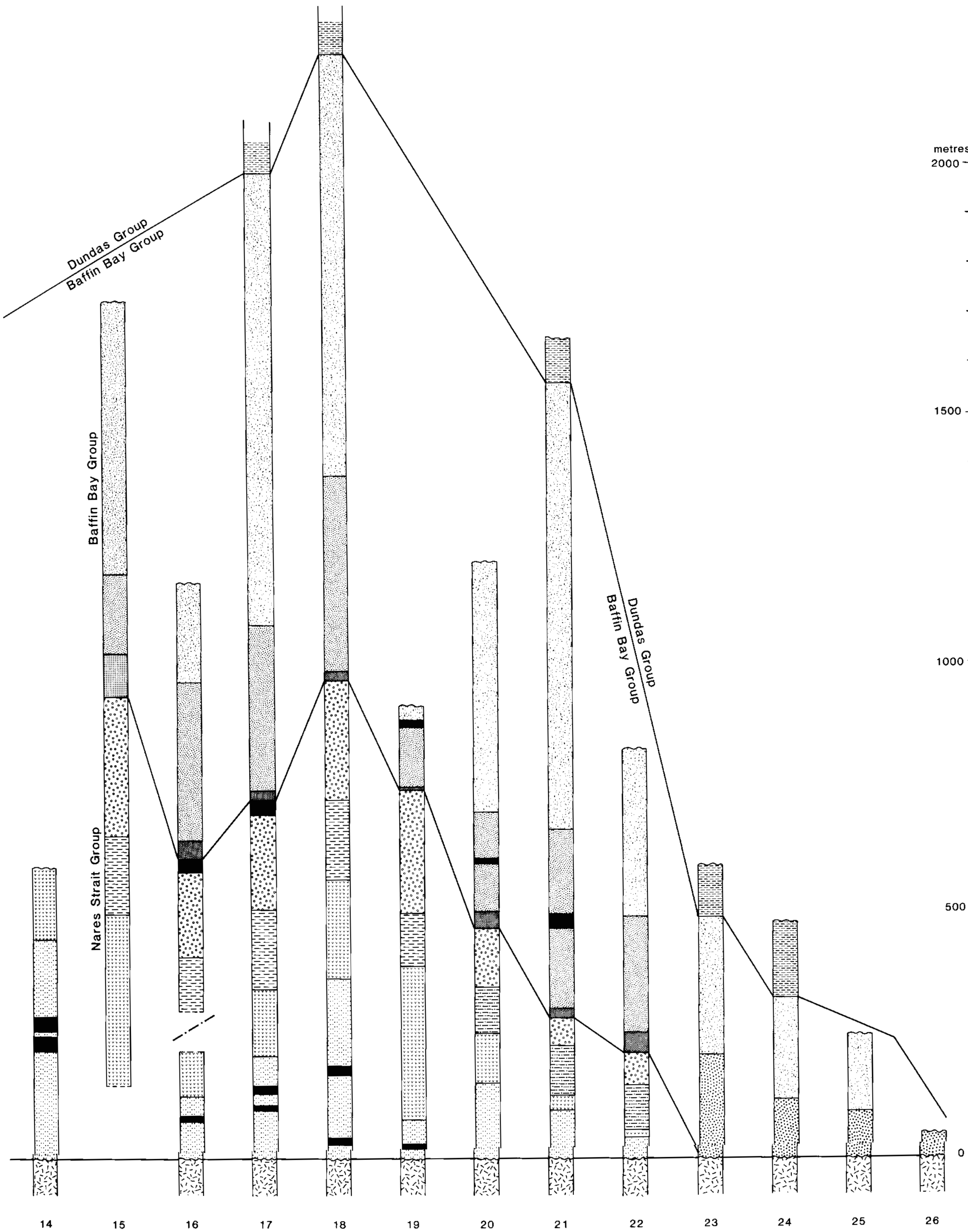


Fig. 12. Stratigraphic chart of the lower Thule Supergroup based on 26 areas. Distribution of the overlying Dundas Group is shown in Fig. 2.



Dundas Group
Baffin Bay Group
Baffin Bay Group
Nares Strait Group
Dundas Group
Baffin Bay Group
metres
2000
1500
1000
500
0
14
15
16
17
18
19
20
21
22
23
24
25
26

Fig. 12 cont.

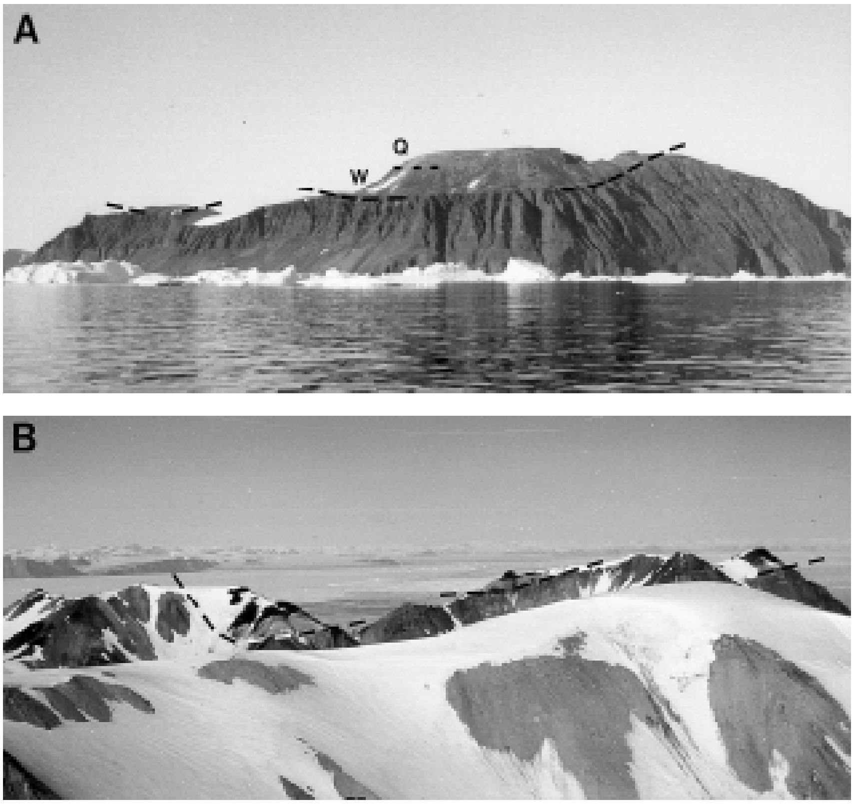


Fig. 13. Small outliers of Thule Supergroup on the Precambrian shield at the margins of the Thule Basin in Greenland (A) and Canada (B).
A: Baffin Bay Group (Wolstenholme and Qaanaaq Formations, W and Q) at De Dødes Fjord, Melville Bugt, with summit at around 600 m.
B: Nares Strait Group (pale sandstones of the Northumberland Formation overlain by dark volcanics of the Cape Combermere Formation) forming mountain summits south-west of Cape Combermere (see Fig. 57). The view is to the north with Greenland in the right background. Photo: T. Frisch.

Thule Supergroup

The Thule Supergroup is subdivided into 36 formal units: 5 groups, viz. the Smith Sound, Nares Strait, Baffin Bay, Dundas and Narssârssuk Groups, composing 15 formations and 16 members.

Thule Supergroup

new supergroup

Composition. The Thule Supergroup is derived from the Thule Formation of Koch (1929a) and Thule Group of Troelsen (1949, 1950a). As so described herein, it differs drastically from its forerunners with respect to geographic and chronostratigraphic limits. The supergroup is restricted to encompass middle to late Proterozoic strata of the Smith Sound – northern Baffin Bay region. It excludes strata in east central Ellesmere Island (Copes Bay – Dobbin Bay area) referred to the Thule Group by Thorsteinsson (1963, also *in* Blackadar, 1957) and in North and North-East Greenland, viz. Thule Formation of Koch (1929a, b, 1935a, b), Thule Group of Troelsen (1949, 1950b, 1956a, b) and the redefined Thule Group of Haller (1961, 1970, 1971, 1983) and Koch (1961).

The supergroup encompasses all strata in the Thule district referred by Koch (1929a, 1933) to the Thule Formation, as well as the basal part of that formation and the basal part of the lower formation of the Thule Group of Troelsen (1950a), in south-western Inglefield Land and Bache Peninsula. It includes strata described by Chamberlin (1895), Munck (1941), Kurtz & Wales (1951), Goldthwait (1954), Fernald & Horowitz (1964) and Dawes (1972, 1975, 1976b), the 'little-disturbed formation (2)' of Christie (1962a, b), the Camperdown Member and the Hatherton and Sverdrup Members of the Rensselaer Bay Formation as defined, respectively, by Christie (1967) and Cowie (1971), the 'Thule basin rocks' of Kerr (1967a), Christie (1972) and Frisch *et al.* (1978) and the Thule Group as used by Davies *et al.* (1963), Dawes (1971, 1976a, 1979a, b), Christie *et al.* (1981b), Dawes & Peel (1981), Dawes *et al.* (1982a, b), Frisch & Christie (1982) and Jackson (1986).

Name. After the site of the abandoned trading station, Thule, at North Star Bugt, North-West Greenland (Figs 2, 105).

Distribution. The supergroup borders the coasts of northern Baffin Bay, Smith Sound and southern Kane Basin between 76º and 79ºN (Figs 1, 2). The southernmost exposures are at 76º05′N at De Dødes Fjord, north of Kap York, where outcrops form mountain tops (Fig. 13); the northernmost exposures are at 79º07′N on Bache Peninsula (Fig. 7). Easternmost outcrops are at 66ºW, east of Academy Bugt at the head of Inglefield Bredning and in Olrik Fjord (see Fig. 103), and westernmost on nunataks at 78º28′W inland from Cape Combermere (Fig. 13).

Type area. The type area is between Bylot Sund and Inglefield Bredning (including islands), Greenland, where the Thule Supergroup has its most complete development (Fig. 2).

Thickness. Varies from feather-edge to at least 6 km, possibly as much as 8 km (Fig. 12).

Dominant lithology. The Thule Supergroup is a multicoloured, mainly shallow-water sedimentary succession with one main interval of basaltic volcanic rocks. Basic sills are common at several levels. In broad lithological terms the succession is bipartite, being composed of a lower siliciclastic part with basaltic rocks and subordinate carbonate, and an upper part of mixed siliciclastic-carbonate strata. Red beds form prominent units in both parts.

Lower strata are characterised by thick units of clean to ferruginous quartz arenites with conglomerates and some shale and carbonate intervals that give way upwards to an interbedded sequence of darker sandstone, siltstone and shale with subordinate dolomite. The upper part is composed of a well-layered carbonate-red bed siliciclastic sequence with algal laminites characterised by cyclicity, with evaporite and subordinate chert.

Depositional environment. The supergroup represents a variety of depositional environments from continental (subaerial to alluvial) to lacustrine and shallow marine (intertidal-subtidal) with intervals of cratonic magmatism. One of the magmatic episodes produced terrestrial tholeiitic effusives. The sediments, representing a very long time span (*c*. 600 Ma), are essentially undeformed but no major unconformities have been observed. Any fundamental breaks in shallow-water deposition must be represented by paraconformities.

The lower siliciclastic part of the succession mainly represents alluvial plain to shallow shelf sedimentation with alternating intervals of tide-dominated and alluvial-dominated deposition followed by deposition in overall deltaic to subtidal environments. The upper part, characterised by cyclic sedimentation involving algal laminated carbonates and evaporites, indicates a low-energy environment and hypersaline conditions analogous to modern lagoonal sabkha deposits.

The red coloration that is characteristic of many siliciclastic units could be taken to indicate a continental oxidising environment (Glennie, 1970). The relative lack of abundant organic matter in the Proterozoic may have increased the probability of oxidising rather than reducing conditions during the diagenesis of the Thule strata. However, much of the red colour is thought to represent diagenetic adjustment of iron contained in 'normal' clastic sedimentary material. Iron would be derived in abundance from the type of eroded granitoid crystalline terrain that surrounds the Thule Basin. Migration of iron compounds in the Thule detrital system has been generally high and is evidenced by the common appearance of liesegang rings and related phenomena.

Fossils. Stromatolites, algal laminites and microfossils (acritarchs and cyanobacterial organisms) have been described by Vidal & Dawes (1980), Strother *et al.* (1983), Dawes & Vidal (1985), Jackson (1986) and Grey (1995). Curvilinear to sinuous structures described as trace fossils by Dawes & Bromley (1975) and similar to the fucoidal markings of Fernald & Horowitz (1964), are reinterpreted as diastasis cracks.

Boundaries. The Thule Supergroup rests with profound unconformity on the eroded and peneplaned Precambrian shield (Figs 7, 9). Between 76º and 78º30′N the supergroup is overlain by Quaternary and Recent deposits; in Bache Peninsula and in Inglefield Land from Force Bugt eastwards, it is disconformably overlain by the Lower Cambrian of the Franklinian Basin (Figs 5, 7, 8, 14).

Geological age. Neohelikian–Hadrynian age between *c*. 1270 and *c*. 650 Ma. The crystalline shield underlying the Thule Supergroup contains Proterozoic (middle Aphebian) crust that has given U-Pb zircon and monazite ages between 1960 and 1912 Ma (Frisch & Hunt, 1988) and a Rb-Sr whole-rock age of 1850 Ma (Dawes *et al.*, 1988). The supergroup is also younger than a period of Paleohelikian basaltic dyking (including the Melville Bugt swarm of Nielsen (1987, 1990)) which in North-West Greenland has given K-Ar whole-

Fig. 14. Proterozoic–Palaeozoic unconformity in Inglefield Land; inland cliffs near Kap Inglefield. Smith Sound Group (RB = Rensselaer Bay Formation; SB = Sonntag Bugt Formation; D = dolerite sill) overlain by Cambrian strata (C). Section height above scree is about 150 m.

rock ages between 1667 and 1313 Ma (Dawes & Rex, 1986). Based on a $^{207}Pb/^{206}Pb$ baddeleyite age of a basaltic sill (LeCheminant & Heaman, 1991), the basal part of the supergroup is at least 1268 Ma (see Nares Strait Group). The supergroup is older than a swarm of Hadrynian basic dykes (K/Ar age range 630–725 Ma; Dawes *et al.,* 1973, 1982b; Dawes & Rex, 1986) that cuts the entire succession (Figs 5B, 64, 105, 106).

The microfossils so far identified from Thule strata are not particularly age-diagnostic and they have long stratigraphic ranges, i.e. Late Riphean – Vendian (Vidal & Dawes, 1980; Dawes & Vidal, 1985).

Following the time-scales of Harland *et al.* (1990) and the International Union of Geological Sciences (Plumb & James, 1986), the Thule Supergroup is of middle to late Proterozoic age (Proterozoic eras II and III or Meso-Neoproterozoic). In terms of Canadian chronostratigraphy (Douglas, 1980) it is of Neohelikian and Hadrynian age. Further details including quantitative data from isotopic age determinations are given under each group.

Subdivisions. The Thule Supergroup is divided into five groups: the Smith Sound, Nares Strait, Baffin Bay, Dundas and Narssârssuk Groups. The first three groups are referred to the lower Thule Supergroup, the latter two to the upper Thule Supergroup (Fig. 2). As listed above the groups are in younging stratigraphic order except that the Smith Sound Group is the basin margin and platform equivalent of the Nares Strait and Baffin Bay Groups (Fig. 4).

Smith Sound Group

The Smith Sound Group represents the northern basin margin and platform succession (Figs 2, 4, 120). It is subdivided into five formations, viz. the Cape Camperdown, Pandora Havn, Kap Alexander, Rensselaer Bay and Sonntag Bugt Formations; with the Rensselaer Bay Formation being split into two members – the Hatherton Bugt and Force Bugt Members.

Smith Sound Group

new group

Composition. Strata of this group are mainly part of the lower red sandstone unit of the Thule Formation of Koch (1929a, 1933; see also Dawes & Haller, 1979, plate 1). The group includes the lowermost strata of the Rensselaer Bay sandstone of Troelsen (1950a), which at Bache Peninsula equates with the Camperdown Member of Christie (1967). Troelsen (1950a, 1956b) restricted the Rensselaer Bay sandstone to Bache Peninsula and Inglefield Land; strata farther to the south between Kap Alexander and Sonntag Bugt referred to the Rensselaer Bay Formation by Dawes (1976a, 1979a) and Peel *et al.* (1982), are included in the group.

Name. After Smith Sound, the seaway separating southwestern Inglefield Land and central Ellesmere Island (Figs 1, 2).

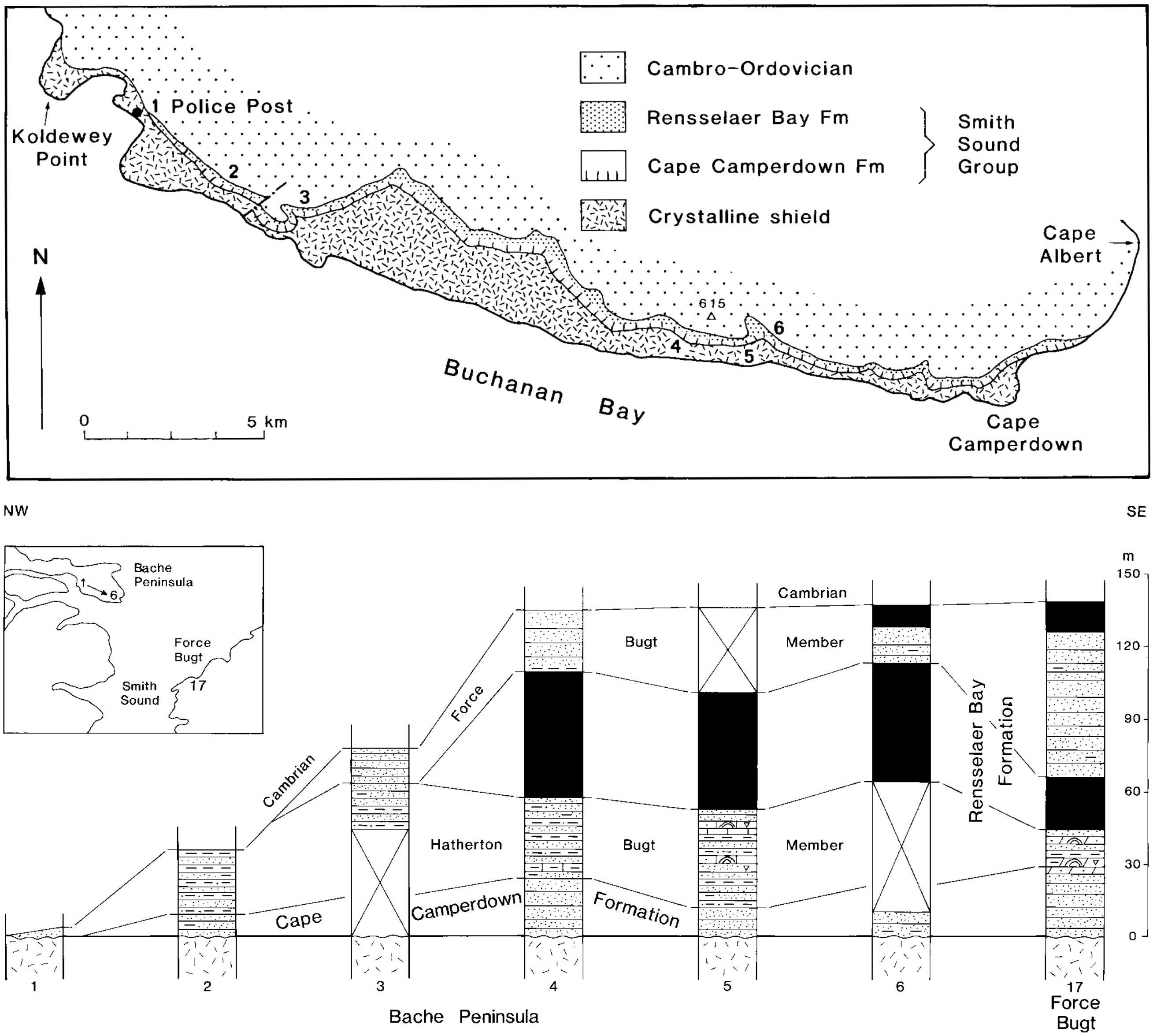


Fig. 15. Geological map and stratigraphic chart of southern Bache Peninsula, Canada. Sections 1 to 6 show westerly thinning and wedging out of the Smith Sound Group. Canadian geology is compiled from Christie (1967) and illustrated in Fig. 7; the Force Bugt section from Inglefield Land, Greenland, for comparison, is simplified from the log given in Fig. 42. Height of 615 is in metres. For regional location, see Fig. 2.

Distribution. Both sides of Smith Sound, viz. in Greenland, coastal, central and south-western Inglefield Land and northernmost Prudhoe Land; in Canada, on Bache Peninsula and a small outlier at MacMillan Glacier on the south side of Johan Peninsula (Fig. 2). Precise northern limit of the group in Inglefield Land is obscured by extensive scree.

Type area. The coast of south-western Inglefield Land between Rensselaer Bugt and Kap Alexander, Greenland (Fig. 2).

Thickness. Varies from a feather-edge in northern exposures in central Inglefield Land and western Bache Peninsula to a composite thickness of around 700 m (Figs 3, 12, 15).

Dominant lithology. A varicoloured sequence of sandstones and shales, including red beds, with subordinate carbonates, cut by basic sills (Fig. 3). Quartz arenites dominate with, in places, interbedded shales with distinct intervals of algal and stromatolitic dolomites that are variously arenaceous. Thick units of clean quartz arenites with pebbly sandstone and quartz-peb-

Fig. 16. Western side of Rensselaer Bugt showing locations of sections 7 and 8 through the Cape Camperdown (CC) and Rensselaer Bay (RB) Formations. Ps = Precambrian shield; C = Cambrian. Distance from foreground houses to base of section 8 is about l.5 km; sea-cliffs are about 300 m high. Dark shale-rich unit (arrowed) seen in detail view of section 8 is 15 m thick and about 120 m above the sea-ice. Sections are given below in Fig. 17.

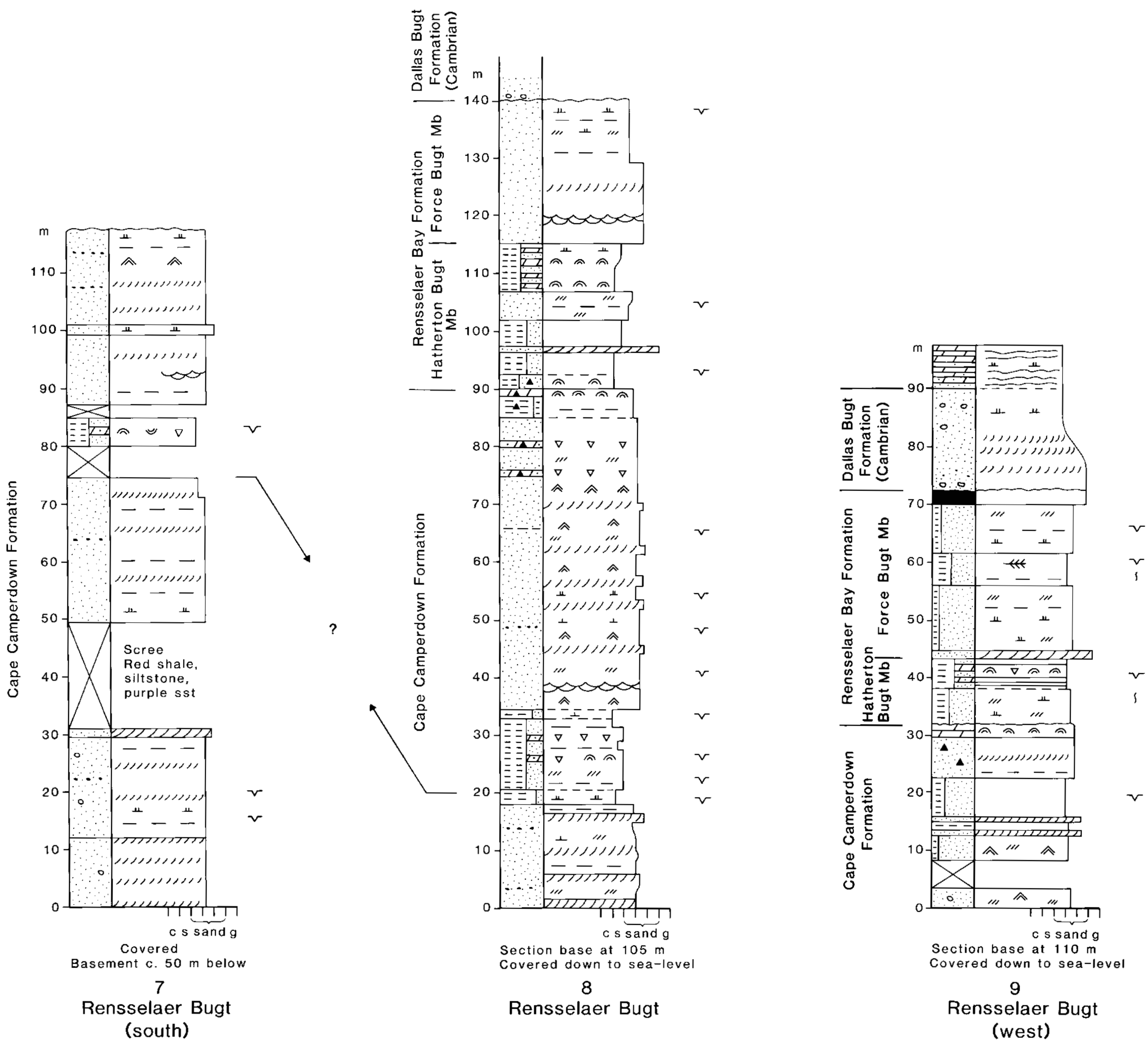
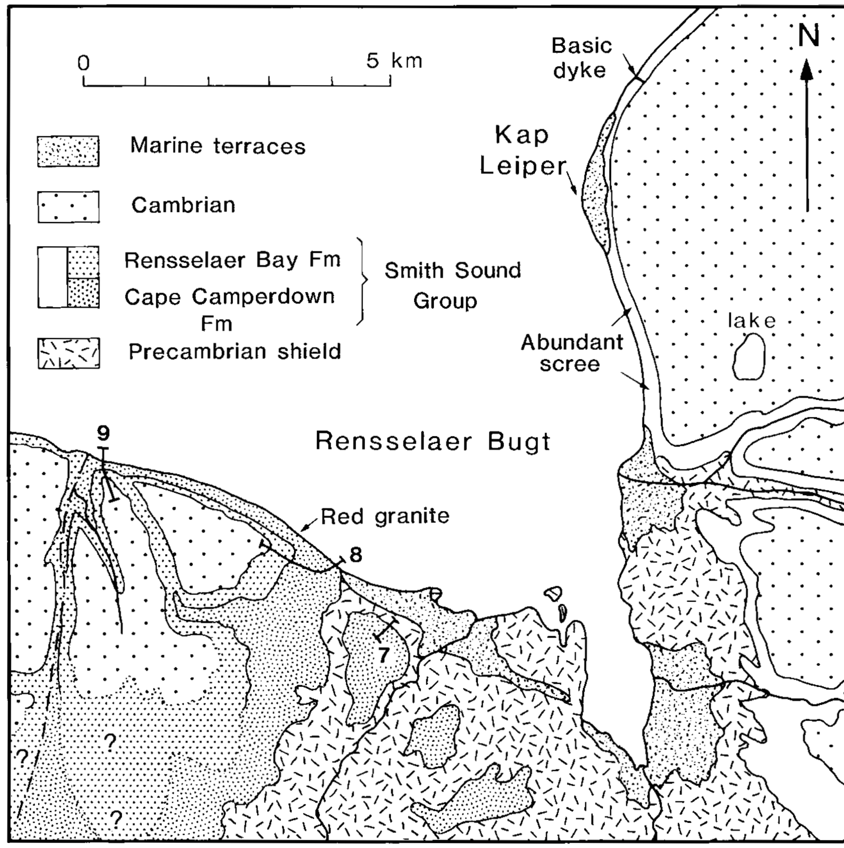


Fig. 17. Stratigraphic logs from Rensselaer Bugt showing the disconformity with the Cambrian. Section 8 is the type section for the Cape Camperdown and Rensselaer Bay Formations. Locations are shown on Figs 5A, 16 and 18.

Fig. 18. Geological map of the Rensselaer Bugt area, Inglefield Land, Greenland, showing locations of sections 7, 8 and 9. Map is drawn from an uncontrolled photomosaic. For location, see Fig. 2.



ble conglomerate characterise the lower and upper parts of the group in southern exposures.

Depositional environment. The Smith Sound Group was deposited in a stable, overall shallow shelf environment that ensured long-lasting conditions for shallow-water to subaerial deposition. Water-lain deposition probably ranged from marginally marine to supratidal and intermittently lacustrine. Southern exposures suggest progradation of the shoreline with uppermost strata indicating approaching fluvial deposition.

Fossils. Stromatolites, algal laminites.

Boundaries and correlation. The group directly overlies the crystalline shield (Figs 7, 9). In northern exposures it is disconformably overlain by Lower Cambrian clastics (Dallas Bugt Formation; Figs 7, 8), elsewhere by Quaternary deposits. Relationships to the Baffin Bay and Nares Strait Groups are not seen at present erosion level, but the Smith Sound Group almost certainly grades laterally into both these groups (Figs 3, 4, 120).

Geological age. Neohelikian. This age is based on the isotopic dating of dolerite sills that cut the upper strata of the group. The K-Ar whole-rock ages on basic sills from Inglefield Land are 1073 ± 40 and 1070 ± 40 Ma (Dawes *et al.*, 1973).

Subdivisions. The Smith Sound Group is divided into five formations: the Cape Camperdown, Pandora Havn, Kap Alexander, Rensselaer Bay and Sonntag Bugt Formations.

Cape Camperdown Formation

new formation

Composition. This formation includes basal strata of the Rensselaer Bay sandstone of Troelsen (1950a) as exposed at Rensselaer Bugt and environs and at Bache Peninsula. It should be noted that it does not incorporate southern exposures of either Troelsen's formation or the Rensselaer Bay Formation as used by Cowie (1961, 1971), Dawes (1976a, 1979a) and Peel *et al.* (1982). At Bache Peninsula it comprises sub-members A and B of the Camperdown Member of Christie (1967).

Name. After Cape Camperdown, south-eastern Bache Peninsula (Figs 2, 7, 15).

Fig. 19. Bedding characteristics of the Cape Camperdown Formation.
A: thin, cross-bedded sandstones with hammer arrowed as scale;
B: massive to laminated, sandstone with some channelling, overlain by thin- to medium-bedded sandstones (staff with 10 cm grid).
Coast, western Rensselaer Bugt.

Distribution. Coastal, central and south-western Inglefield Land between Force Bugt and Bancroft Bugt, and along the south coast of Bache Peninsula (Fig. 12). The formation may also occur east and south-east of Bancroft Bugt occupying hollows in the palaeosurface, as well as at the base of the scree-covered section in south-westernmost Inglefield Land.

Geomorphic expression and colour. Generally cliff-forming but at the base of sea-cliffs characteristically scree covered (Figs 5, 16). Purple to reddish unit with thinner darker purple, more recessive units.

Type and reference sections. The type section is on the west side of Rensselaer Bugt in the sea-cliffs (section 8, Figs 16, 17, 18); basal strata in contact with crystalline basement occur on a hill 1 km to the south (section 7, Figs 16, 17). Reference sections occur farther west in Rensselaer Bugt (section 9, Figs 5A, 17) and at Force Bugt (section 17, see Figs 41, 42) and along the south side of Bache Peninsula, for example sections 2, 4 and 5/6 (Fig. 15).

Thickness. The Cape Camperdown Formation shows marked thickness variations both locally and regionally (Fig. 12). At the type section it attains a thickness of about 190 m; on the eastern side of Rensselaer Bugt it varies from less than 50 m to around 150 m over a distance of a couple of kilometres, filling topographic lows in the eroded shield. To the south-west, coastal outcrops reveal a thinning so that at Force Bugt the formation is between 20 m and 30 m thick, probably petering out farther south. The formation also thins to the east and north-east, although exposures are generally scree covered and precise thicknesses obscured. In Canada on Bache Peninsula, it has a maximum thickness of 25 m, thinning and pinching out to the west near Koldewey Point (Fig. 15).

Fig. 20. Basal bed of the Cape Camperdown Formation (Smith Sound Group) on Precambrian shield at western Force Bugt. The granite substratum is severely weathered and rubbly; the conglomeratic sandstone contains quartz and pink feldspar granules, as well as granite clasts.

Lithology. Varicoloured thin- to thick-bedded sandstones with lesser amounts of siltstones and shales (Fig. 19). Some discrete shale-dominated units occur. Thin, green, jasper-rich arenaceous dolomite beds that are often brecciated characterise the upper part of the formation along with stromatolitic dolomite beds. The uppermost beds, where examined at Rensselaer Bugt and Force Bugt, are arenaceous dolomite with stromatolites, either in growth position or reworked to form a jasper-rich dolomite breccia.

The sandstones vary in colour from pink to purple, green, brown and buff; they are predominantly orthoquartzites but in many samples feldspar occurs, and in places at the base of the formation the rocks are subarkosic. Some pale green sandstones contain a sparse to abundant carbonate matrix. A green glauconite-bearing, fine conglomerate with well-rounded quartz and feldspar grains, rock fragments and a carbonate matrix occurs in contact with the crystalline basement at Force Bugt (Fig. 20). Glauconite occurs in basal beds at Bache Peninsula (Christie, 1967). The sandstones vary from fine to coarse grained and are generally fairly well sorted; some are characterised by very well-rounded quartz grains. Thin grit and quartz pebble layers occur and some are associated with the upper surfaces of sandstone beds. Many sandstones are characterised by green and red laminations (Fig. 19B); cross-bedding is common throughout. Cross-beds are low-angle mainly tabular type in sets up to 3 m; trough bedding also occurs in units up to 1 m thick. Some are catenary beds with truncated tops suggesting that many are the preserved bases of once thicker sets. Some channelling occurs locally and current ripples and symmetrical wave ripples are frequent.

The shale-rich units form dark purple recessive intervals that show considerable thickness and facies variation along strike. They are composed of interbedded red and green shales, siltstones and fine sandstones with pale arenaceous dolomite beds (Fig. 21). Some of the sandstones are calcareous and contain rip-up clasts of fine dolomite. Mudcracks are common.

Depositional environment. The formation represents shallow water to subaerial deposition of sand sheets with some intervals of low detrital input when stromatolites survived. Glauconite in basal beds is taken to mark an initial marine transgression. The truncated tops of large-scale cross beds suggest wind erosion and some of the sands are deemed aeolian. An ephemeral lake with periodic inundations by floods is a possible overall environment for the bulk of the formation (J. D. Collinson, personal communication, 1980).

Fossils. Stromatolites.

Boundaries and correlation. The formation overlies the crystalline shield and is followed disconformably by the Rensselaer Bay Formation. In central Inglefield Land and western Bache Peninsula, relationships to the Rensselaer Bay Formation are obscured, and the formation may be overstepped by the Cambrian Dallas Bugt Formation. At Rensselaer Bugt and Force Bugt the upper boundary is taken at the top of a sandstone unit topped by a stromatolitic dolomite bed (Fig. 22). Relationships to the Rensselaer Bay Formation south of Force Bugt are obscured by scree and the formation has not been identified over the structurally high basement around Hatherton Bugt.

Fig. 21. Thin, green arenaceous dolomite beds with irregular algal-laminated tops within purple shale and fine-grained sandstones. Reduction spots are prominent. Cape Camperdown Formation, western Rensselaer Bugt, section 8.

Correlation of the Cape Camperdown Formation with strata south of Force Bugt can only be surmised. The Pandora Havn and Kap Alexander Formations, which are also overlain by the Rensselaer Bay Formation, as well as one or more formations of the Nares Strait Group, may well contain coeval strata (Figs 12, 120). The Cape Camperdown Formation may contain strata as old as the basal rocks of the basinal section, viz. Northumberland Formation (Figs 11, 120).

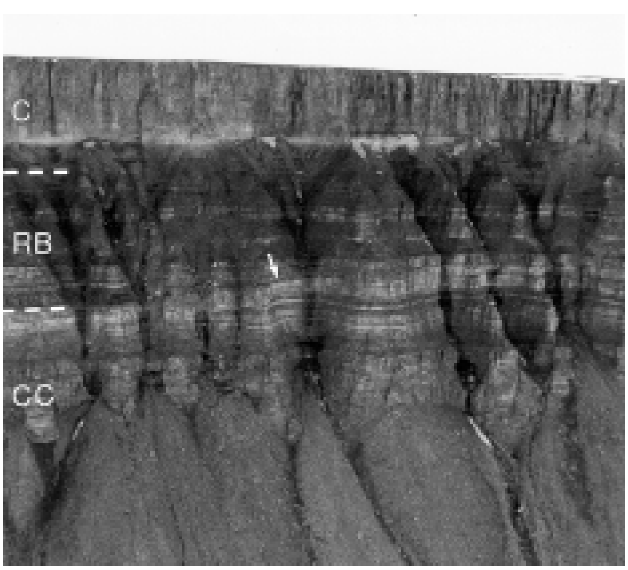


Fig. 22. Detail of disconformable contact between the Cape Camperdown (CC) and Rensselaer Bay (RB) Formations. The uppermost strata of CC is a transgressive sandstone topped by a stromatolite surface (arrowed). Lower beds of RB overlap onto the topographic high. C = Cambrian. Section height above scree is about 150 m. Sea-cliffs west side of Rensselaer Bugt.

Subdivisions. On Bache Peninsula, the strata that are now included in the Cape Camperdown Formation were subdivided by Christie (1967) into two units (submembers A and B) – a bipartite subdivision not recognised in Greenland. These units are not defined formally here.

Pandora Havn Formation

new formation

Composition. This formation comprises strata previously included in the Hatherton Member of the Rensselaer Bay Formation of Dawes (1976a) as exposed at McCormick Bugt.

Name. From Pandora Havn, the inner part of McCormick Bugt (Fig. 23).

Distribution. As yet only identified from the south side of McCormick Bugt. Profuse scree covering the lower part of the section in south-western Inglefield Land obscures recognition of a possible wider distribution.

Geomorphic expression and colour. A red to purple-weathering unit tending to recessivity and scree cover.

Type section. At sea level on the northern side of Crystal Palace Cliffs, McCormick Bugt (section 10, Figs 23, 24).

Thickness. At minimum 7.4 m. At the type section the base of the sequence is not exposed but position rela-

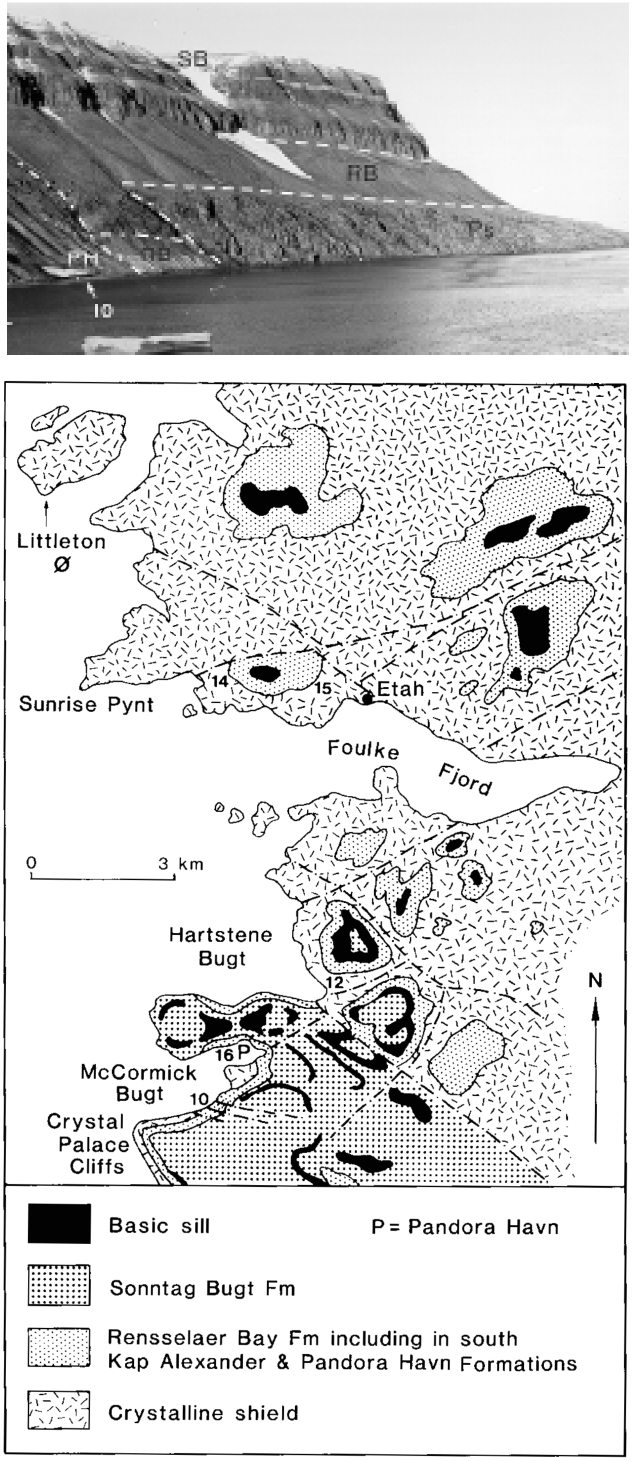


Fig. 23. Geology of the McCormick Bugt – Etah area, Greenland. Map showing the locations of sections 10, 12, 14, 15 and 16 is drawn from an uncontrolled photomosaic. The distinction between the Rensselaer Bay and Sonntag Bugt Formations, east of McCormick Bugt, is schematic. The view is south to Crystal Palace Cliffs showing basic sills within Sonntag Bugt Formation (SB) and the location of the Pandora Havn Formation (PH) in down-faulted section. Basal strata above Precambrian shield (Ps) hidden by scree. RB = Rensselaer Bay Formation. Summit of cliffs is at about 400 m. For location, see Fig. 2.

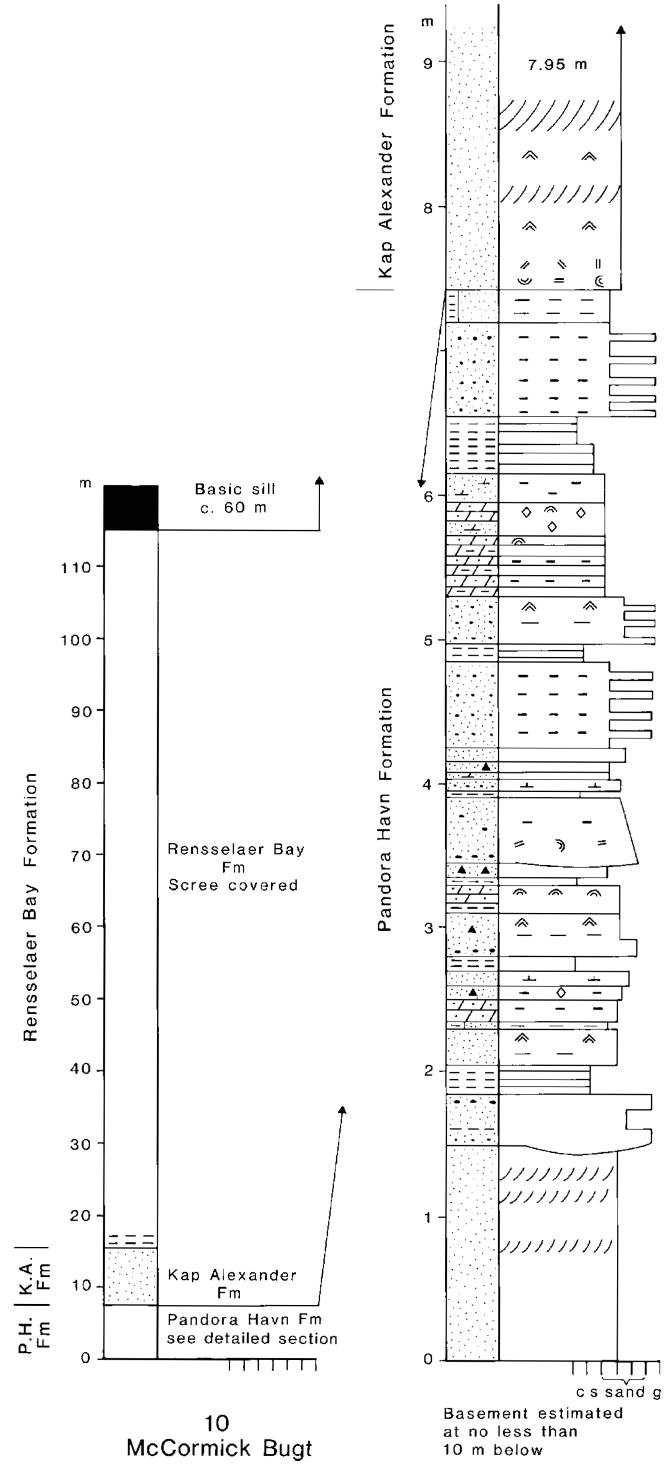


Fig. 24. Generalised section through the Pandora Havn, Kap Alexander and Rensselaer Bay Formations on the south side of McCormick Bugt, and stratigraphic log for the type section of the Pandora Havn Formation. For location, see Fig. 23.

Fig. 25. Bedding characteristics of the Pandora Havn Formation. Varicoloured, irregularly bedded sandstones and shales, with pale dolomitic beds, with slump beds (arrows) and ripple marks. McCormick Bugt, section 10.

tive to nearby crystalline basement outcrops suggests a maximum thickness of 20 m.

Lithology. A red bed unit composed of interbedded sandstones and shales with some dolomitic beds (Fig. 25). The sandstones have generally purple and mauve colours, both on weathered and fresh surfaces but some red, grey and greenish rocks occur. Streaky mottling is common. The sandstones are thin bedded, variously laminated, and many show prominent shale partings. Most beds are medium grained but finer sands, coarse-grained and granule beds also occur. Some of the latter contain polymict clasts, the largest of which are up to 3 cm long, composed of green silicified shale. Quartz sandstone, purple shale and pale dolomite clasts are smaller. Bedding is characteristically irregular with beds varying laterally and with channels common. Channel fill varies from poorly sorted, collapse material containing quartz sandstone pebbles to graded siltstone and sandstone. Many sandstones are cross-bedded with prominent ripple-marked surfaces, predominantly symmetrical wave ripples (Fig. 25).

Shales are usually well laminated and red and green. Green shales can show purple mottling in streaks. Shale ranges from lamellae and partings that are particularly common in some sandstones, to beds 40 cm thick. Beds often have irregular thicknesses due to encroachment by the flanking sandstones.

The third component of the lithology, dolomite, occurs in thin beds that often show irregular, even lenticular form. Typical rock is pink to pale green, fine-grained, showing some degree of lamination. Dolomites are variously arenaceous and argillaceous, and some contain white and green clasts of shale and dolomite. Small stromatolite domes occur in growth position at the upper surface of some beds but more commonly stromatolitic material occurs as rotated fragments and clasts. Some beds have a brecciated rubbly character. Ripple marks, mainly symmetrical, and mudcracks occur on upper surfaces of some dolomite beds.

Depositional environment. From the restricted exposure, the environment is suggested to be supratidal possibly lacustrine but with active channelling suggesting some influence by streams. Some reworking of detrital material is evident, as well as intermittent detrital-poor intervals in which carbonate was precipitated and stromatolites grew.

Fossils. Stromatolites.

Boundaries and correlation. The formation is conformably overlain by the Kap Alexander Formation; its base is not seen but it is assumed to rest on the crystalline shield (Figs 12, 24).

The Pandora Havn Formation may be a correlative to part of the Cape Camperdown Formation to the north. It is thought to represent the northern featheredge of a red bed sequence that in the basin in the south is defined as the Josephine Headland Formation of the Nares Strait Group (see Fig. 120). The nearest outcrops of that group are 35 km distant at Bamse Gletscher (see Fig. 64).

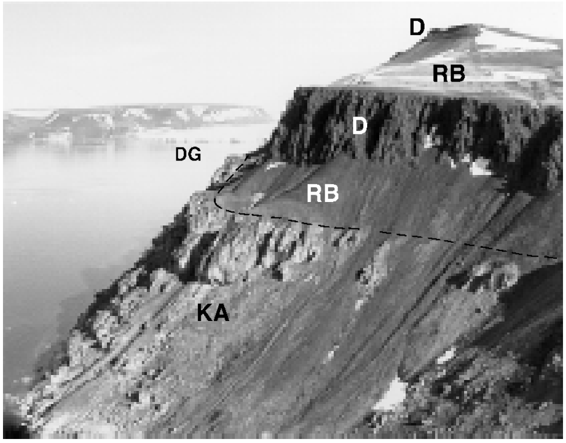


Fig. 26. Two views over Kap Alexander showing massive sandstones of the Kap Alexander Formation (KA, about 200 m thick) overlain by recessive Rensselaer Bay Formation (RB) with the Sonntag Bugt Formation (SB) forming pale strata at the summit around 500 m. The Kap Alexander Formation thins markedly across the basin margin overlapping onto crystalline basement at Dodge Gletscher (DG) and tapering out towards the north. D = Neohelikian dolerite sills. Sections 11 and 13, given in Figs 29 and 35, are located; for map location, see Fig. 27. Right photo: 543 B-NØ/2712, July 1950; Kort- og Matrikelstyrelsen, Denmark.

Kap Alexander Formation

new formation

Composition. This formation corresponds to the lower sandstone unit of Dawes (1976a) as exposed at Kap Alexander, sandstone formation A of Dawes (1979a) and the lower of three members of the Rensselaer Bay Formation of Peel *et al.* (1982) outcropping in the Kap Alexander – Storm Gletscher area. In south-western Inglefield Land up to 37 m of basal strata included by Dawes (1976a) in the Hatherton Member of the Rensselaer Bay Formation, are now referred to the Kap Alexander Formation.

Name. After Kap Alexander, a cape in Smith Sound and the westernmost point of Greenland (Figs 2, 26, 27).

Distribution. South-western Inglefield Land and northernmost Prudhoe Land between Hartstene Bugt and Sonntag Bugt (Fig. 12). Heavy scree cover farther north obscures its potentially wider extent below the recessive Rensselaer Bay Formation.

Geomorphic expression and overall colour. White to pale grey, resistant quartzitic unit forming in northern Prudhoe Land steep sections at the base of the sea cliffs (Fig. 26). Thin sections farther north have heavy scree cover.

Type and reference section. Well-exposed, accessible but relatively thin sections occur along the northern side of Dodge Gletscher. The type section is at the western end of this exposure (section 11, Figs 28, 29); reference sections exposing the contact with the overlying Rensselaer Bay Formation occur to the east (see Figs 34, 36). A poorly exposed reference section showing contact to the crystalline shield is exposed on the north side of Hartstene Bugt (section 12, Fig. 29). Thicker reference sections but with bases not exposed occur along the coast south of Kap Alexander.

Thickness. Thickest on the Kap Alexander peninsula where the formation is estimated at about 200 m (Fig. 12). The formation thins rapidly to the north over the basin margin so that to the north of Dodge Gletscher only 5 km distant it is 37 m thick, thinning to between 0 and 10 m in the McCormick Bugt – Hartstene Bugt area (Figs 26, 27).

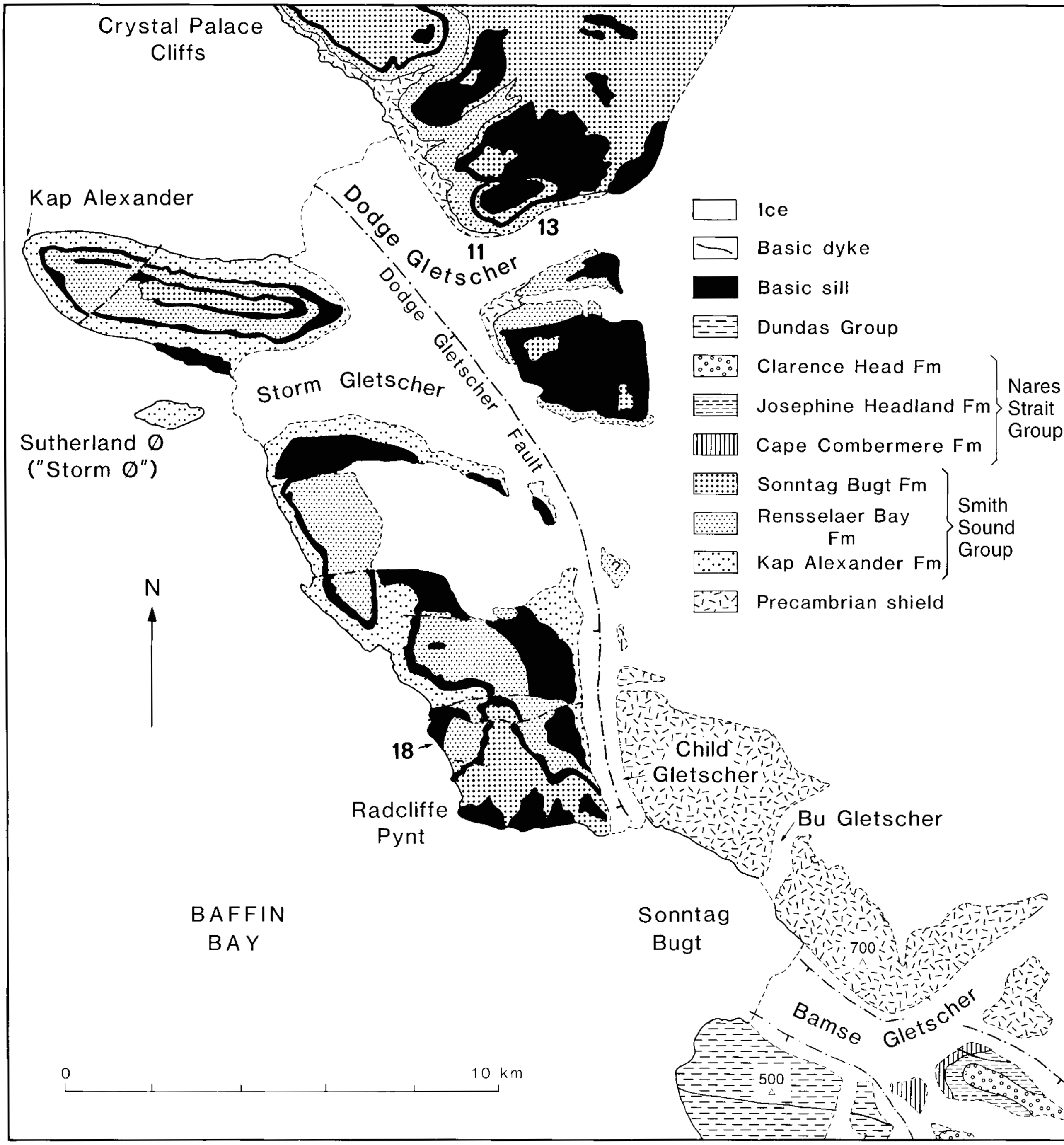


Fig. 27. Geological map of the Dodge Gletcher – Sonntag Bugt area, Greenland, showing the locations of sections 11, 13 and 18. The map covers the faulted northern margin of the Thule Basin, and shows the northernmost exposures in Greenland of the Nares Strait and Dundas Groups in coastal-parallel fault blocks (see also Figs 1, 5B). The Kap Alexander Formation of the Smith Sound Group (the assumed equivalent of the Clarence Head Formation of the Nares Strait Group) shows abrupt thickness variation. On the Kap Alexander peninsula (Fig. 26), the formation is at least 200 m thick; on the landward side of the Dodge Gletscher Fault the formation overlaps onto the Precambrian shield (Fig. 28), finally petering out farther north so that the Rensselaer Bay Formation overlies the shield (see Figs 9, 23, 38). The map is drawn from an uncontrolled photomosaic; an oblique photograph showing the same area is given in Fig. 1. Heights are approximate and in metres. For location, see Fig. 2.

Fig. 28. The type section of the Kap Alexander Formation (KA), on the north side of Dodge Gletscher, with dark shale beds conspicuous. The contact with the Precambrian shield (Ps) is poorly exposed. RB = Rensselaer Bay Formation with profuse scree, D = basic sill, SB = Sonntag Bugt Formation. Section 11, about 40 m thick, is given below in Fig. 29; for map location, see Fig. 27.

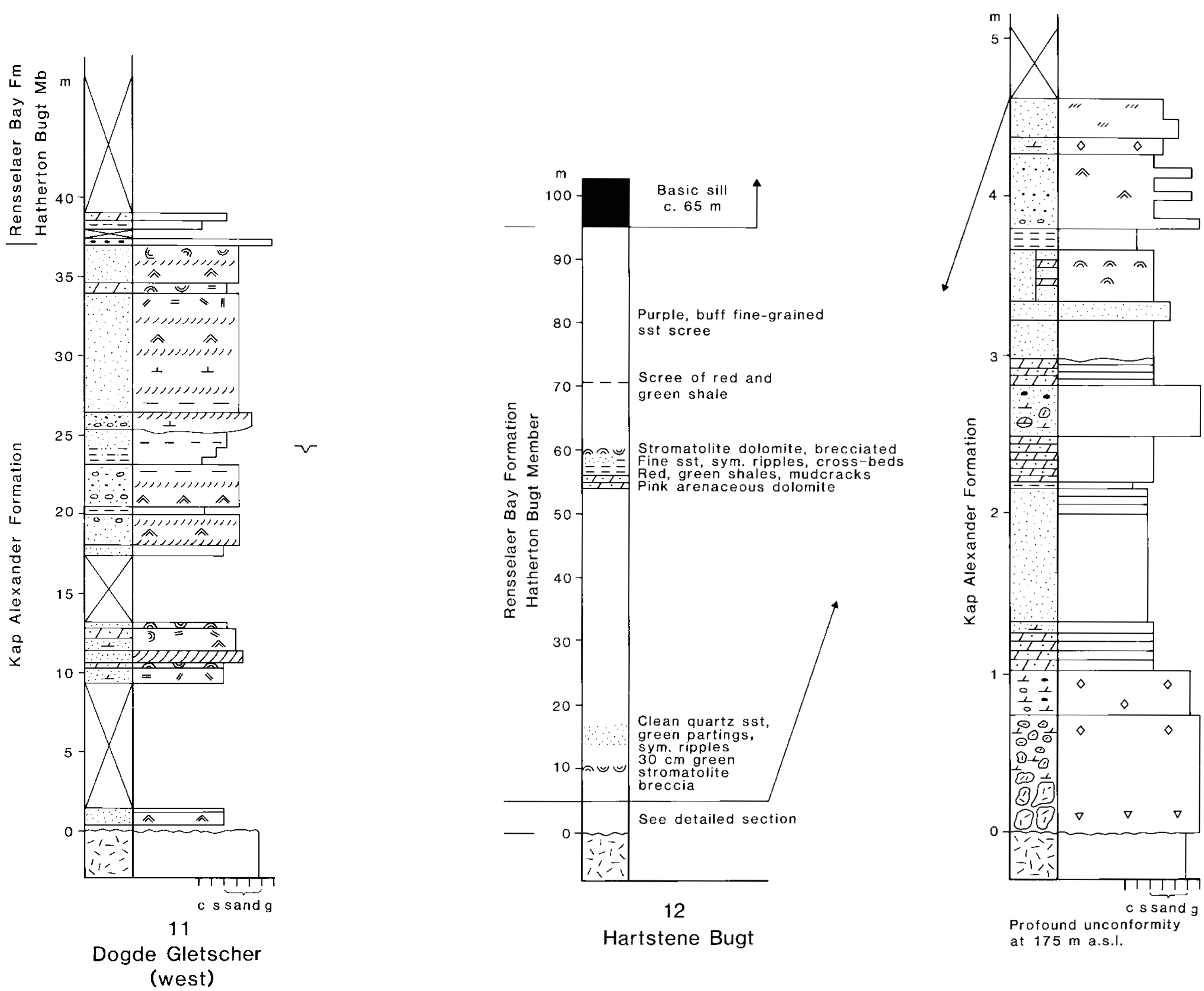


Fig. 29. Stratigraphic logs of the Kap Alexander Formation and generalised section of the Rensselaer Bay Formation. Section 11 is the type section at Dodge Gletscher located in Figs 27 and 28; section 12 is located in Fig. 23.

Fig. 30. Bedding characteristics of the Kap Alexander Formation. Massive, lenticular sandstone interleaved with finer grained beds that display low-angle cross-bedding. Hammer arrowed as scale. Coast, south of Storm Gletscher (Fig. 27).

Lithology. The formation is dominated by clean, white to grey and pale pink, medium-grained quartz sandstones that are generally medium to thick bedded and characterised by lenticular and cross-bedding (Fig. 30). The sandstones are well sorted with subrounded to well-rounded quartz grains with occasional feldspar; some have a 'sugary' quartzitic texture. Some beds show conspicuous quartz granules and there is a gradation to pebbly sandstone and conglomerate characterised by well-rounded quartz pebbles. Several coarse sandstone beds show channelled bases. A common association is medium to coarse sandstones that show thickness variation interbedded with finer grained, more fissile sandstone (Fig. 30). Tabular cross-bedding in sets generally less than a metre is common, and some beds show herringbone cross stratification. Wave and asymmetrical ripples occur.

Argillaceous material is restricted to thin lamellae and partings, and to very occasional thin, green to purple shale beds often interbedded with purple, fine-grained sandstones as at the type section (Figs 28, 29). These beds, together with areas of dark brown ferruginous sandstone, provide the only colour variation to the formation. The ferruginous material occurs in small spots and patches to lamellae that cause a distinct bedding-parallel banding, liesegang rings and irregular and

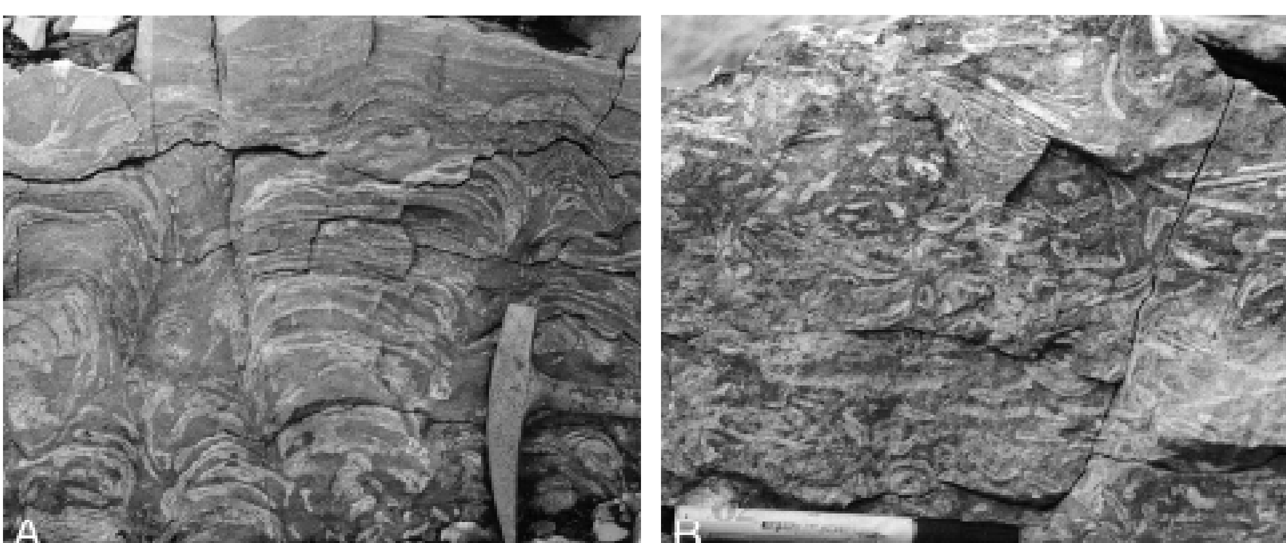


Fig. 31. Stromatolitic arenaceous dolomites of the Kap Alexander Formation. **A:** columnar stromatolites; **B:** breccia of stromatolite clasts; from respectively Dodge Gletscher sections L and M (Fig. 39). Hammer head is 17 cm, pen is 12 cm long.

discordant dark brown veins and ferruginous dykes up to two centimetres thick.

In the thin northern exposures some sandstones are calcareous and thin beds of pale green arenaceous dolomite occur. White stromatolites occur either in growth position or as resorted clasts and in flat-pebble conglomerates (Fig. 31). Several stromatolite conglomerate beds characterise the upper part of the formation at Dodge Gletscher (see Fig. 39).

At one section where the contact with the crystalline shield is exposed (section 12, Fig. 29), conglomeratic material including granitic fragments occur up to 3 m above the unconformity. The basal bed is a red stained breccio-conglomerate about 75 cm thick, clast-supported at the base, matrix-supported above, that is composed of green-weathered (?glauconite) granite boulders, cobbles and pebbles in a pale dolomitic matrix. The red granite below is heavily fractured and weathered, and is penetrated by veins of pink arenaceous dolomite.

Depositional environment. The clean, thick-bedded sandstones with prevalent cross-bedding, some of which is of herringbone type, are taken to indicate overall deposition on a shallow intertidal shelf. The thinner, northern strata containing stromatolitic dolomites showing frequent reworking suggest shallower water conditions, probably of the high tidal or supratidal zone.

Fossils. Stromatolites.

Boundaries and correlation. The lower boundary of the formation is only exposed in Inglefield Land, i.e. north of Kap Alexander where it is in contact with the crystalline shield. At McCormick Bugt the formation conformably overlies the Pandora Havn Formation, while to the east and north it overlaps onto the crystalline basement. The upper boundary, described later under the Rensselaer Bay Formation, is a disconformable contact with the Hatherton Bugt Member (see Figs 34, 39).

The formation may contain strata coeval with those of the Cape Camperdown Formation; to the south it is a supposed correlative of the Clarence Head Formation of the Nares Strait Group (Figs 11, 120).

Rensselaer Bay Formation

redefined

Composition. This redefinition entails a considerable reduction of stratigraphic range. The formation is now restricted to the middle part of the Rensselaer Bay sandstone of Troelsen (1950a) as exposed at Rensselaer Bugt and environs and at Bache Peninsula. It is represented by sub-members C and D of the Camperdown Member of Christie (1967) at Bache Peninsula, the Hatherton Member of Cowie (1961, 1971) in Inglefield Land south of Force Bugt but excluding basal strata between Hartstene Bugt and Dodge Gletscher (herein referred to the Pandora Havn and Kap Alexander Formations), and in northern Prudhoe Land, sandstone

Fig. 32. Rensselaer Bay Formation (RB) in the sea-cliffs on the western side of Rensselaer Bugt showing the disconformity with the Palaeozoic. The dark layer marked by the arrow contains an erosional relict of basic sill under the red beds of the Cambrian Dallas Bugt Formation (DB). A section about 3 km to west (section 9, Fig. 17) has eroded basic sill at the unconformity; to the east (section 8, Figs 17, 33) it is absent. H = Hatherton Bugt Member, F = Force Bugt Member, CC = Cape Camperdown Formation. Cliffs about 300 m high with the sea-ice at bottom right.

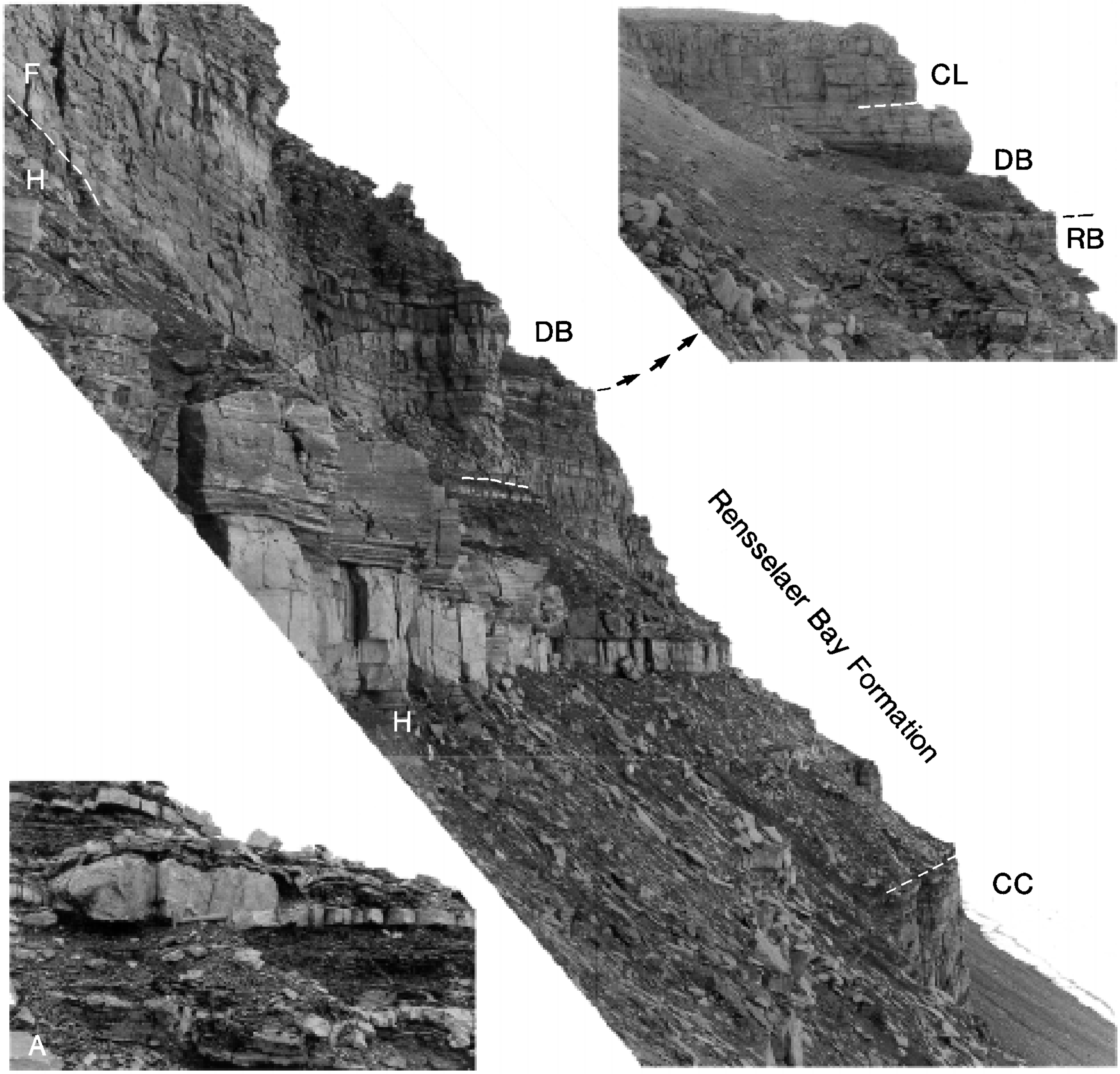


Fig. 33. Lithological characteristics of the Rensselaer Bay Formation (RB) at the type section (section 8, Fig. 17) with disconformities to the Cape Camperdown Formation (CC) and Cambrian Dallas Bugt Formation (DB). H = recessive Hatherton Bugt Member, F = cliff-forming Force Bugt Member, C = Cambrian Cape Leiper Formation. Pale resistant sandstone in the middle section is about 2 m thick. **Inset A:** from a strike section (section 9, Fig. 17) showing irregular and bulbous stromatolite beds of arenaceous dolomite within purple and green shales that is a typical lithology of the upper part of the Hatherton Bugt Member. Western Rensselaer Bugt.

formation B of Dawes (1979a) and the middle of three unnamed sandstone units of Dawes (1976a) and Peel *et al.* (1982).

Name. After Rensselaer Bugt, Inglefield Land, a prominent bay and the type locality of Troelsen's (1950a) Rensselaer Bay sandstone (Figs 2, 5A, 18).

Distribution. In Greenland, Inglefield Land and northernmost Prudhoe Land from the Bancroft Bugt area to Sonntag Bugt; in Canada at Bache Peninsula (Fig. 12). Its precise distribution in central Inglefield Land is unknown. A small outlier at MacMillan Glacier, west of Wade Point, (Frisch & Christie, 1982; Fig. 2), is referred to this formation.

Geomorphic expression and overall colour. A red and purple weathering sequence that, apart from basic sills,

Fig. 34. Unconformity between the Rensselaer Bay (RB) and Kap Alexander (KA) Formations; for stratigraphic detail see Fig. 39. Northern side of Dodge Gletscher; person on right as scale.

is recessive and very often scree covered, particularly where it directly overlies crystalline basement (Figs 7, 9, 32).

Type section. The type section is on the west side of Rensselaer Bugt in the sea-cliffs (section 8, Figs 16, 17); a reference section was measured farther west along the coast (section 9, Fig. 17). Other reference sections are the type and reference sections named for two members of the formation (Hatherton Bugt and Force Bugt Members; section 13, Fig. 35; section 17, Fig. 42).

Thickness. The formation reaches a maximum thickness of about 145 m in southernmost exposures at Radcliffe Pynt (Fig. 12). At Rensselaer Bugt it ranges from about 40 m to 70 m thick decreasing to zero towards the east and north-east; at Bache Peninsula it has a maximum thickness of about 65 m wedging out towards the west (Fig. 15).

Dominant lithology. A complex sequence of multicoloured, dominantly reddish sandstones and siltstones, with red and green shales and pale dolomitic rocks characterised by stromatolites (Fig. 33). The sandstone/shale ratio shows marked lateral variation, as is well seen in the cliffs on the west side of Rensselaer Bugt; vertically the formation is more sandy upwards. Shale, sandstone and dolomite characterise the lower and middle parts of the formation (Hatherton Bugt Member); sandstone with minor shale, the upper part (Force Bugt Member).

Depositional environment. The Rensselaer Bay Formation is taken to represent deposition in intertidal to supratidal conditions, possibly a large protected embayment. The passage from the mixed sandstone-shale-dolomite assemblage of the lower member to the siliciclastic upper sequence is taken to indicate shoreline progradation.

Fossils. Stromatolites, algal laminites.

Boundaries and correlation. In northern and southern exposures the Rensselaer Bay Formation disconformably overlies, respectively, the Cape Camperdown Formation and the Kap Alexander Formation (Figs 22, 34). Between Force Bugt and Etah, and west of Wade Point, it directly overlies crystalline rocks (Fig. 9). In Inglefield Land as far south as Force Bugt, and on Bache Peninsula, it is disconformably overlain by the Cambrian Dallas Bugt Formation (Figs 15, 32, 33); to the south it has a conformable contact with the overlying Sonntag Bugt Formation although commonly a basic sill follows the contact (Figs 9, 14). Although pertinent outcrop is missing, the formation is considered to be a lateral equivalent of strata of the Baffin Bay Group (Figs 11, 120).

Subdivisions. The formation is divided into two members: Hatherton Bugt and Force Bugt Members. These members are easily recognised in the cliff-sections at Bache Peninsula and between Rensselaer Bugt and Force Bugt but less evident farther south where the formation is poorly exposed.

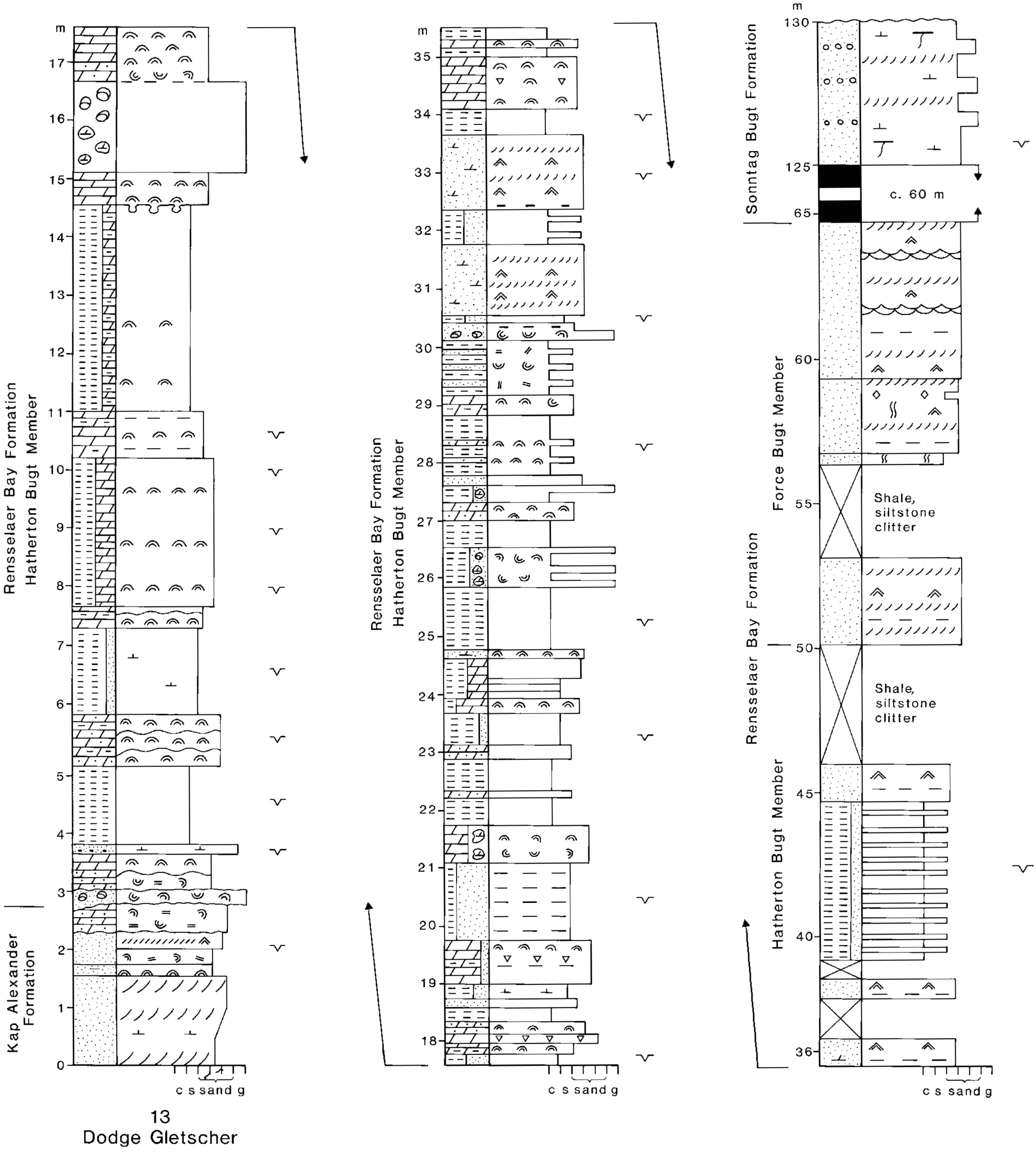


Fig. 35. Stratigraphic logs of the Rensselaer Bay and parts of the Kap Alexander and Sonntag Bugt Formations. Section 13 from the north side of Dodge Gletscher, the type section of the Hatherton Bugt Member of the Rensselaer Bay Formation, is located in Figs 27 and 36. Sections 14 and 15 through basal strata of the Hatherton Bugt Member are 3 km and 1 km respectively west of Etah; section 14 is the same locality as reported on by Cowie (1961; see Fig. 38). Section 16 is from the northern side of Pandora Havn. Sections 14, 15 and 16 are located in Fig. 23. Sections compiled from own data (15, 16) and joint measurement with B. O'Connor (13, 14). Note the varying scales of the sections.

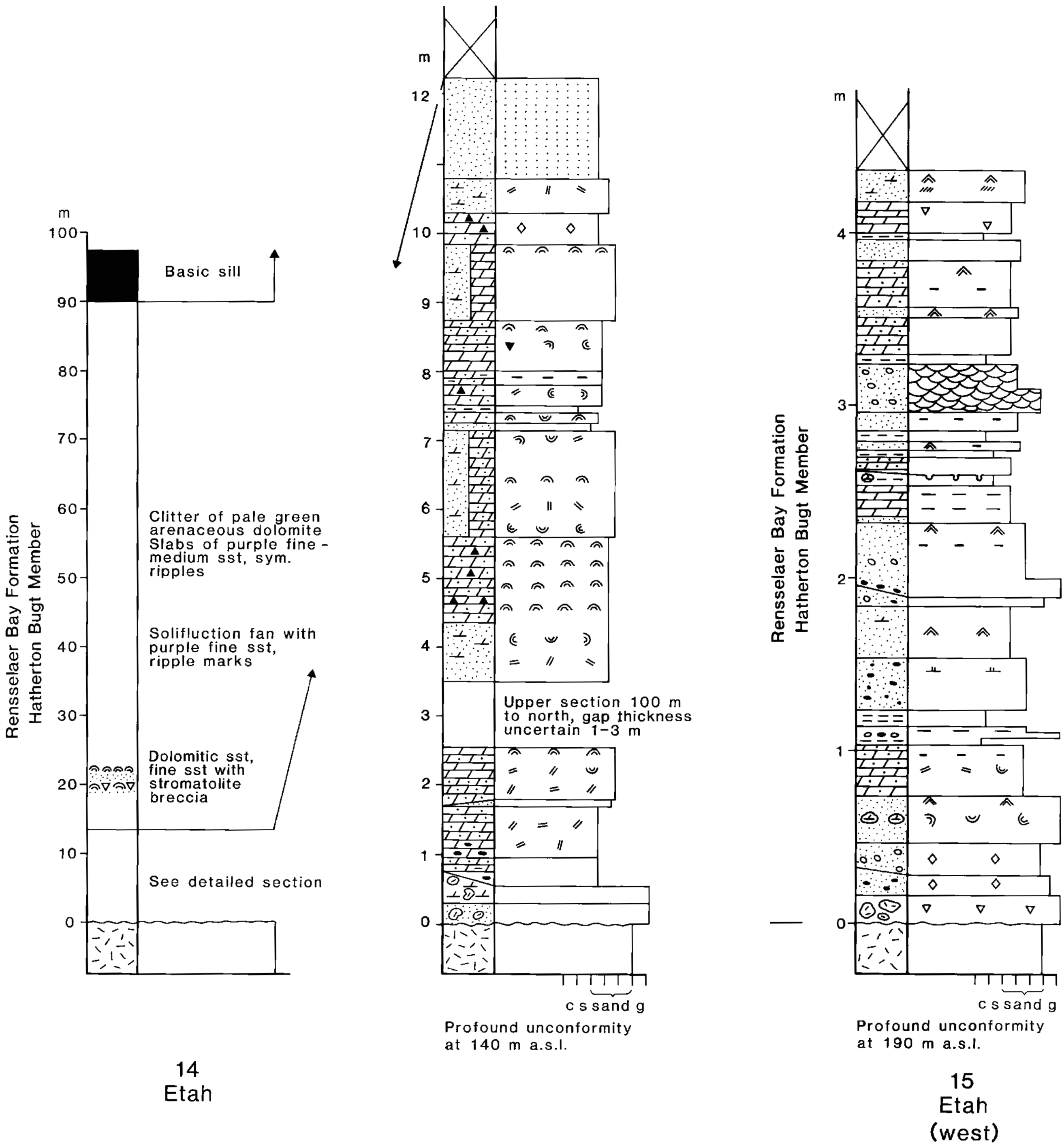


Fig. 35 cont.

Fig. 35 cont. →
Section 16

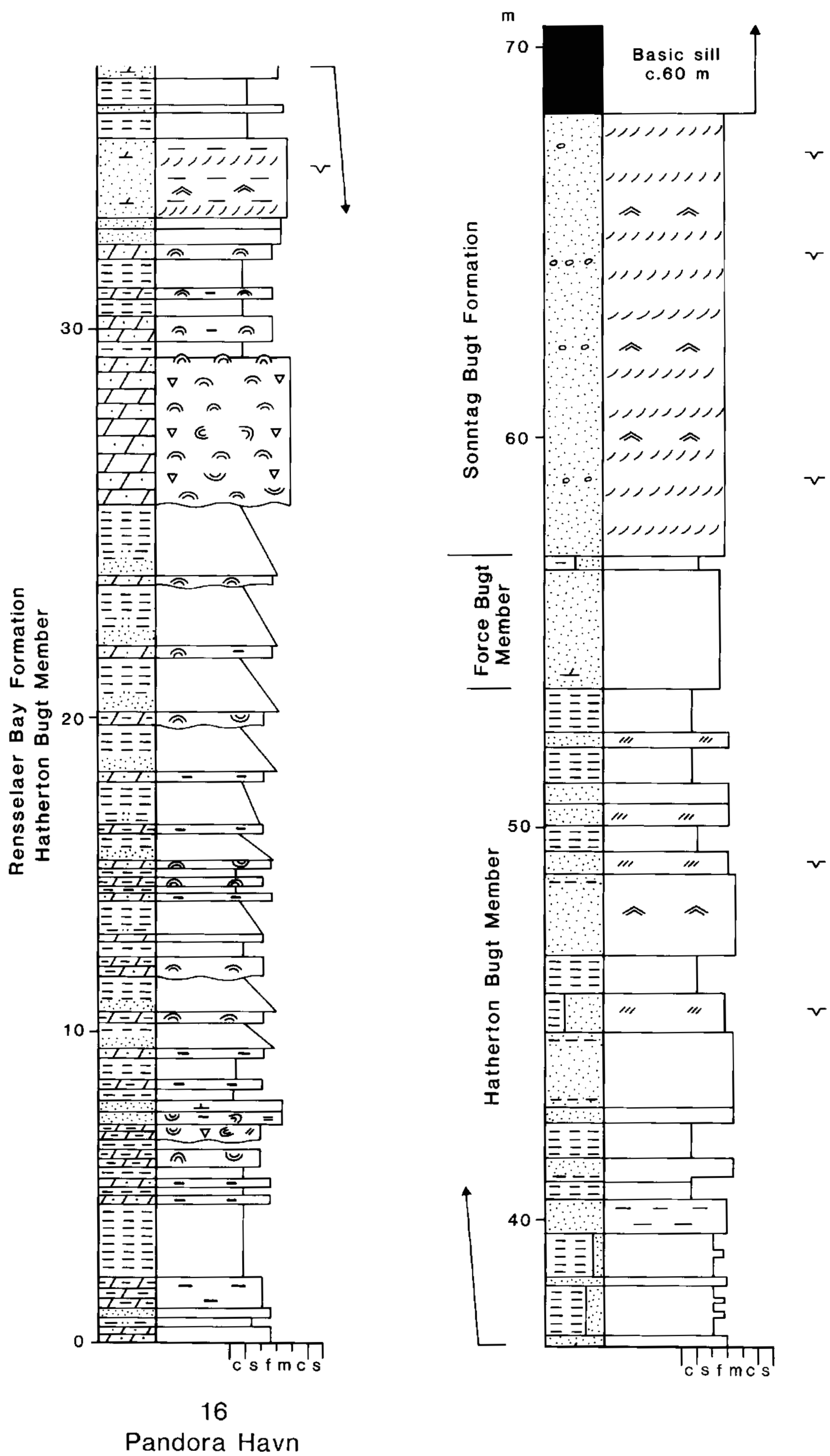


Fig. 35 cont.
Section 16, from the northern side of Pandora Havn, is located in Fig. 23.

Hatherton Bugt Member

new member

Composition. This member encompasses the lowermost strata of the redefined Rensselaer Bay Formation. It includes all but the uppermost strata of the Lower Beds of Cowie (1961) at Hatherton Bugt redefined by Cowie (1971) as the Hatherton Member (Fig. 9), all but the uppermost beds of the sandstone unit B of Dawes (1979a) in northern Prudhoe Land and submember C of the Camperdown Member of Christie (1967) at Bache Peninsula. It should be noted that it does not include the Hatherton Member as defined by Cowie (1971) at Kap Ingersoll or as exposed farther north in Inglefield Land, neither does it include the basal beds of that member as used by Dawes (1976a) in the McCormick Bugt area.

Fig. 36. The type section (foreground ridge) of the Hatherton Bugt Member of the Rensselaer Bay Formation (RB) on the north side of Dodge Gletscher. KA = Kap Alexander Formation, SB = Sonntag Bugt Formation, D = dolerite sill about 60 m thick. Section 13 is given in Fig. 35; for map location, see Fig. 27.

Name. After Hatherton Bugt, the broad bay in south-western Inglefield Land (Figs 2, 9).

Distribution. In Inglefield Land and northernmost Prudhoe Land between Bancroft Bugt area and Sonntag Bugt, at Bache Peninsula and west of Wade Point.

Geomorphic expression and overall colour. A purple to red predominantly recessive unit. Over large parts of south-westernmost Inglefield Land the member is scree-covered (Figs 9, 28; see also Koch, 1933, plate 1).

Type and reference sections. The type section is in the cliffs on the north side of Dodge Gletscher (section 13, Figs 35, 36). Sections measured by Cowie (1961) west of Etah (section 14, Fig. 35) and at Hatherton Bugt and re-examined during this study are poorly exposed; much better reference sections occur at Pandora Havn (section 16, Fig. 35), Rensselaer Bugt (sections 8, 9, Fig. 17), Force Bugt (section 17, Fig. 42) and Radcliffe Pynt (section 18, Fig. 45), although in the latter two sections the base is not seen. Reference sections through basal strata are west of Etah (e.g. section 15, Fig. 35). At Bache Peninsula the best reference section is situated about 7 km west of Cape Camperdown (section 5, Fig. 15).

Thickness. The member shows marked thickness variations. It is thickest in the south, about 130 m at Radcliffe Pynt (see Fig. 45) and thins markedly over the basin margin to under 60 m at the type section. In Hatherton Bugt the member is up to 100 m thick thinning to the north so that at Force Bugt it is between 10 and 20 m thick (see Fig. 42). At Bache Peninsula in eastern outcrops it is about 35 m thick, thinning out to a feather-edge in the west (Fig. 15). To the west of Wade Point the section is topped by the present erosion surface and the member is only a few tens of metres thick (Frisch & Christie, 1982).

Lithology. Interbedded variously coloured mudstone, siltstone and mainly fine-grained sandstones, which in most sections are associated with thin beds of pale

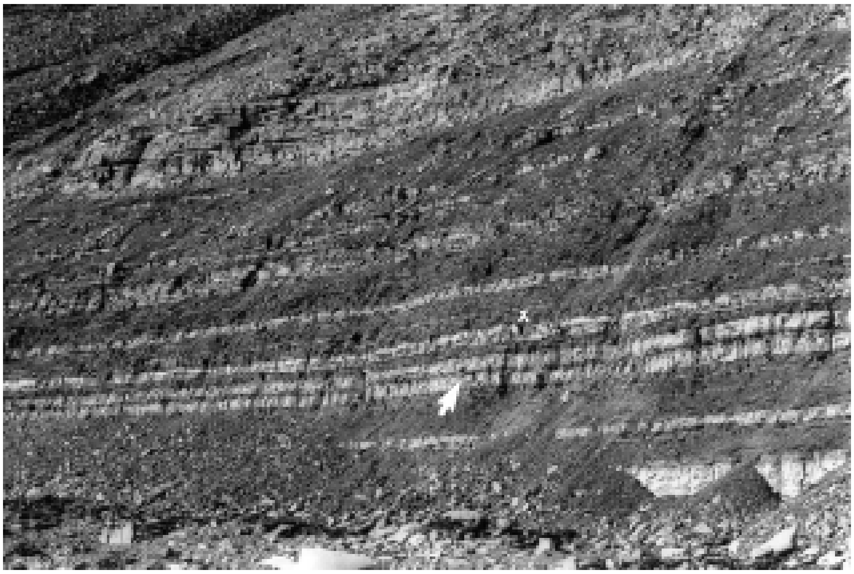


Fig. 37. Typical lithology of the Hatherton Bugt Member of the Rensselaer Bay Formation. Purple shales with thin arenaceous stromatolitic dolomite and breccia beds. Disturbed stromatolite bed at x; hammer arrowed as scale. Northern side of Pandora Havn, section 16.

dolomite and arenaceous dolomite (Figs 36, 37). The member shows marked lithological variation along strike; some sections show prominent sandstone intervals, elsewhere shales and arenaceous dolomite dominate. The basal beds, characterised by stromatolite-bearing sands and carbonates, show lateral variation governed in part by the nature of the substratum. In the Hatherton Bugt – Etah area, where the member directly overlies the crystalline basement, the basal strata, variously dolomitic, contain prominent granite components (Fig. 38). The actual contact is very often a diffuse zone; fractured and weathered granite with veins of dolomite passing upwards into a white to cream-coloured, often red stained, fine-grained dolomite or arenaceous dolomite that contains angular blocks of granite up to boulder size. Arenaceous dolomite up to 1 m above the diffuse zone can contain granite fragments; higher conglomeratic sandstone and dolomite beds contain polymictic clasts.

At Dodge Gletscher the basal strata are characterised by a silicified pink conglomerate up to 45 cm thick composed of stromatolite clasts and green siliceous pebbles set in a pink to green sandstone matrix. This may form the basal bed infilling the irregular surface of the top of the Kap Alexander Formation or it can be up to as much as 2 m above the contact (Fig. 39). The 2 m interval comprises a variety of predominantly purple, thin sandstone and arenaceous dolomite beds characterised by stromatolites either in growth position or resorted; in places a green shale bed, 35 cm thick to a feather-edge, forms the basal bed (Fig. 39).

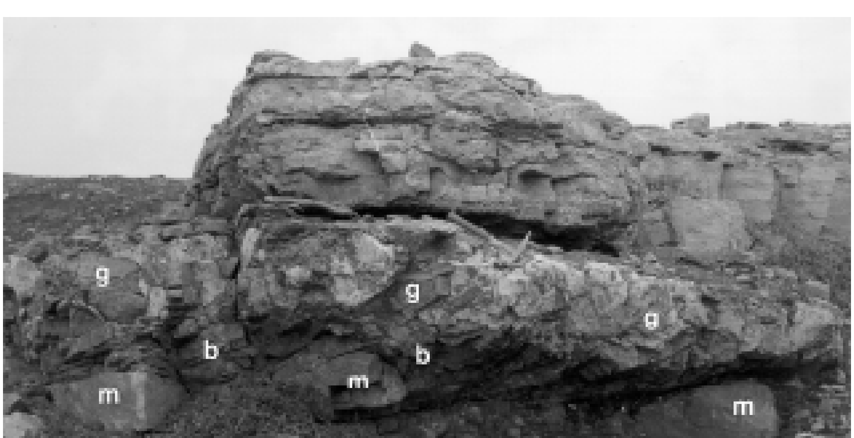


Fig. 38. The unconformity at the base of the Rensselaer Bay Formation (Hatherton Bugt Member) showing rubbly reworked crystalline basement (b) with massive gneiss (m) below, invaded by pale dolomite that contains angular gneiss blocks (g). Overlying beds are arenaceous dolomite with shale. West of Etah, section 14; cf. Cowie (1961, fig. 2).

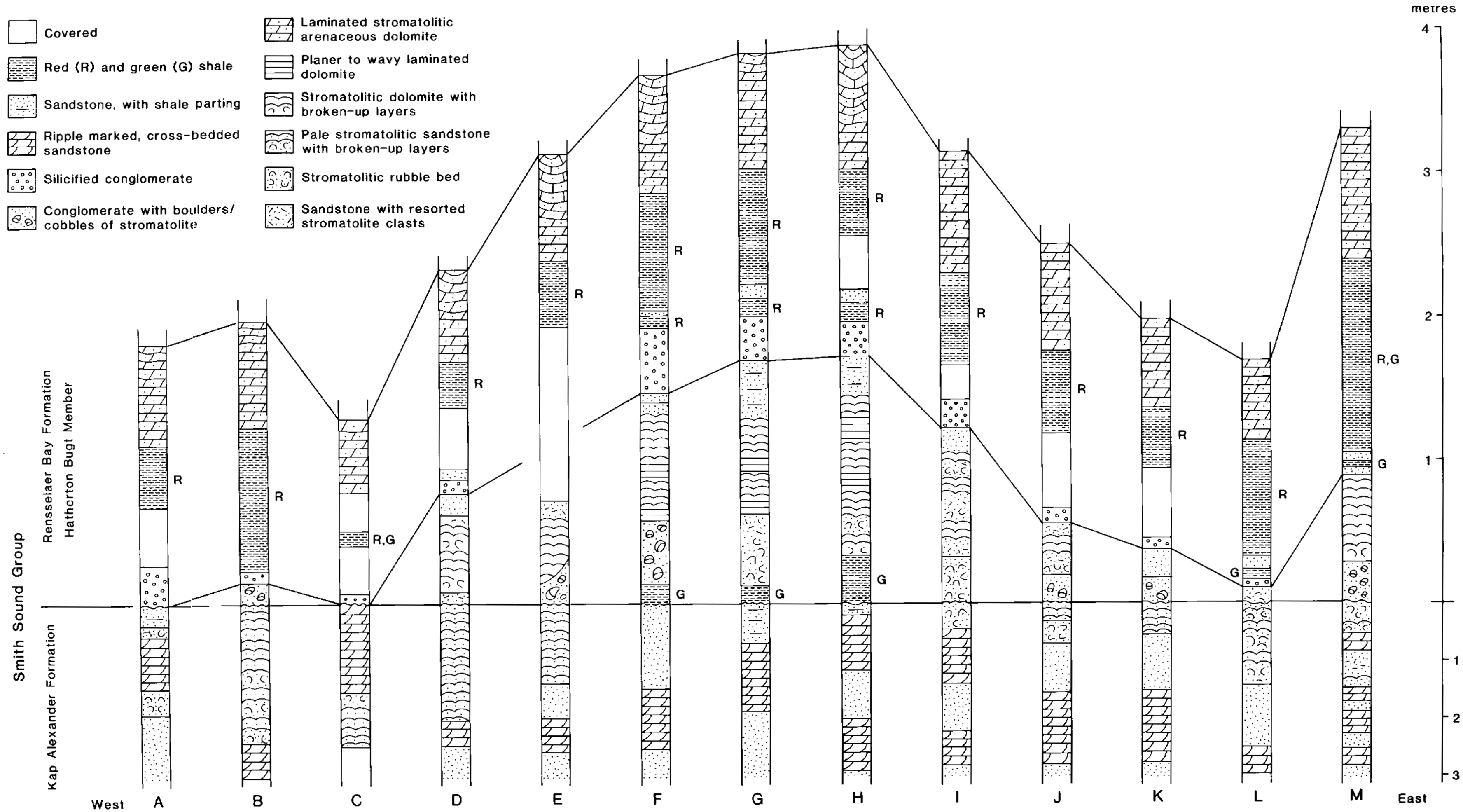


Fig. 39. Stratal variation at the unconformity between the Rensselaer Bay and Kap Alexander Formations at Dodge Gletscher (see Fig. 34). The 13 sections span about 400 m. Largest spacings are 100 and 47 m between respectively sections B & C, and A & B; shortest spacings are 10 and 12 m between sections H & I and I & J. Section M is the base of the type section for the Hatherton Bugt Member, section 13, Fig. 35. Note scale difference above and below the unconformity.

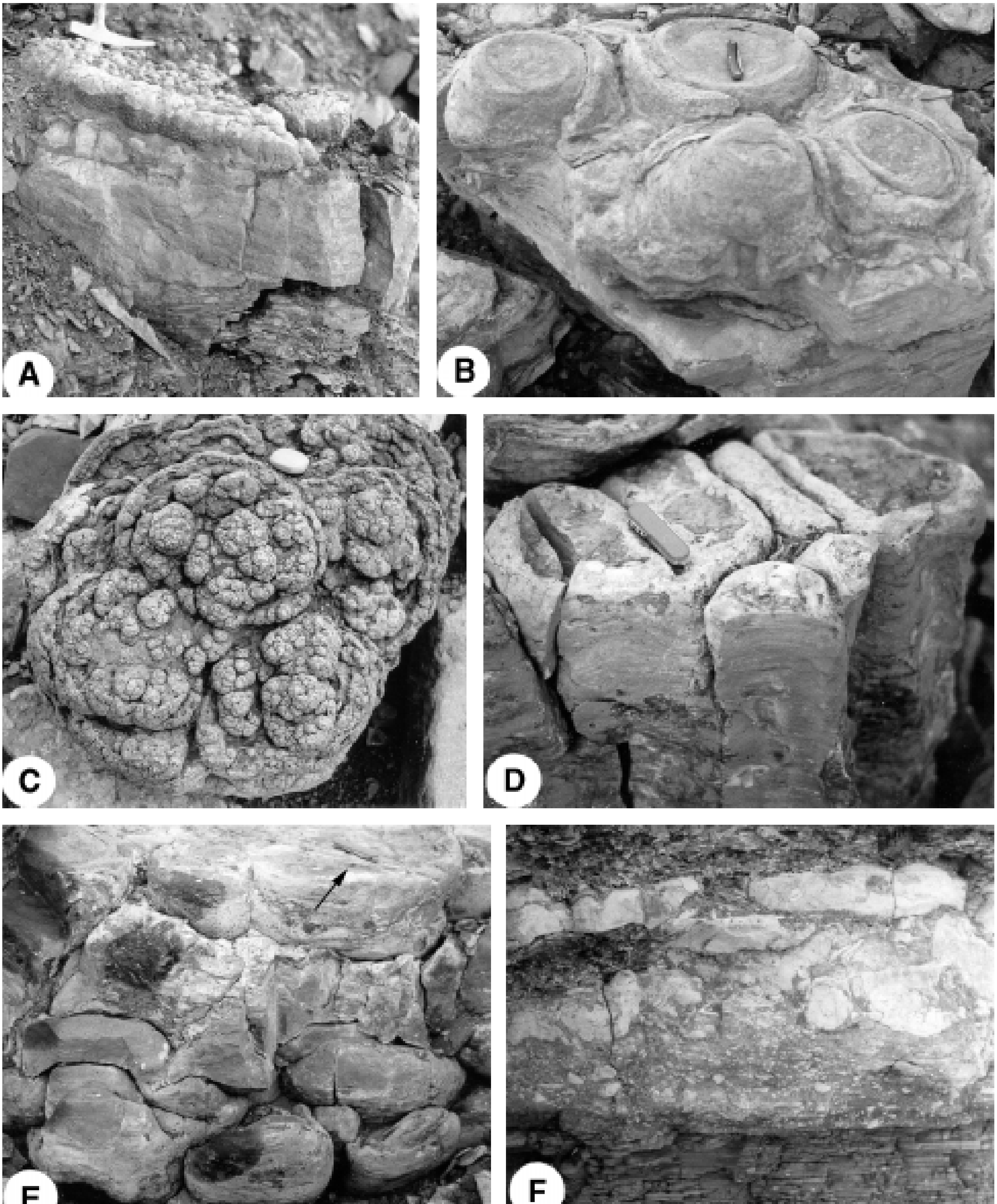


Fig. 40. Stromatolite forms in the Hatherton Bugt Member of the Rensselaer Bay Formation. **A:** arenaceous dolomite bed with bulbous base into shale capped by thin stromatolite bed; **B:** pudding-shaped domes with flat to concave surfaces; **C:** cauliflower dome; **D:** bulbous elephant-foot columns with concave tops; **E:** flat-topped bulbous domes separated by wavy laminated dolomite; **F:** breccia bed, 40 cm thick, with stromatolites in growth position at top, disturbed and rotated forms below and reworked clast breccia at base. Locations: **A**, Rensselaer Bugt, section 9; **B, D** and **E**, Dodge Gletscher, section 13; **C**, Force Bugt, section 17; **F**, Hartstene Bugt, section 12. Scales: Hammer head 17 cm, penknives 7–9 cm, eraser 4 cm.

The sandstones are purple, maroon, red, brown and buff, mainly fine-grained quartz arenites varying to calcarenites and arenaceous dolomite, and they are characteristically thin bedded. They are often flaggy with shale partings showing desiccation cracks. Some of the thicker beds up to 50 cm are cross-bedded. At Dodge Gletscher and elsewhere, distinct benches are formed of white to pale pink medium-grained sandstone characterised by well-rounded quartz grains, sometimes with a carbonate matrix and with in places festoon cross-bedding.

The shales and siltstones are typically red to purple with some green beds. They are interbedded on all scales with sandstone, and many discrete shale units contain thin silts and sand layers. Mudcracks are common. A common association is with thin dolomite beds. In places the strata are arranged in fining-up units up to 1.5 m thick, fine sandstone and siltstone passing upwards into shale that is overlain by stromatolitic dolomite.

The dolomites, pale green and pink and variously argillaceous and arenaceous, form planar to lenticular and irregular beds varying from a few centimetres to about 40 cm, rarely up to 90 cm. Discrete dolomite units interbedded with shale may represent single beds, but thick-bedded units up to 4 m occur in Hatherton Bugt and Pandora Havn. The base of the member at Etah is particularly dolomite rich. Generally, the dolomites show irregular internal structures, but both algal lamination, and columnar and domal stromatolites are common (Fig. 40). All gradations occur from stromatolites in growth position to completely disorganised breccio-conglomerates. Domal stromatolites are usually laterally linked, 10–30 cm in diameter; columnar stromatolites reach up to 40 cm in diameter.

Depositional environment. The alternation of siliciclastic and brecciated stromatolitic clastic carbonates is taken to represent deposition in a high-energy tidal flat or near-lagoonal or lacustrine environment. Carbonate precipitation and stromatolite growth were interrupted intermittently by floods with sand sheet transportation. According to Grey (1995), the internal structure of the stromatolites, together with an oncolitic habit, are consistent with formation in a closed system such as a lacustrine environment subject to seasonal influences. Some of the fining-upwards cycles noted in southern exposures may indicate channel-fill deposits.

Fossils. Stromatolites, algal laminites.

Boundaries and correlation. The lower boundary of the Hatherton Bugt Member is that of the formation; the upper boundary is with the Force Bugt Member. In places both contacts are followed by basic sills. At Dodge Gletscher the disconformable relationship to the Kap Alexander Formation is regarded as a shallow topographic unconformity (Fig. 34). The boundary to the Force Bugt Member is conformable but on a regional scale complicated and the two members are deemed to interdigitate. In many sections, for example at Rensselaer Bugt, the boundary is taken at the abrupt incoming of major sandstone units. Farther to the south the boundary is more arbitrarily drawn at the top of the last shale-siltstone-dolomite strata.

The relationship of the Hatherton Bugt Member to the strata of the central basin to the south is not exposed but the member is a possible lateral equivalent of the Robertson Fjord Formation of the Baffin Bay Group (Fig. 120).

Fig. 41. The type section of the Force Bugt Member (FB) of the Rensselaer Bay Formation at western Force Bugt. Arrows indicate traverse sites for section 17 given in Fig. 42. Dark rocks (s) are two basic sills, the upper of which is at the disconformity with the Cambrian (C). Ps = Precambrian shield, SS = Smith Sound Group, CC = Cape Camperdown Formation. Summit of cliffs about 300 m.

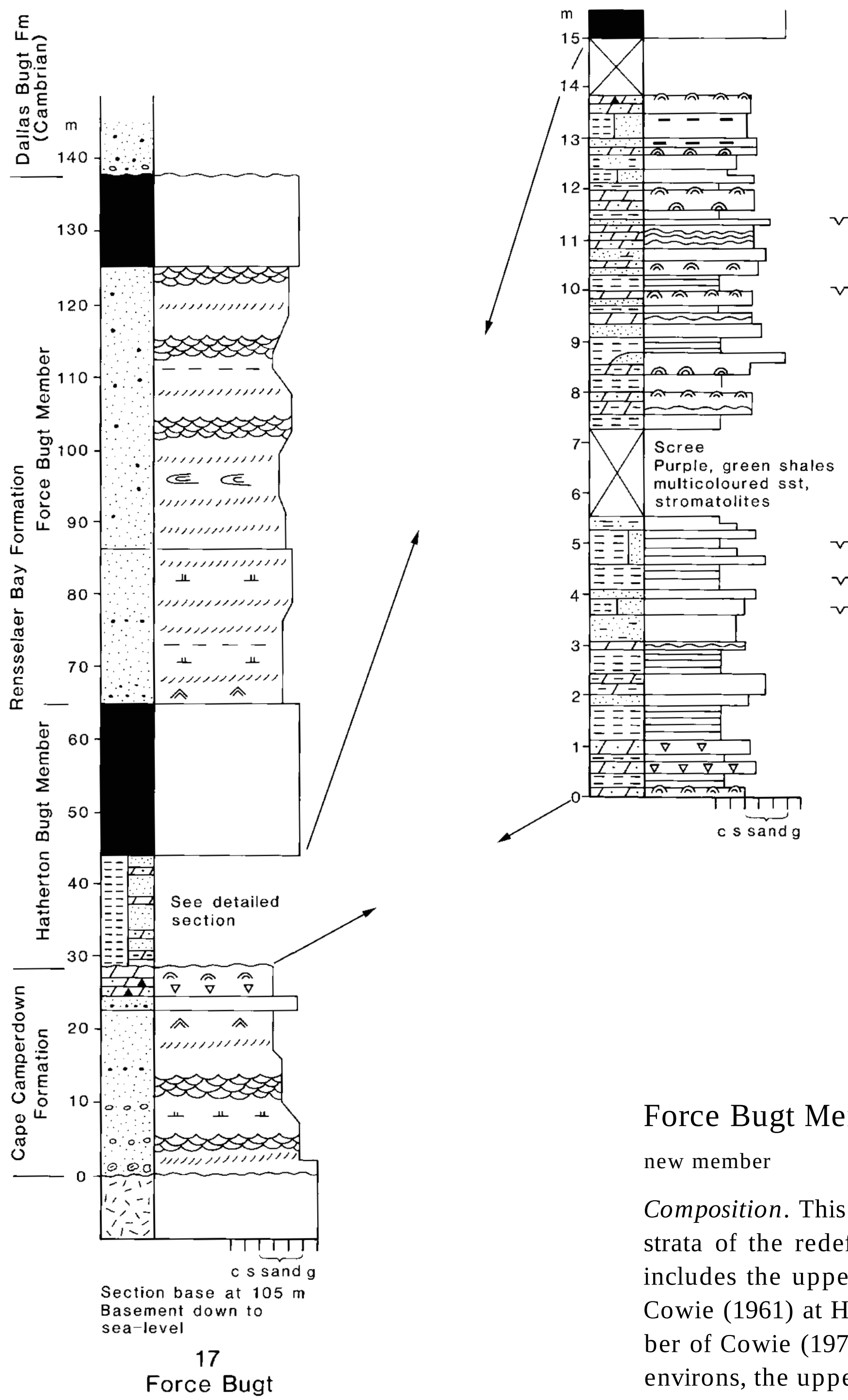


Fig. 42. Stratigraphic log of the Cape Camperdown and Rensselaer Bay Formations, western Force Bugt. This is the type section for the Force Bugt Member that is located in Fig. 41.

Force Bugt Member

new member

Composition. This member represents the uppermost strata of the redefined Rensselaer Bay Formation. It includes the uppermost strata of the ‘Lower Beds’ of Cowie (1961) at Hatherton Bugt, the Hatherton Member of Cowie (1971) as exposed at Kap Ingersoll and environs, the uppermost strata of the Hatherton Member as used by Dawes (1976a), and sub-member D of the Camperdown Member as described by Christie (1967) from Bache Peninsula.

Name. After Force Bugt, the broad bay in south-western Inglefield Land (Figs 2, 41).

Distribution. In Inglefield Land and northernmost Prudhoe Land between the area around Bancroft Bugt and Sonntag Bugt, and at Bache Peninsula.

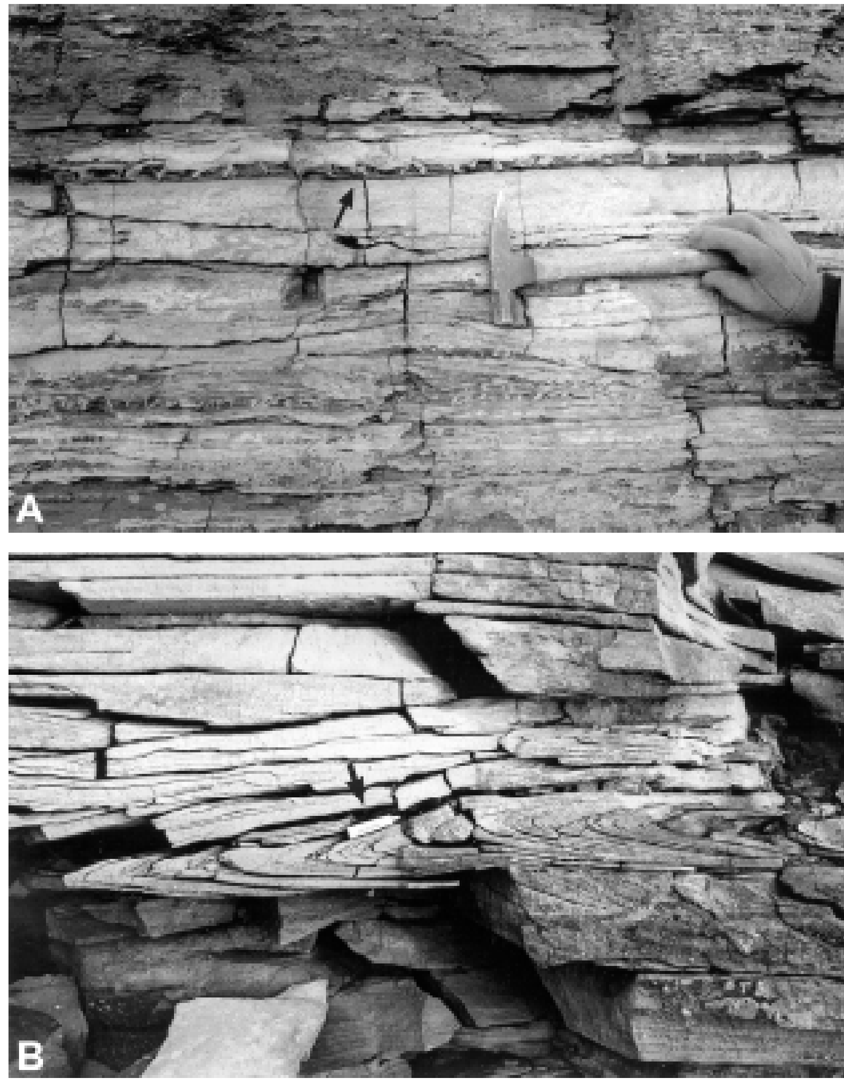


Fig. 43. Bedding characteristics of the Force Bugt Member of the Rensselaer Bay Formation.
A: thin-bedded sandstones with shale interbeds that may be discontinuous and severely disturbed by irregular sandstone infillings interpreted as diastasis cracks, e.g. thin shale bed arrowed. Western Rensselaer Bugt, section 9.
B: long-limbed recumbent fold developed from overturned cross-bedding. Current direction, left to right. Scale (arrowed), is almost 8 cm long. Western Force Bugt, section 17.

Fig. 44. Sea-cliffs of eastern Force Bugt showing the resistant cliff-forming Force Bugt Member (FB) of the Rensselaer Bay Formation and the hiatus with the Cambrian (C). The upper of two basic sills, marked on left, is cut out at the erosional disconformity; the lower sill (s) is visible through the scree that covers the recessive Hatherton Bugt Member. Height of the sea-cliffs is around 250 m, with the sea-ice at bottom left.

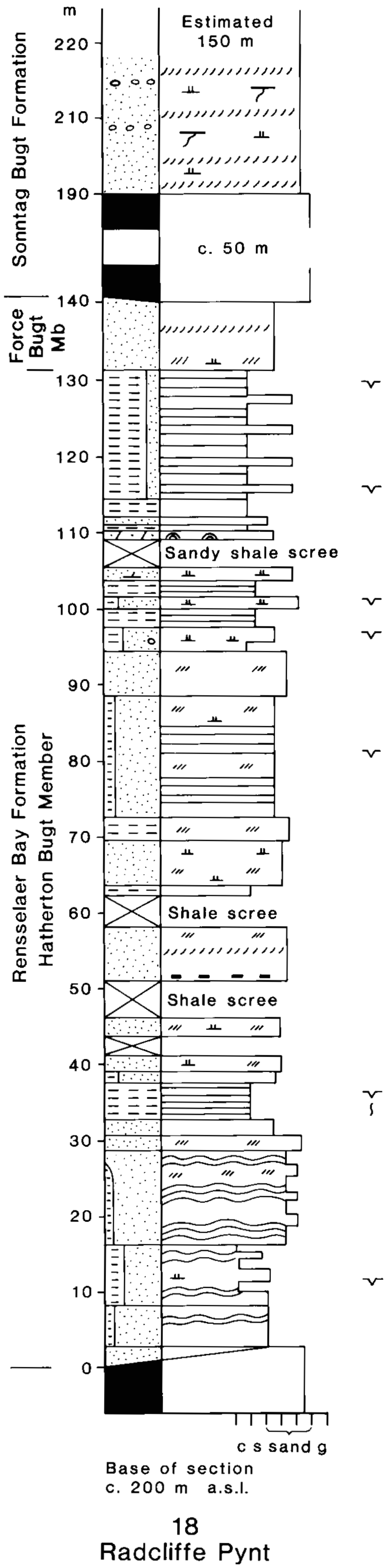


Fig. 45. Stratigraphic log of the Rensselaer Bay and Sonntag Bugt Formations; this is the type section for the latter formation. For location, see Figs 27 and 46.

Geomorphic expression and colour. Pale purple to buff, variously banded, with occasional darker more recessive units; locally cliff-forming but commonly with scree cover (Figs 32, 41).

Type and reference sections. The type section is in the sea-cliffs on the west side of Force Bugt (section 17, Figs 41, 42); reference sections are on the west side of Rensselaer Bugt (sections 8, 9, Fig. 17), at Dodge Gletscher (section 13, Fig. 35) and at Bache Peninsula, for example section 4 about 10 km west of Cape Camperdown (Fig. 15).

Thickness. True sediment thicknesses are obscured by basic sills. The member is thickest at Force Bugt – up to 60 m – thinning to the north and south. At Rensselaer Bugt it is about 25 m thick, at Radcliffe Pynt less than 5 m of strata can be referred to the member. At Bache Peninsula it has a maximum thickness of 30 m pinching out to the west.

Lithology. The main lithology is thin- to thick-bedded, clean to slightly ferruginous sandstones with local thin mudstone and siltstone beds (Fig. 43A). In Inglefield Land, argillaceous lithologies are best developed in northern sections. The sandstones vary in colour: purple, pink, brown, buff and white. Interbedded purple and pale sandstones give the unit a striped or banded appearance.

Sandstones are fine- to medium-grained quartz arenites with typically subangular to poorly rounded grains, with locally coarser beds grading to grits. Beds vary from planar to lenticular. Cross-bedding in planar sets up to 50 cm thick is common, with some herringbone and local trough cross-bedding, as well as overturned cross-bedding (Fig. 43B). Current ripples and symmetrical wave ripples are locally common; channels are seen at some levels.

Argillaceous material varies from shaly laminae and partings in sandstones to discrete planar to lenticular beds of shale, siltstone and sandy shale up to *c.* 30 cm thick. A common feature is the irregular nature of thin shale beds both in bed form and internal structure (Fig. 43A). Mudcracks and the mixing of sands and mud resemble the diastasis cracks of Cowan & James (1992).

Depositional environment. The strata of the Force Bugt Member, that are characterised by wave ripples and bimodal and overturned cross-bedding, are interpreted to represent an intertidal deposit reflecting shoreline progradation over the underlying carbonate-bearing sequence.

Fossils. None known.

Boundaries and correlation. The lower boundary of the Force Bugt Member is with the Hatherton Bugt Member; the upper boundary is that of the Rensselaer Bay Formation (see earlier). In many locations, for example on eastern Bache Peninsula and in Inglefield Land south-west of Rensselaer Bugt, the upper boundary of the Force Bugt Member is a basic sill. Between Rensselaer Bugt and Force Bugt the sill is discontinuous; it shows an irregular weathered top surface and is in places cut out by the overlying Cambrian Dallas Bugt Formation (Figs 17, 32, 44). The Force Bugt Member interdigitates with the Sonntag Bugt Formation in the Force Bugt area.

Sonntag Bugt Formation

new formation

Composition. The formation encompasses the uppermost part of the Rensselaer Bay sandstone of Troelsen (1950a) as exposed between Force Bugt and Dodge Gletscher, the Middle and Upper Sandstones of Cowie (1961), later referred by Cowie (1971) to the Sverdrup Member, sandstone formation C of Dawes (1979a), and the upper of three members at Storm Gletscher illustrated in Peel *et al.* (1982).

Name. After Sonntag Bugt, the prominent bay on the northern coast of Prudhoe Land (Figs 1, 2, 27).

Distribution. Inglefield Land and northernmost Prudhoe Land between Force Bugt and Sonntag Bugt (Fig. 12).

Geomorphic expression and overall colour. A brown, orange to buff weathering, cliff-forming unit, every-

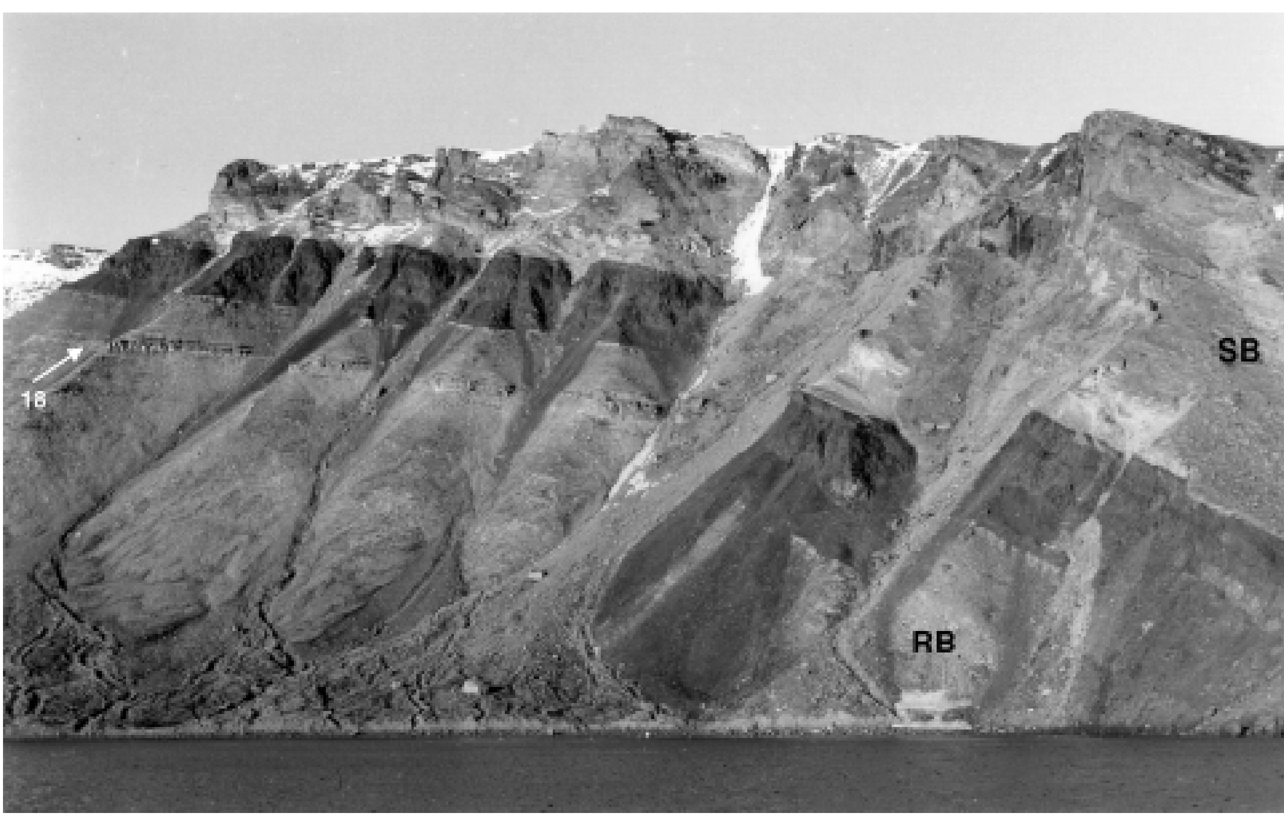


Fig. 46. Faulted sea-cliffs north of Radcliffe Pynt showing cliff-forming sandstones of the Sonntag Bugt Formation (SB) overlying the more recessive Rensselaer Bay Formation (RB); the contact is followed by a basic sill about 50 m thick. This is the type section for the Sonntag Bugt Formation (section 18, Fig. 45). For map location, see Fig. 27.

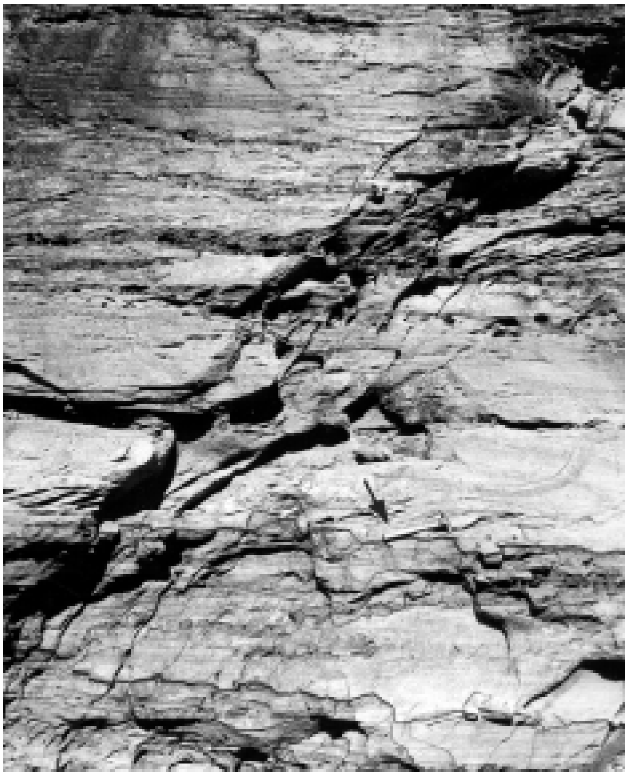


Fig. 47. Bedding characteristics of the Sonntag Bugt Formation. Medium to thick cross-bedded, variously laminated, ferruginous sandstones. Liesegang rings just right of hammer (arrowed). Coast, north of Radcliffe Pynt.

where associated with basaltic sills, as illustrated in the tiered landscape at Crystal Palace Cliffs (Fig. 23).

Type and reference sections. The type section is in the cliffs north of Radcliffe Pynt (section 18, Figs 45, 46); reference sections are at Dodge Gletscher, McCormick Bugt (sections 13, 16, Fig. 35) and in Hatherton Bugt (Fig. 9).

Thickness. Ranges from 15 to 180 m (Fig. 12). The formation is thickest in the south at Radcliffe Pynt and McCormick Bugt. Although the top of the formation over most of its outcrop is the present erosion surface, the southerly thickening is taken to be an original feature corresponding to the thickening shown by the underlying Kap Alexander and Rensselaer Bay Formations over the basin margin.

Lithology. Well-bedded, clean to ferruginous quartz arenites with cross-bedding and ripple marks common (Fig. 47). Fresh surfaces are cream, buff, grey or brown in colour; pale pink to purple hues appear due, at least in places, to contact metamorphism adjacent to basic intrusions. Orange to yellow weathering colours are very characteristic.

The quartz arenites are generally medium grained and well sorted with subangular to subrounded grains. Variations to fine sand and to coarse grit occur. Grit, fine conglomerate and pebbly conglomerate are characterised by very well-rounded quartz grains and pebbles, in combination with a much less rounded, finer grained matrix. Some sandstones are finely laminated; mudstone partings show desiccation cracks. Cross-bedding in tabular sets up to 30 cm is common; some cross beds are up to 60 cm thick.

In all sections examined, some intervals show dark brown, highly ferruginous veins and irregular partings that can reach a centimetre or more in thickness. These veins may show a random pattern but are oblique to bedding. They are characteristically composed of well-rounded quartz grains separated by iron oxide and may represent wind-blown sand infillings. Liesegang rings also occur (Fig. 47).

Depositional environment. The interpretation of the sedimentary environment is tentative; shallow water to subaerial deposition is suggested. The rudaceous incursions might represent a fluvial source and the sand infilling structures may be subaerial.

Fossils. None known.

Boundaries and correlation. Over much of its outcrop the Sonntag Bugt Formation is bounded at the base by a basic sill separating it from the Rensselaer Bay Formation, and at its top by the present erosion surface (Figs 9, 36, 46). Where preserved the sedimentary contact is conformable and fairly abrupt and drawn at the incoming of prominent buff-brown sandstones. In the Force Bugt area, the Sonntag Bugt Formation interdigitates with the Rensselaer Bay Formation, and both formations are overlain disconformably by the Cambrian Dallas Bugt Formation (Fig. 14).

Contact with the Baffin Bay Group is not exposed but the Sonntag Bugt Formation is taken to be a correlative of that group, more specifically of the Qaanaaq Formation (Figs 11, 120).