Lithostratigraphy and depositional setting of the Holm Dal Formation (Middle Cambrian), central North Greenland

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The Holm Dal Formation (late Middle Cambrian) is formally described and assigned to the Tavsens Iskappe Group of central North Greenland. The formation consists largely of fossiliferous argillaceous lime mudstones and dolomites, interbedded at intervals with peloidal packstones and grainstones, carbonate breccia beds and sandstones. Deposition occurred mainly from suspension, but periodically also from mud-rich density currents or storm currents and viscous mass flows in a low-energy, marine outer shelf environment. The Holm Dal Formation records progressive shallowing; it represents the initial stage of a major regressive cycle that culminated in exposure of the shelf.

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The Holm Dal Formation (Middle Cambrian) is one of seven formations making up the Tavsens Iskappe Group in central North Greenland (Figs 1, 2). The carbonates and subordinate siliciclastics assigned to this group have an age range of mid Middle Cambrian to earliest Ordovician and a maximum thickness of 750 m. They form part of the Lower Palaeozoic shelf sequence of the Franklinian basin, which extends across Arctic Canada into North Greenland. These strata are bordered to the south by Precambrian sediments and gneissic basement along the fringes of the Inland Ice and to the north by deformed Lower Palaeozoic trough deposits (Figs 1, 3).

The aims of this paper are firstly to define formally the lithostratigraphy of the Holm Dal Formation and secondly to place the formation in its environmental context within the shelf sequence.

Regional setting

The Franklinian basin extends from Arctic Canada eastward across North Greenland to Kronprins Christian Land (Fig. 1). The preserved sediment column has a thickness of about 8 km and is essentially of Early Palaeozoic age, although possibly extending down into the Precambrian and up into the earliest Devonian (see Peel 1985, for review). Two distinct depositional regimes are recognised within this sequence – a southern shelf bordering the Precambrian craton and a northern deep-water trough. The shelf deposits are largely undeformed whereas the trough sediments were folded during the Devonian Ellesmerian orogeny; the degree of deformation and metamorphism increases northwards to the northern coastline of North Greenland.

The parallel evolution of shelf and trough during the Early Palaeozoic has been described by Surlyk & Hurst (1984), Hurst & Surlyk (1983) and in a recent review article by Higgins et al. (in press). Factors influencing sedimentation in the region included rifting and differential subsidence of the deep-water trough, and Caledonian uplift and nappe emplacement at the eastern limit of the basin. In particular, Surlyk & Hurst (1984) suggested that the position of the shelf-slope break at various stages in its development was governed by several east-west tectonic lineaments. The trough was restricted to northernmost North Greenland in earliest Cambrian times and expanded southwards in steps during the Early Palaeozoic as successive lineaments became active.

From the late Early Cambrian to the early Ordovician, the North Greenland shelf was composed of two major depositional settings: a shallow-water carbonate platform flanked to the north by a deeper-water outer shelf. Outer shelf deposits are a mixed siliciclastic-carbonate assemblage that grades northwards at the shelf-slope break into cherts and shales of the Cambro-Ordovician starved trough sequence (Surlyk & Hurst 1984; Higgins & Soper 1985). This simple palaeogeographic picture is complicated by lateral (east-west) variation in the subsidence history of the shelf. In the west, shelf subsidence was relatively uniform and a thick, conformable sequence of restricted platform carbonates accumulated over a wide area (Ryder Gletscher Group, see

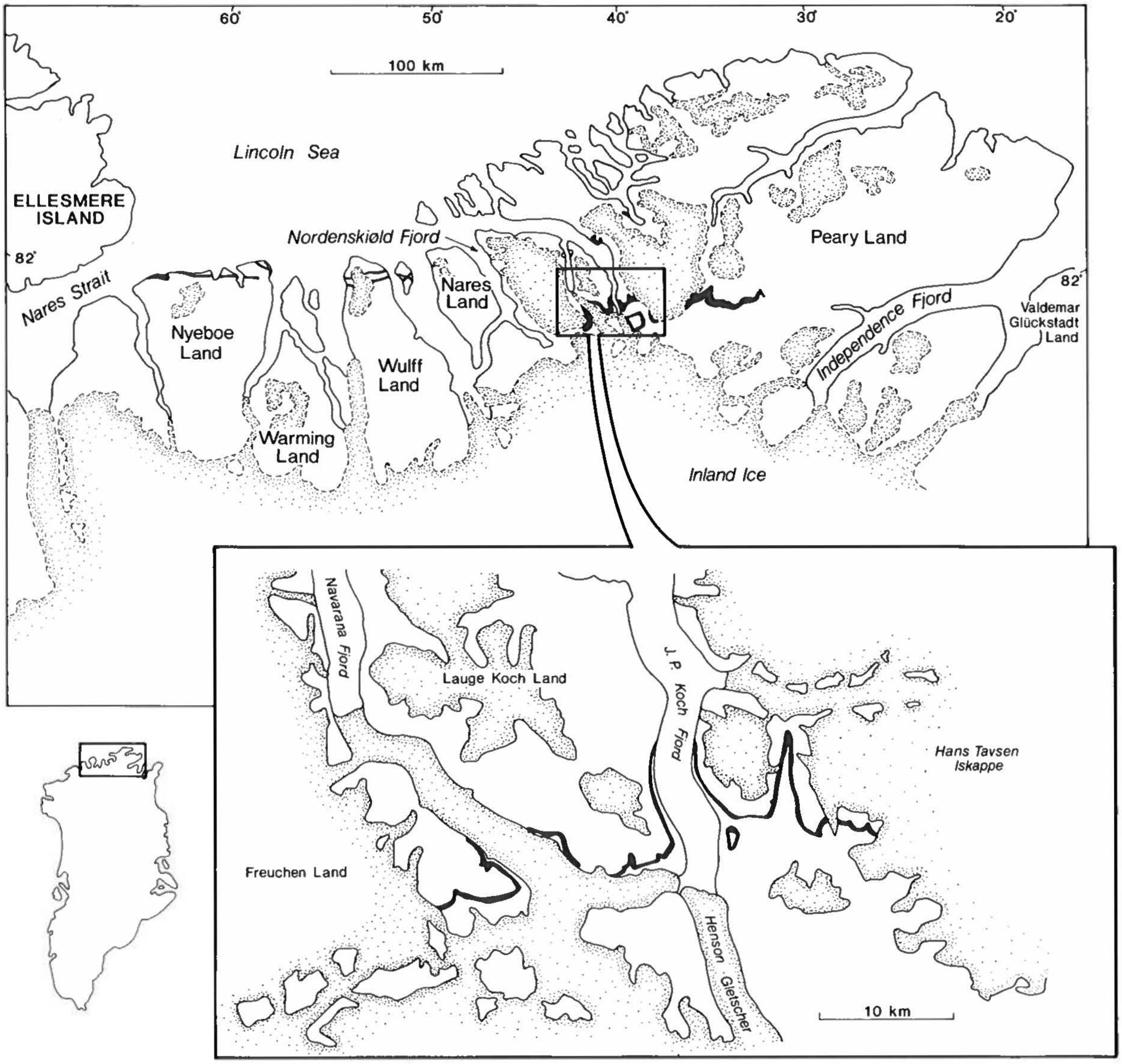


Fig. 1. Map showing the distribution of the Tavsens Iskappe Group (black) in North Greenland. Inset shows the area of outcrop of the Holm Dal Formation across west Peary Land, Lauge Koch Land and east Freuchen Land.

Figs 2, 3); coeval outer shelf deposits crop out on the north coast of Nyeboe Land and Wulff Land, near the transition into the deep-water trough (Fig. 3). Farther east, however, in Freuchen Land, Lauge Koch Land and Peary Land (Figs 1, 3), Cambrian strata record a more complex, tectonically unstable history. Uplift of the easternmost portion of the shelf, probably in response to early Caledonian events (Surlyk & Hurst 1984), resulted in tilting and progressive exposure of the shelf. Shelf subsidence was greatest in Freuchen Land and west Peary Land, where outer shelf conditions persisted over much of the region until the late Middle Cambrian (Fig. 3). Shallow-water carbonates and siliciclastics prograded intermittently northwards from the late Early Cambrian to the early Ordovician but, unlike the western platform sequence, shallow-water, platform-interior facies are only locally preserved due to progressive exposure of the platform (Fig. 3). The stratigraphic importance of the hiatus developed at the top of this regressive sequence decreases westwards and the unconformity is not recognised farther west than Nares Land (Peel & Wright 1985).

This regressive trend from outer shelf to shallow-water carbonate platform is recorded in the Brønlund Fjord and Tavsens Iskappe Groups (Fig. 4). A well-developed reciprocal sedimentation pattern is evident within this sequence; periods of carbonate platform accretion and progradation, probably during relative sea-level highs (cf. James & Mountjoy 1983), alternated with regressive periods characterised by mixed siliciclastic-carbonate sedimentation (Fig. 4). The subject of this paper, the Holm Dal Formation, forms part of the uppermost regressive cycle and is overlain by the Perssuaq Gletscher Formation, a sequence of offlapping siliciclastics that were deposited prior to exposure of the shelf (Surlyk & Ineson 1987).

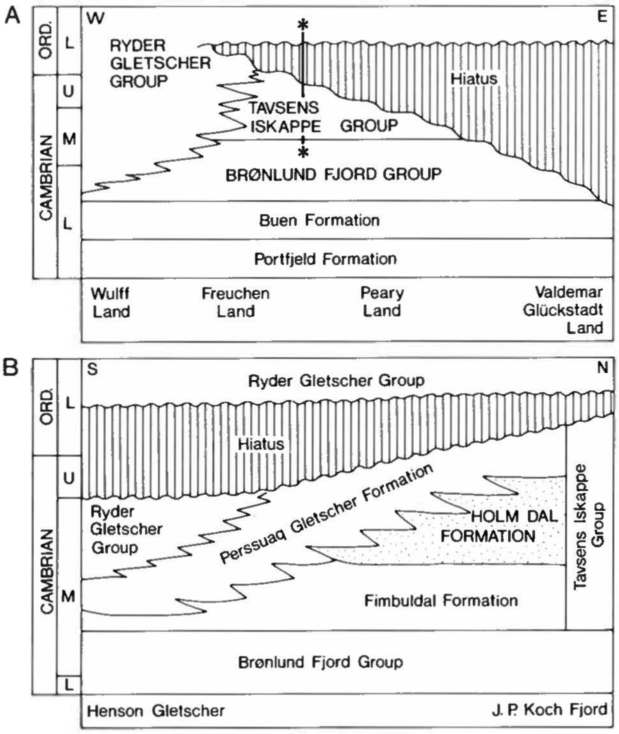


Fig. 2. A: Cambro-Ordovician lithostratigraphic relationships from Valdemar Glückstadt Land in eastern North Greenland to Wulff Land in central North Greenland. Asterisks mark the position of N-S section shown in Fig. 2B. B: Lithostratigraphic relationships of the Tavsens Iskappe Group in a N-S profile in west Peary Land, showing the stratigraphic position of the Holm Dal Formation.

Lithostratigraphy

The Tavsens Iskappe Group was defined by Peel (1979) following fieldwork in 1978, and was discussed further by Palmer & Peel (1979); subsequently Ineson & Peel (1980) and Peel (1982) described seven informal formations within the Tavsens Iskappe Group. The formal lithostratigraphy of the Brønlund Fjord and Tavsens Iskappe Groups is presented by Ineson & Peel (in press; see Fig. 2) but the formal definition of the Holm Dal Formation is more aptly placed here to accompany the following palaeontological and biostratigraphical contributions.

Holm Dal Formation, new formation

History. – The formation has been described informally as formation 2 and formation T2 of the Tavsens Iskappe Group (Peel 1979; Ineson & Peel 1980).

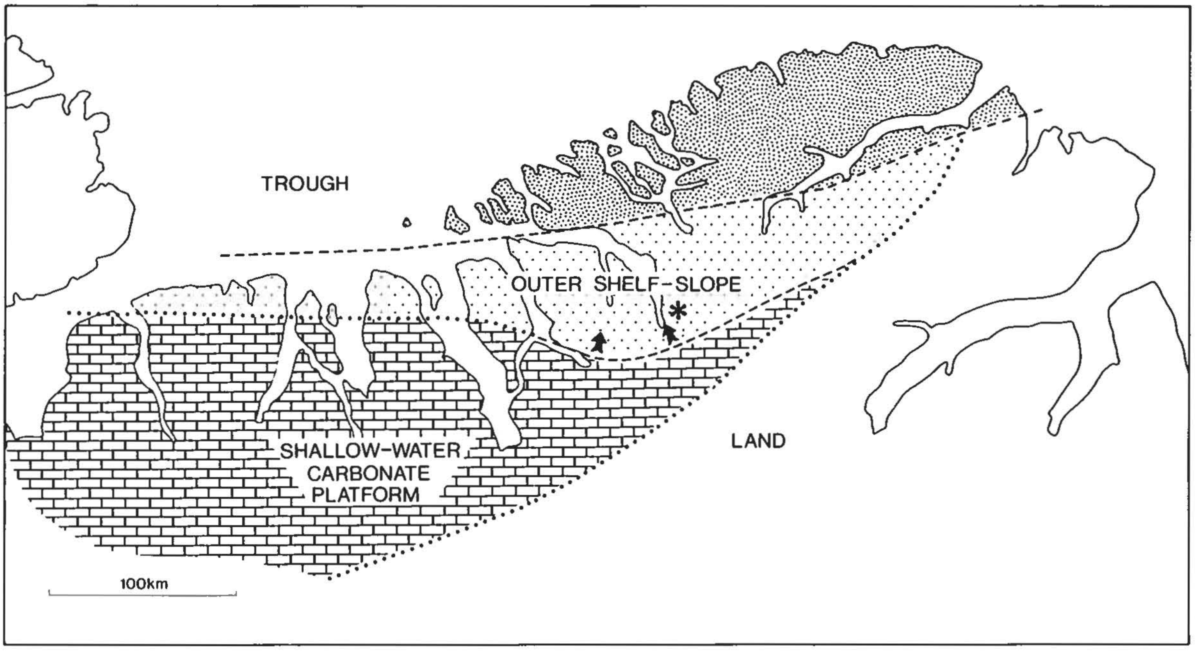


Fig. 3. Palaeogeography of North Greenland during the Middle Cambrian. Arrows show the direction of progradation of the carbonate platform; asterisk indicates the position of Gustav Holm Dal.

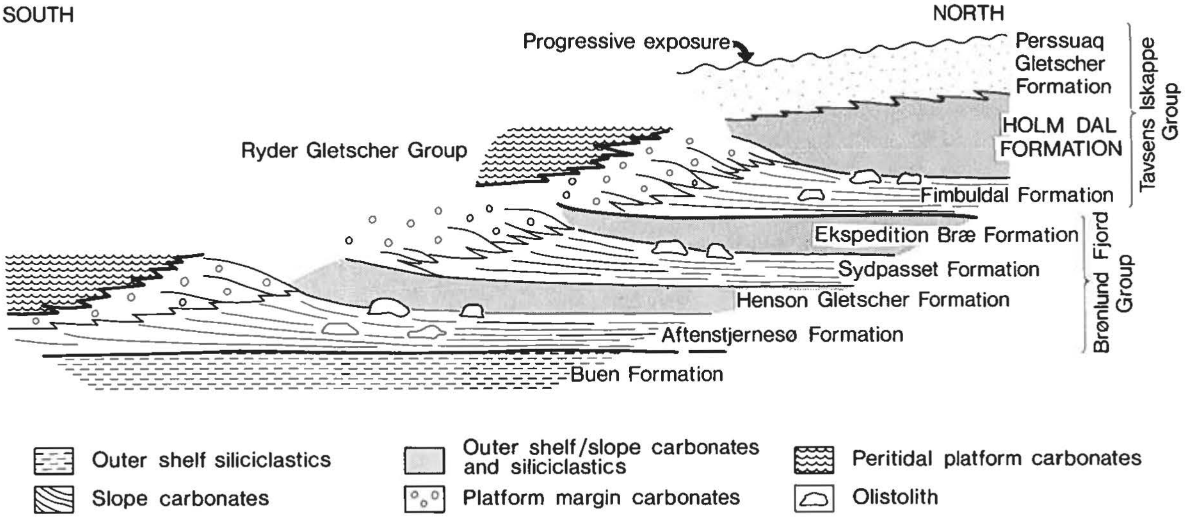


Fig. 4. Schematic diagram showing the evolution of the Cambrian shelf. Note the three major pulses in carbonate platform development, separated by mixed siliciclastic-carbonate shelf deposits.

Name. – After Gustav Holm Dal, the north-south valley linking Fimbuldal with Perssuaq Gletscher, south-west Peary Land (Figs 5, 6).

Type section. – North of the prominent gully on the east side of Gustav Holm Dal, at the junction with Fimbuldal (Figs 5–7).

Thickness. – 155 m at the type locality, thinning south and pinching out 5 km south of the type locality (Fig. 5). The formation appears to thicken northwards from the type section, but exposure is poor.

Lithology. – The Holm Dal Formation lies conformably between the Fimbuldal Formation and the Perssuaq Gletscher Formation (Figs 6, 7) and typically forms recessive dark-weathering slopes between these two pale, cliff-forming formations. The Holm Dal Formation consists largely of thin, parallel and wavy-bedded argillaceous lime mudstones and dark grey, laminated dolomites (Fig. 8). In places these fine-grained limestones are interlaminated with skeletal, peloidal packstones and grainstones. Wavy, thin-bedded peloidal grainstones, packstones and wackestones dominate the upper third of the formation, typically becoming dolomitic upwards. Silty, calcareous mudstones occur as partings and interbeds throughout the formation and quartz sandstones and siltstones are present in the upper levels (Fig. 7). Carbonate breccia beds and slumped horizons occur sporadically throughout. A detailed account of the lithofacies of the formation is given below.

Boundaries. – The base of the formation is a conformable contact, although typically abrupt (Fig. 6). The upper Fimbuldal Formation consists of massive mass-flow carbonate breccias and in many sections the top surface of these deposits is notably irregular. At the type section, this hummocky surface has a relief of up to 5 m and the basal dark, laminated dolomites of the Holm Dal Formation drape the surface topography.

The upper boundary is more complex. In vertical section it is readily placed at the conformable junction between dark, thin-bedded sandy carbonates and pale, cliff-forming carbonate breccias or sandstones (Fig. 9; see also Surlyk & Ineson 1987). On the scale of a fjord cliff-line, however, the diachroneity of this boundary is clear; pale carbonates and siliciclastics of the Perssuaq Gletscher Formation interdigitate northwards with dark carbonates of the Holm Dal Formation (Figs 4, 10). For mapping purposes, this zone of interdigitation is included in the Perssuaq Gletscher Formation.

Distribution. – The Holm Dal Formation crops out around the head of J. P. Koch Fjord in south-west Peary Land and along the cliffs flanking the glacier south of Navarana Fjord (Fig. 1). It wedges out against platform margin carbonates (Perssuaq Gletscher Formation) to the south and west and is not recognised east of Hans Tavsen Iskappe (Fig. 1). Cambrian strata dip northwards beneath Ordovician and Silurian carbonates but reappear in east-west trending anticlines near the northern coast of central North Greenland (Fig. 1; Higgins & Soper 1985). Equivalent outer shelf-slope strata in these inliers are assigned to a new formation of the Tavsens Iskappe Group (Kap Stanton Formation of Ineson & Peel, in press. Unit 3 of Higgins & Soper 1985).

Geological Age. – In its type section the Holm Dal Formation is late Middle Cambrian in age (Robison 1984, this volume). The formation contains a rich fauna

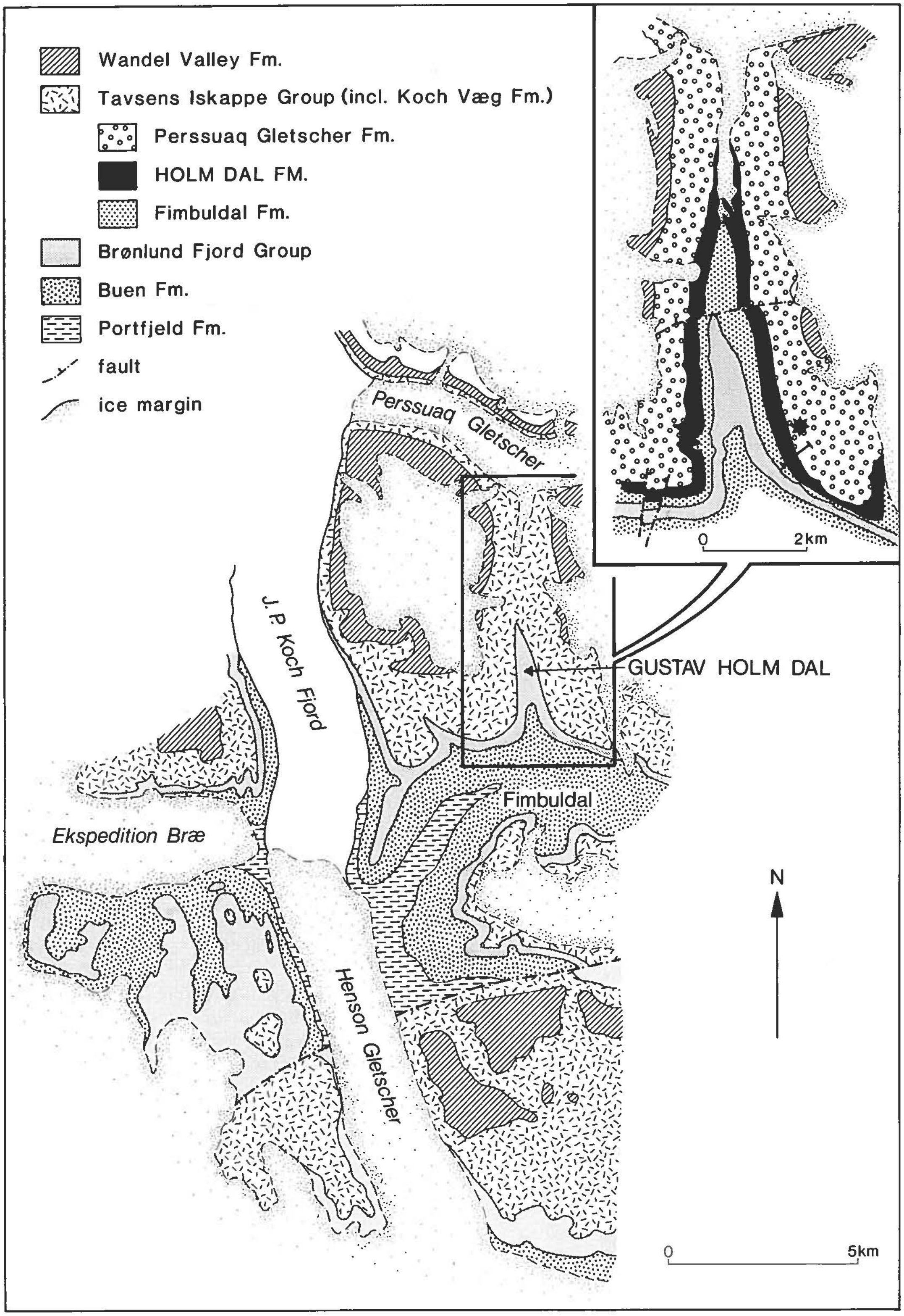


Fig. 5. Geological sketch map of the J. P. Koch Fjord region, west Peary Land. Inset of Gustav Holm Dal shows the position of the type section of the Holm Dal Formation (asterisk). The outcrop of the Tavsens Iskappe Group east of Henson Gletscher and south of the fault includes strata referred to the Koch Væg Formation of the Ryder Gletscher Group.

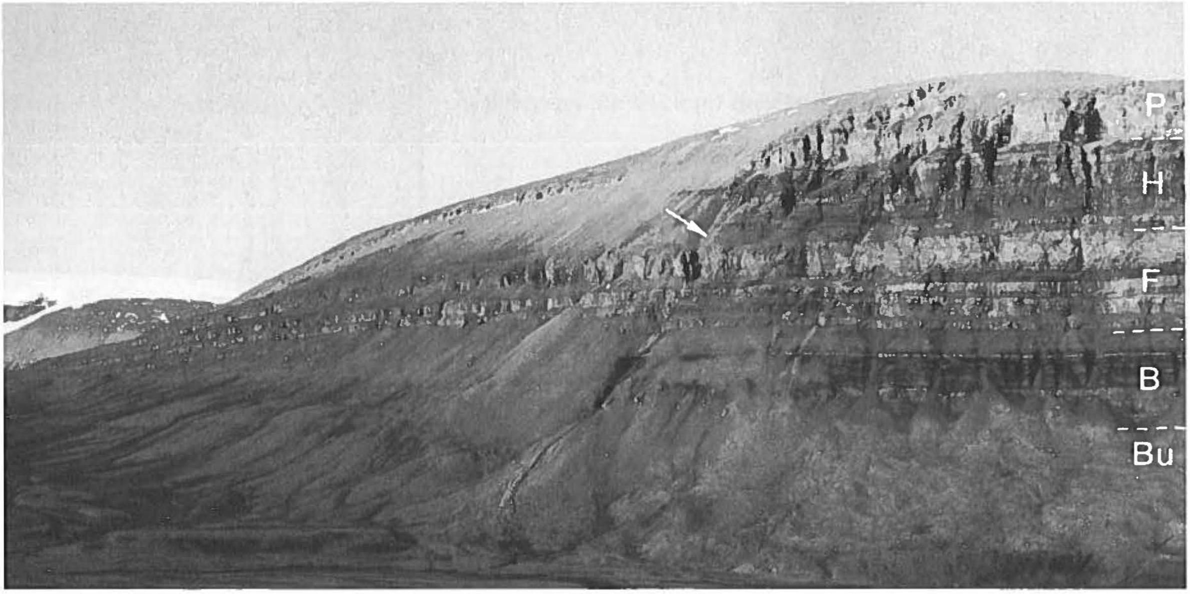


Fig. 6. The Brønlund Fjord Group (B) and Tavsens Iskappe Group (F: Fimbuldal Formation; H: Holm Dal Formation; P: Perssuaq Gletscher Formation) on the north side of Fimbuldal, west Peary Land. Bu: Buen Formation. The type section of the Holm Dal Formation is at the western (left) end of the steep cliff (arrow).

of trilobites, brachiopods and molluscs, details of which are given in accompanying papers by Robison, Hood & Robison, Zell & Rowell and Peel (this volume).

Sedimentology

The following facies analysis of the type section of the Holm Dal Formation is based primarily on the undolomitised portions of the section. Secondary dolomitisation affects nearly one third of the formation but sufficient primary fabrics and structures are retained to refer the dolomitised intervals to the following facies scheme.

Lithofacies 1, laminated silty limestones

Dark grey or black, bituminous lime mudstones show a well-developed, millimetre-scale parallel-lamination, defined by subtle variations in grain size or composition. Some laminae are picked out by quartz silt or very fine-grained sand while others show a concentration of dark bituminous matter. Brown phosphorite pellets are present in places and calcite-replaced sponge spicules are common. Siliciclastic detritus can form up to 30 % of the rock and discrete mudstone partings occur locally. Bioturbation is rare.

Interpretation. – The fine-grained, delicately laminated nature of these deposits and the absence of current-formed structures indicate deposition primarily out of suspension in a low-energy environment below wave-base. The bituminous character of these deposits, the scarcity of bioturbation and consequent preservation of fine lamination reflect oxygen-deficient bottom waters (Waples 1983; the dysaerobic-anaerobic zone of Byers 1977).

Lithofacies 2, thin-bedded argillaceous lime mudstone

This lithofacies dominates the sequence (84 % of type section, Fig. 7), forming thick, uniform intervals of alternating lime mudstone and silty, calcareous mudstone. Bedding is typically parallel (Figs 8, 11) but can be wavy or nodular; limestone beds are generally 2–5 cm thick with intervening shale partings or beds up to 5 cm thick. Limestone and shale components are well-segregated. Pressure solution features are common at bed boundaries but gradational and sharp, microscoured depositional contacts have been observed.

Limestone beds consist of weakly laminated lime mudstone, locally interlaminated with peloidal, skeletal packstone or grainstone laminae up to 1 cm thick. The lime mudstones contain up to 5 % quartz silt which in places defines a faint parallel lamination together with silt-sized micritic peloids and sponge spicules. Packstone and grainstone laminae are often broadly lenticular and in places form starved ripples. Basal contacts are sharp and sometimes scoured; coarser laminae grade up from skeletal grainstone through packstone into the overlying lime mudstone (Fig. 12). Peloids and

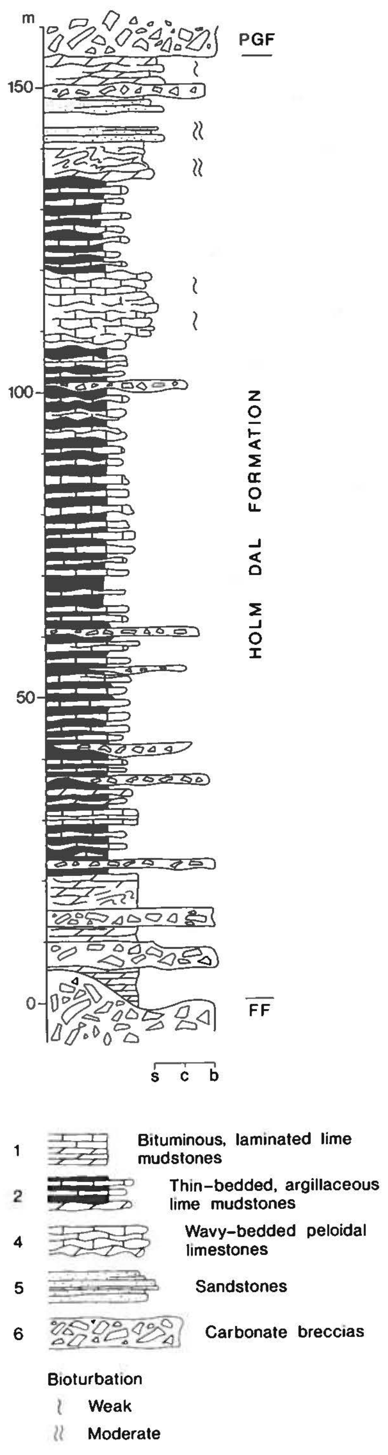


Fig. 7. Type section of the Holm Dal Formation. Numbers 1–6 refer to facies described in this paper. The limestones of the Holm Dal Formation have been locally dolomitised, indicated by oblique brick ornament. FF: Fimbuldal Formation; PGF: Perssuaq Gletscher Formation.

skeletal grains make up these grainstone laminae; the skeletal fraction is composed mainly of trilobite and phosphatic brachiopod elements together with fragments of *Girvanella* and sponge spicules. Some peloids and intraclasts are partially phosphatised. Quartz silt forms up to 30 % of the grainstone laminae.

Evidence of bioturbation is scarce in this lithofacies, the lamination is rarely disturbed and skeletal grains lie parallel with bedding.

Interpretation. – A low-energy, open marine environment is indicated by the fine-grained, fossiliferous nature of this facies and the rare evidence of current action. The scarcity of bioturbation and the presence of phosphoritic peloids and intraclasts reflect largely oxygen-deficient conditions. Lime mud was deposited mainly from suspension, probably derived from shallow-water environments during storms (cf. Neumann & Land 1975). The segregation of shale and lime mudstone is clearly diagenetic in part but probably reflects a primary fluctuation in sediment supply (cf. Brady & Koepnick 1979). The thin, silty shelly laminae record periodic action of weak tractional bottom currents that were capable of winnowing and transporting silt and sand-sized detritus. The nature of these currents is not clear; they may represent dilute density currents or the action of waves during major storms. Reworking and transport of bioclasts is also indicated by the disarticulated fragmented nature of the skeletal elements (Robison, this volume).

Comparable facies are common in 'deeper-water' carbonate sequences and are typically attributed to a deep shelf or basinal environment (e.g. Read 1980; Handford 1986).

Lithofacies 3, phosphoritic limestone

Phosphoritised intraclasts and pellets occur locally in the previous two lithofacies but a phosphorite-impregnated surface was located on frost-heaved slabs that originated within the basal 5–10 m of the formation. The finely laminated phosphoritised layer is a few millimetres thick and drapes an irregular, scoured surface. The underlying impregnated limestone is composed mainly of bioturbated skeletal wackestone or packstone with localised winnowed skeletal grainstone lags.

Interpretation. – The phosphatised surface was interpreted as a hardground, possibly formed by early diagenetic phosphorite replacement of cyanobacterial mats by Palmer et al. (1986). Exposure of the impregnated layer on the sea floor is suggested by numerous crater-like holdfasts.

The formation of phosphorite requires a slow sedimentation rate, a supply of phosphate and a reducing microenvironment (Baturin 1982). Winnowed shell lags at this horizon attest to the first of these, while reducing conditions may have been enhanced locally by the deg-

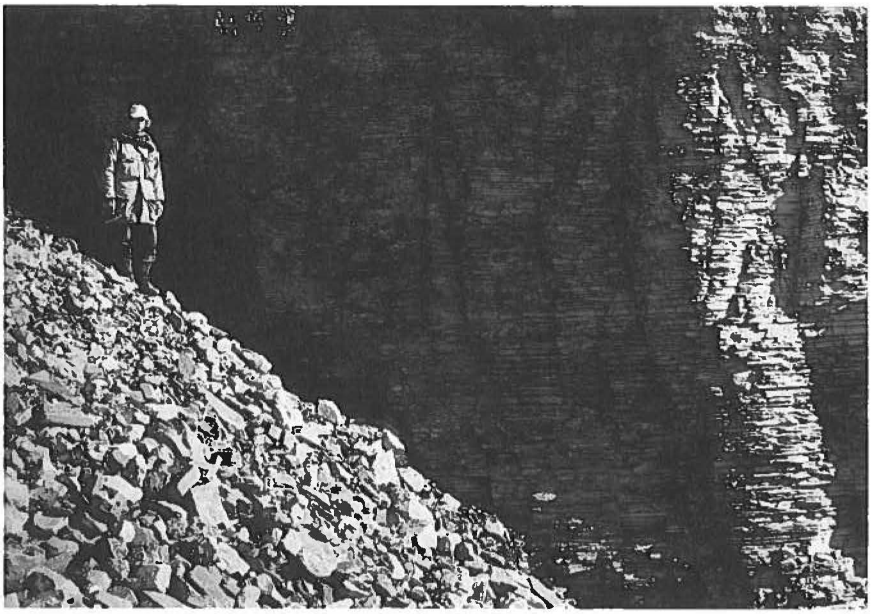


Fig. 8. Thin-bedded argillaceous lime mudstones (Lithofacies 2) near the middle of the Holm Dal Formation type section.

radation of the cyanobacterial mats. Finely laminated, bituminous carbonate forms much of the section at this stratigraphic level, reflecting the general lack of oxygen within the environment (see Lithofacies 1).

Although the exact location of this discontinous hardground could not be determined it may be significant that the basal beds of the Holm Dal Formation in this area drape the hummocky upper surface of the Fimbuldal Formation which has a relief of up to 5 m in places. Hardground development may have been favoured on these relict depositional 'highs', while mud accumulated in surrounding depressions.

Lithofacies 4, wavy-bedded peloidal limestones

Thin, wavy or nodular-bedded grey limestones in the upper third of the formation consist of fine-grained (silt-fine sand grade) packstones and grainstones, thinly interbedded with skeletal wackestones. The grainstones and packstones are composed of peloids, intraclasts and micritised skeletal grains, with an admixture of quartz silt (<5 %).

Sedimentary structures are rare, being restricted to wispy, undulating lamination; faint mottling and occasional discrete burrows attest to pervasive bioturbation.

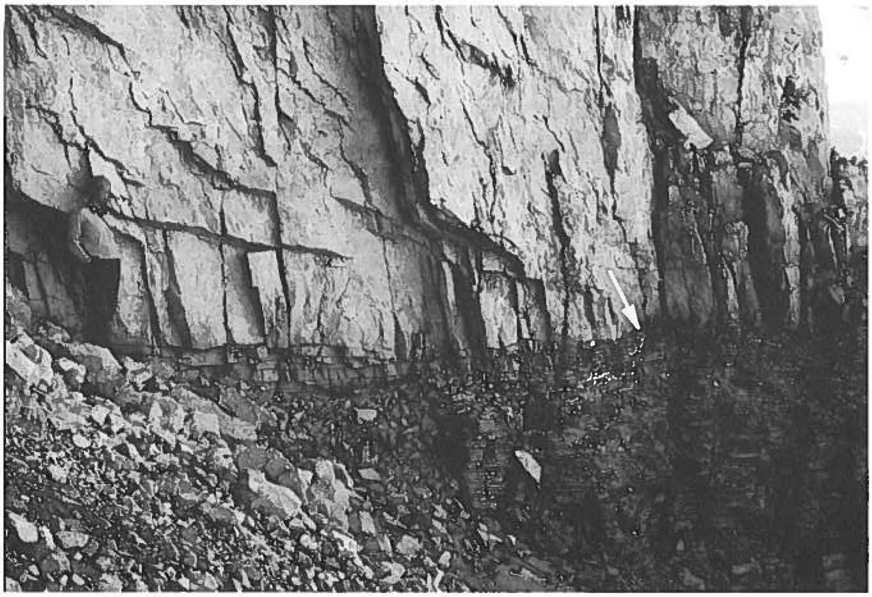
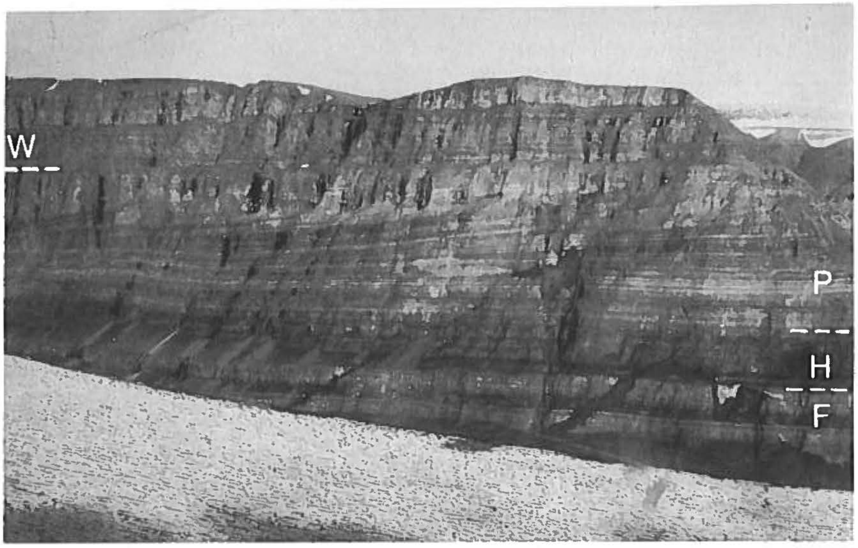


Fig. 9. Junction (arrowed) between the uppermost thin-bedded dolomites of the Holm Dal Formation and pale, cliff-forming dolomites (mass-flow breccias) of the overlying Perssuaq Gletscher Formation. Type locality of the Holm Dal Formation.

Fig. 10. Tavsens Iskappe Group on the east side of inner J. P. Koch Fjord. F: Fimbuldal Formation; H: Holm Dal Formation; P: Perssuaq Gletscher Formation; W: Wandel Valley Formation. Note the interdigitation of pale and dark strata within the lower Perssuaq Gletscher Formation, and the northward progradation of the pale facies.



Towards the top of the formation, dolomitised representatives of this facies show small-scale slumping and pull-apart structures.

Interpretation. – The widespread bioturbation and the presence of a trilobite-brachiopod fauna indicate an oxygenated open-marine environment. Sedimentary structures are not preserved but the alternation of mud-rich carbonates and lime silts or fine sands suggests an environment periodically winnowed by gentle bottom currents; deposition at or just beneath normal wave base is envisaged.

Handford (1986) described similar muddy peloidal lime sands from the Carboniferous of Arkansas which he attributed to deposition at moderate depths (15–30 m) on a storm-dominated shelf. The possibility of storm influence cannot be ascertained in this bioturbated facies.

Lithofacies 5, sandstone

Pale fawn or brown, fine-grained dolomitic sandstones form a small proportion (5 %) of the Holm Dal Formation; siliciclastic deposits are more typical of the overlying Perssuaq Gletscher Formation (see Surlyk & Ineson 1987). They occur in the upper levels of the Holm Dal Formation in its type section and characteristically show thin, flaggy bedding. Parallel lamination and ripple cross-lamination were recorded although bioturbation commonly obscures depositional structures; the trace fossil *Multipodichnus* has been described from this facies (Bergström & Ineson, this volume).

Interpretation. – Parallel and cross-lamination indicate deposition from tractional bottom currents. The siliciclastic sand was probably introduced into the carbonate-dominated environment by offshore storm-surge currents (the 'punctuated mixing' of Mount 1984).

Lithofacies 6, carbonate breccias

Limestone and dolomite breccia beds range in thickness from 0.1 to 6 m; the thicker beds generally occur near the base of the formation (Fig. 7). These thicker beds (>1 m) are laterally persistent sheets with flat, non-erosional bases and flat or hummocky tops. Thinner beds often pinch and swell, however, and can be lat-

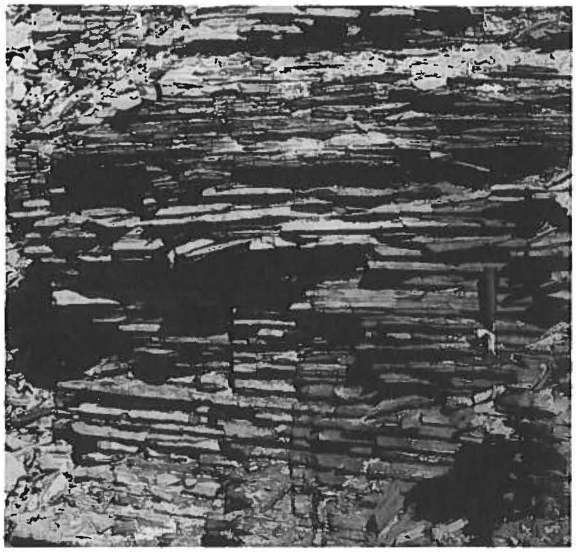


Fig. 11. Thinly-bedded argillaceous lime mudstones (Lithofacies 2). Note the regular alternation of limestone and shale and the flat, parallel bedding planes. Hammer (centre right) for scale.

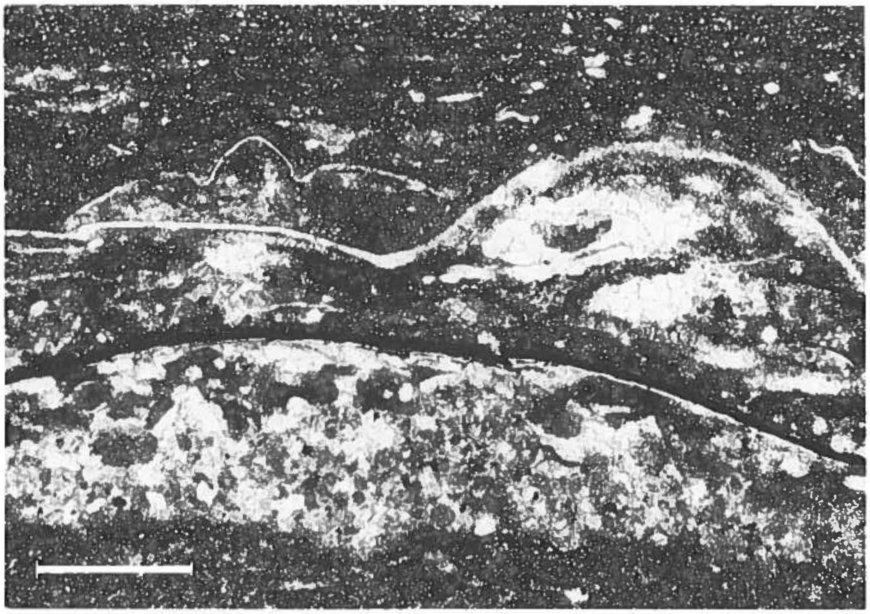


Fig. 12. Photomicrograph of laminated lime mudstone (Lithofacies 2) with thin silty laminae of peloidal skeletal packstone or grainstone. Skeletal elements are mainly trilobite. Scale bar = 0.5 mm.

erally discontinuous (Fig. 13), locally grading laterally into slumped but essentially in situ strata.

The breccias are clast-supported and largely ungraded. Although predominantly disorganised some beds show a preferred orientation of large flat clasts, parallel to bedding. Clasts are typically flat and tabular with an average long dimension of 5–20 cm, although slabs consisting of thin-bedded limestone may reach several metres in length. Such large slabs are often internally slump-folded. A few beds show a lower portion mainly composed of large contorted slabs, grading up into disaggregated pebble-cobble grade breccia.

Where undolomitised, the clasts are composed of slabs and fragments of parallel or wavy-bedded lime mudstones, packstones and grainstones comparable to Lithofacies 2 and 4; the interstitial matrix is typically argillaceous lime mudstone but quartz sandstone matrices were recorded near the top of the formation. Several breccia beds are capped by a graded peloidal lime grainstone bed, up to 50 cm thick, showing parallel and ripple cross-lamination.

Interpretation. – These chaotic, poorly sorted muddy breccias are interpreted as viscous debris flow deposits (Ineson 1980; see also Johnson 1970; Lowe 1979; Hiscott & James 1985). The outsized 'floating' slabs and hummocky upper surfaces attest to the cohesive and frictional strength of the debris. Grainstone caps on

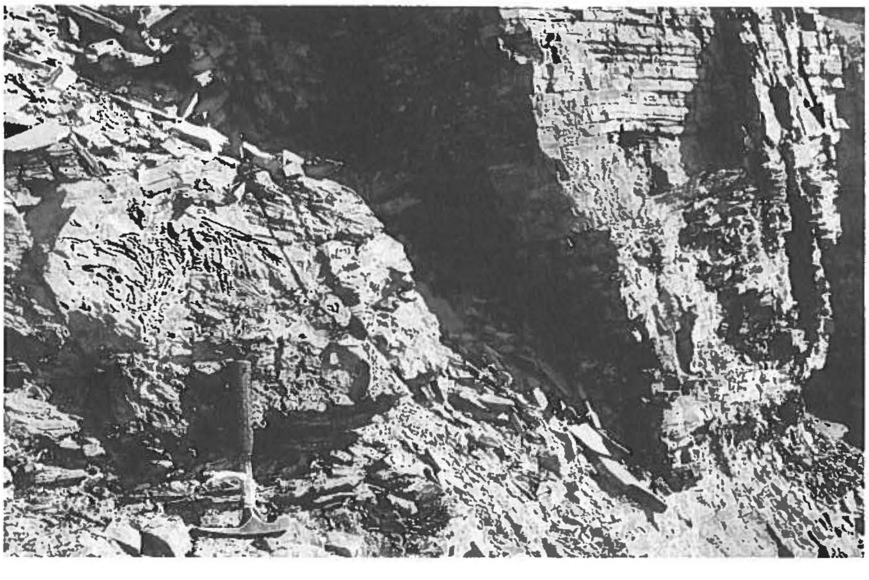


Fig. 13. Thin limestone breccia bed (Lithofacies 6) pinching out laterally (arrow) within thin-bedded lime mudstones. Note the clast-supported chaotic internal structure of the mass-flow breccia bed.

these debris flow deposits are attributed to turbidity currents associated with these viscous mass flows (Ineson 1980; see Krause & Oldershaw 1979).

Local derivation of the mass flows is suggested firstly by the close lithological match between clasts and enclosing strata and the lack of blocks of shallow-water origin, as seen elsewhere in the succession, for example in the underlying Fimbuldal Formation (see discussion below). Secondly, several thin breccia beds grade laterally into slumped, partially disaggregated strata. Atypical in this respect is the uppermost breccia bed in the type section, which has a medium-grained quartz sand matrix and clearly was derived from outside the immediate environment.

Facies distribution

The distribution of Lithofacies 1–6 in the type section is shown schematically in Fig. 14. Carbonate breccia beds (Lithofacies 6) occur sporadically throughout but the remaining facies show a systematic upward change. Silty, laminated bituminous carbonates (Lithofacies 1) occupy much of the basal 20 m; the phosphorite hardground (Lithofacies 3) occurs within this lower unit. Argillaceous lime mudstones (Lithofacies 2) dominate the middle two-thirds of the section; skeletal grainstone laminae appear in this lithofacies at about 40 m above the base of the formation and are most abundant between 70 and 80 m. Burrowed peloidal grainstones, packstones and wackestones (Lithofacies 4) form much of the upper 50 m, with occasional thin sandstone interbeds.

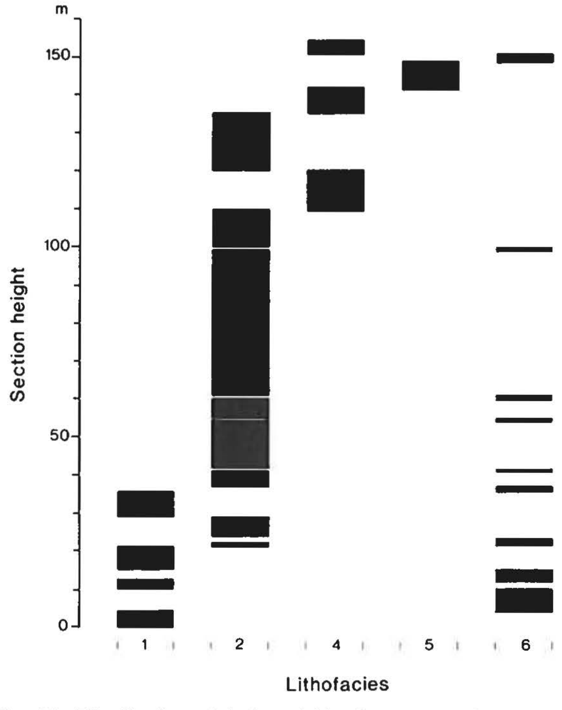


Fig. 14. Distribution of facies within the type section of the Holm Dal Formation.

Although mass-flow deposits occur at intervals throughout the formation, the thicker more extensive deposits occur within the basal 25 m, and small-scale evidence of downslope movement (minor slump folds, pull-aparts) is most common within the lower and uppermost levels of the formation (Fig. 7). Mass-flow breccias are thin and laterally discontinuous in the intervening central portion of the formation.

A similar facies trend occurs in the Holm Dal Formation in the Navarana Fjord area (Fig. 1) where bituminous, laminated dolomites forming the basal 25 m are succeeded by thin-bedded argillaceous lime mudstones with skeletal grainstone laminae (J. S. Peel, pers. comm. 1986). At the top of the formation, dolomitic argillaceous lime mudstones are overlain by bioturbated fine sandstones of the Perssuaq Gletscher Formation (Surlyk & Ineson 1987; Fig. 6).

Depositional environment

Considered in isolation from the underlying Fimbuldal Formation and overlying Perssuaq Gletscher Formation, the Holm Dal Formation records deposition in an open marine, mainly low-energy environment. Poor circulation commonly resulted in oxygen-deficient bottom waters. Carbonate and siliciclastic muds and silts accumulated mainly from suspension or, less commonly, from dilute density currents or storm currents. The mass-flow deposits and small-scale slope creep and slump structures reflect periodic slope instability in the immediate depositional area. The facies represented are closely comparable with those of 'open shelf' or 'deep shelf' environments (e.g. Wilson 1975); this broad depositional setting is compatible with that deduced from the trilobite assemblage (Robison, this volume).

The type section can be readily subdivided into three units, each reflecting stages in the progressive shallowing of the environment. The basal 20 m of bituminous, laminated silty carbonates, intercalated with mass-flow breccias, represent a period of sediment starvation; carbonate input was low and consequently siliciclastic silt and mud form an important component of the sediment column. The presence of phosphoritised pellets and locally a phosphorite-impregnated hardground, are further evidence of reduced sedimentation rates (Baturin 1982). The succeeding 80 m of argillaceous lime mudstones with rare, thin mass-flow breccia beds, represent an environment beneath normal wave base but periodically swept by weak bottom-currents. The upward increase in winnowed skeletal laminae reflects the progressive shallowing of the environment. The uppermost interval of fossiliferous peloidal grainstones, packstones and wackestones records shallowing to close to normal wave-base. Fine sandstones in this interval were probably introduced by offshore storm-induced currents and herald the northward progradation of shallow-marine sandstones forming the overlying Perssuaq Gletscher Formation.

Some discussion of the environmental implications of adjacent formations is needed to further this interpretation. The underlying Fimbuldal Formation consists of 180 m of platy nodular lime mudstones and dolomites interbedded with thick, laterally persistent carbonate breccia beds, locally containing blocks of ooid grainstone several tens of metres across. This sequence is interpreted as a suite of carbonate slope deposits (Ineson 1980, 1985). Coeval rocks farther south represent a northward-prograding platform margin fringed by ooid sand banks; the ooidal grainstone blocks within the Fimbuldal Formation mass-flow deposits were probably derived from the unstable outer margin of this advancing platform.

In complete contrast, the Holm Dal Formation is overlain by a mixed sequence of quartz arenites and carbonates assigned to the Perssuaq Gletscher Formation (*c.* 400 m). In its type section, the Perssuaq Gletscher Formation includes sandy dolomite mass-flow deposits but is dominated by bioturbated and trough cross-bedded sandstones. This sequence typically shows northward-dipping clinoforms and demonstrably progrades northwards, individual units wedging out into the underlying Holm Dal Formation (Fig. 10; Surlyk & Ineson 1987). South of Navarana Fjord, the sandstones are locally interbedded with stromatolitic dolomites forming low-relief thrombolite mounds up to 2 m in height (Surlyk & Ineson 1987). The shallow-marine siliciclastics of the Perssuaq Gletscher Formation are truncated upwards by an unconformity; they reflect the northward progradation of the shoreline accompanying progressive exposure of the platform (Higgins et al., in press).

Thus the depositional history of the shelf between the mid-Middle Cambrian and the Late Cambrian can be regarded in terms of two distinct stages (Fig. 15):

1. During the medial Middle Cambrian a shallow-water carbonate platform prograded northwards, flanked to the north by an accreting wedge of carbonate slope deposits (Fimbuldal Formation), grading out onto the deep-water, outer shelf (Fig. 15a).

2. The bituminous silty carbonates of the basal Holm Dal Formation abruptly overlie these slope deposits and represent the onset of a major regressive cycle during the late Middle and Late Cambrian (Fig. 15b, c). This initial period of slow sedimentation and carbonate starvation on the outer shelf recorded in the basal strata probably reflects a relative sea-level fall (cf. James & Mountjoy 1983), resulting in exposure of much of the platform and consequently a marked decline in carbonate production. Although drowning of a carbonate platform can produce a similar starved sequence in coeval deeper-water environments (James & Mountjoy 1983), the increase in siliciclastic detritus in the Holm Dal Formation and the subsequent regressive sedimentation pattern exhibited by the Holm Dal and Perssuaq Gletscher Formations favour the former interpretation. Thus, following a relative fall in sea-level, carbonate sedimentation was re-established on the vestigial platform and outer shelf; the latter may have closely resembled a carbonate ramp in the late Middle and Late Cambrian (Fig. 15b). The clinoforms in the Perssuaq Gletscher Formation and the mass-flow deposits in both the Holm Dal and Perssuaq Gletscher Formations reflect relief inherited from the previous phase of carbonate platform development (Fig. 15b, c).

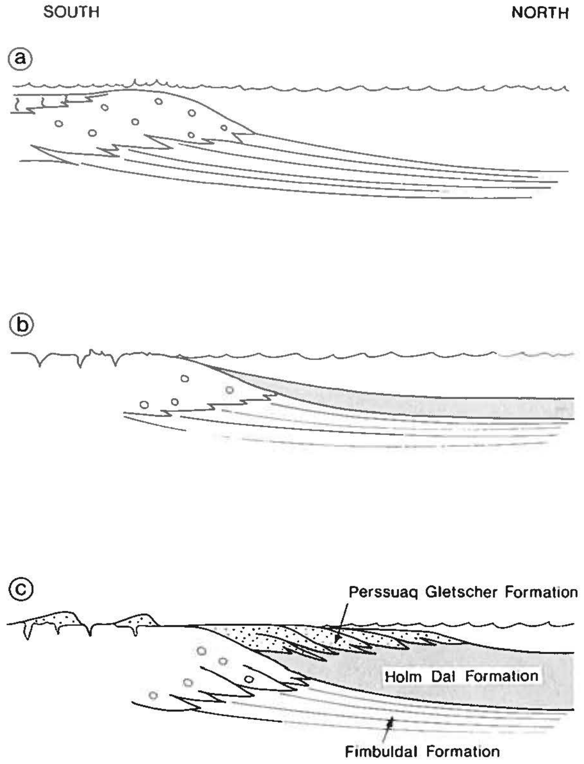


Fig. 15. Schematic cross sections illustrating the inferred evolution of the shelf during Middle-Late Cambrian. The sequence of events is described in the text.

The Holm Dal Formation thus forms the lower portion of a regressive cycle, probably initiated by a relative sea-level fall, and recording shallowing from starved deep-shelf into the shallow subtidal zone. Carbonate production was ultimately stifled by prograding littoral clastics heralding the exposure of the platform (Fig. 15c).

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