Upper Ordovician to Silurian facies patterns in eastern Ellesmere Island and western North Greenland and their bearing on the Nares Strait lineament

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The upper Ordovician and lower Silurian sediments in the northern Nares Strait region formed during a series of platform margin collapses and platform subsidences. Facies changes from platform carbonates to slope and trough clastics are intricate, but two almost vertical facies fronts can be correlated across Nares Strait.

The northernmost facies front is the carbonate platform margin (associated with a horst) which apparently formed at the fault-bounded edge of the stable craton. At this margin there is a facies boundary (interdigitation) between platform carbonates and clastics of the trough and this feature had a stationary location during the upper Ordovician and lower Silurian. On Ellesmere Island it is traceable from Cañon Fiord to Judge Daly Promontory; on Greenland, directly along strike, available data indicate that the linear coastline of northern Hall Land, and probably Nyeboe Land, coincides with the platform margin. There appears to have been little or no post-depositional offset of this margin along Nares Strait.

Mudstones progressively migrated southward in Ellesmere Island during the upper Ordovician and the same facies reached Washington Land and Hall Land, Greenland, in the middle Llandovery (lower Silurian). The line of interdigitation (facies front) between carbonate and mudstone facies was a static, near vertical, feature from the middle Llandovery to upper Silurian in Washington Land and into the lower Devonian in Ellesmere Island. This facies boundary has a slightly curved form when projected across Nares Strait; a shape which is entirely consistent with the meandering nature of facies boundaries.

The present distribution and relationship of upper Ordovician to lower Silurian sediments indicate that they were part of a single laterally continuous sedimentary regime. Both vertical facies fronts are entirely consistent with no post-depositional movement along Nares Strait; however, they cannot rule out left-lateral displacement of as much as 25 km. Displacements greater than this introduce far more geological problems than they solve.

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Nares Strait is a strikingly linear waterway that connects Baffin Bay in the south with the Arctic Ocean in the north, and separates Greenland from Ellesmere Island, Arctic Canada (Fig. 1). This prominent feature has become the focus of a debate concerning whether the Strait is the locus of great sinistral strike-slip faulting during the Cretaceous and Tertiary (e.g. Wegener 1924, Carey 1958, Wilson 1963, 1965, Bullard et al. 1965, Keen et al. 1972, Kristoffersen & Talwani 1977, Newman 1977, Sclater et al. 1977, Newman & Falconer 1978) or not (e.g. Kerr 1967a, b, 1980a, b, 1981, Grant 1975, Le Pichon et al. 1977).

Proponents of great displacement along Nares Strait have pointed out some of the difficulties of assessing geological features across it. The main difficulty is that geological units tend to be deposited as near horizontal sheets and only near vertical changes can be used for *precise* measurement of offset. The situation is complicated where stratigraphic and structural trends cross Nares Strait at a very oblique angle (Trettin et al. 1972). Features which are most suited to successfully show displacement or lack of it are vertical features, but these are rare. However, recent increase in activity in high arctic regions now makes it possible to confidently cor-

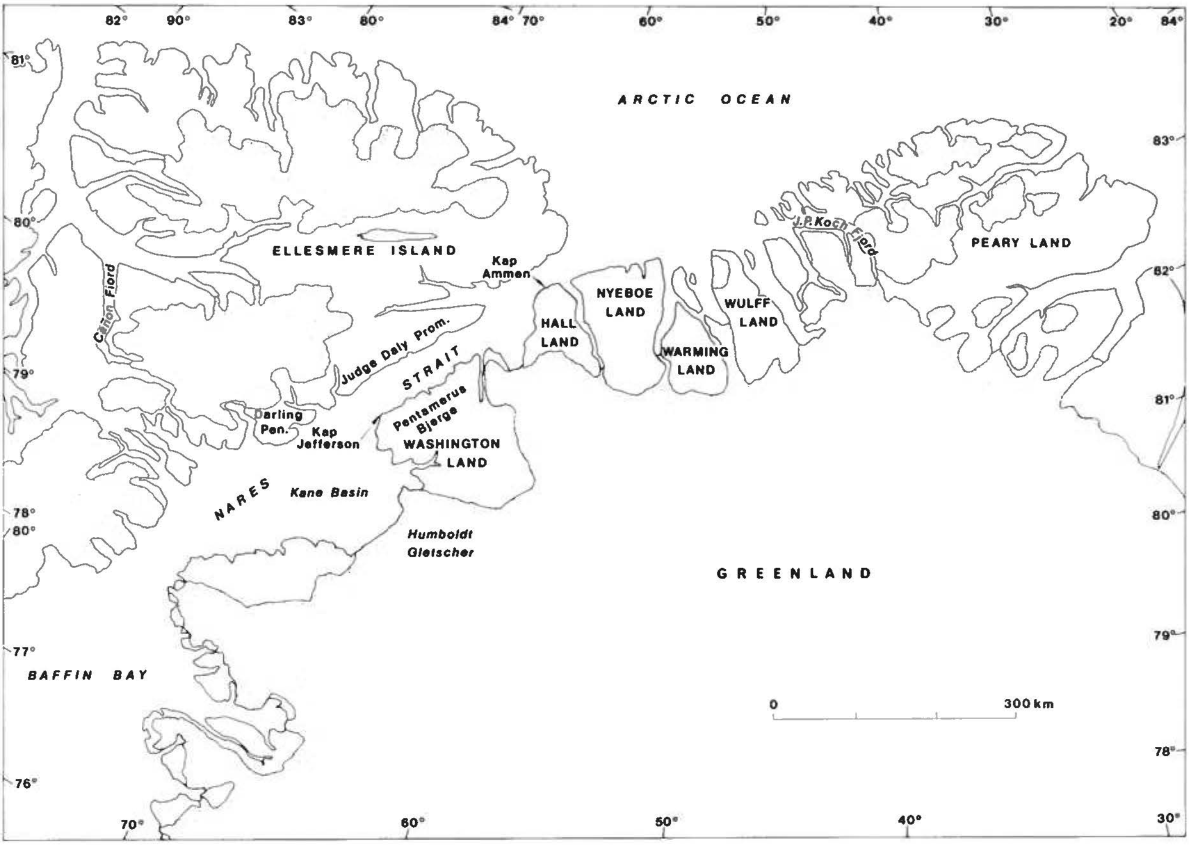

Fig. 1. The Nares Strait region showing the main geographic features referred to in the text. The main ice limits are illustrated.

relate Palaeozoic facies and stratigraphies on both sides of Nares Strait and to assess their bearing on later Cretaceous–Tertiary movement along the Strait.

This paper is concerned specifically with upper Ordovician to Silurian facies patterns and stratigraphic histories in the Nares Strait region. This time interval is of particular importance because linear facies fronts, resulting from rapid facies changes can demonstrate offset or lack of offset along Nares Strait. This paper documents and analyses what these facies changes are and shows how they relate to solving the dilemma. Facies changes between platform carbonates and trough clastics produce marker boundaries (often vertical) that are traceable with varying degrees of accuracy from one side of Nares Strait to the other. The situation in the time interval treated here differs from that in many other intervals, where the sediments are more uniform over large areas and with few internal vertical markers that can demonstrate precisely offset or lack of offset along Nares Strait.

Regional setting

The lower Palaeozoic histories of North Greenland and Ellesmere Island are very similar and closely related. In general terms this similarity is exemplified by the upper Ordovician facies patterns (Fig. 2). Throughout the Palaeozoic a sequence of limestones, dolomites and evaporites developed on a platform which bounded the northern edge of the North American craton (Kerr 1967a, 1976, Dawes 1971, 1976). In western North Greenland the platform carbonates terminated in the upper Llandovery to Ludlow interval (Hurst 1979, 1980a, b, Surlyk et al. 1980, Fig. 3), whilst in eastern Ellesmere Island they continue through into the lower Devonian (Kerr 1976, Trettin 1979, column 4 in Fig. 3). To the north and west of the platform (Fig. 2) the carbonates passed abruptly into mudstones, resedimented limestone and chert conglomerates and turbidites of a slope and trough sequence (Fig. 3).

The platform margin was not a static feature. During the Palaeozoic the area of trough sediments expanded in Ellesmere Island and Greenland (Dawes 1976, Trettin & Balkwill 1979) but the tectonic mechanisms promoting this were not explained. In Greenland Hurst

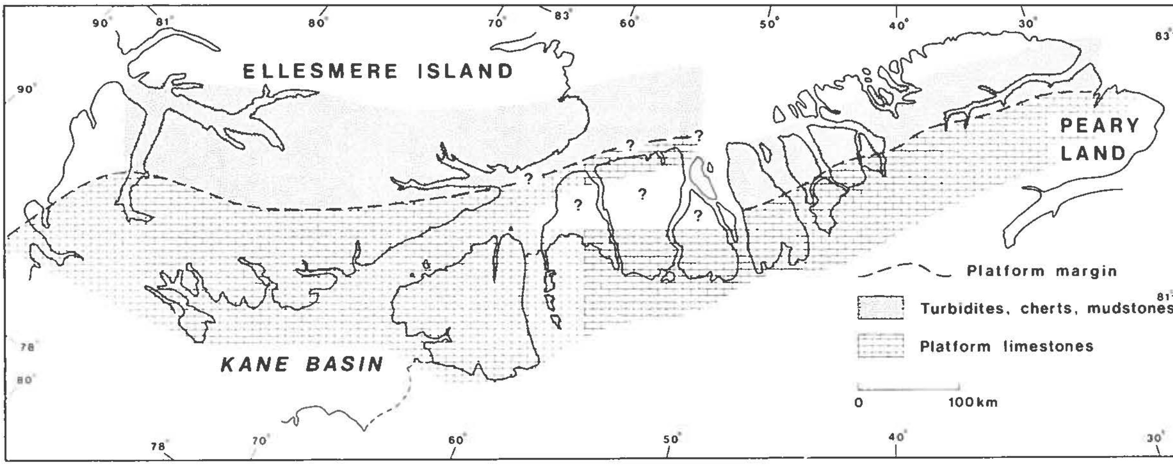

Fig. 2. Regional setting of upper Ordovician (Eden–Richmond) sediments in eastern Ellesmere Island and North Greenland, immediately prior to situation in Fig. 4.

(1980a), Hurst & Surlyk (1980) and Surlyk et al. (1980) relate it to repeated platform margin collapse with resultant drowning of platform carbonates by trough clastics.

During the upper Ordovician the platform margin trended roughly northeast–southwest in both Ellesmere Island and North Greenland (Fig. 2). Repeated collapsing and drowning of the platform in the upper Ordovician to middle Silurian in western North Greenland (Hurst 1980a, b) and eastern Ellesmere Island produced some geological features which can be traced accurately across Nares Strait.

Geological features across Nares Strait

During the upper Ordovician and lower Silurian a marked change occurred in facies patterns adjacent to Nares Strait (Figs 3 and 4, Kerr 1967a, b, Trettin & Balkwill 1979, Hurst 1980a) due to platform margin collapse and platform subsidence. The mechanisms responsible for the partial and differential subsidence of the platform and platform margin are not yet clearly understood. Nevertheless, during the upper Ordovician and lower Silurian the southern platform of Ellesmere Island, bordering the turbidite trough, broke down into three sub-parallel and interfingering facies belts, which proceeding from north to south onto the North American craton (Fig. 4) are:

1) linear intrabasinal horst; at approximately the site of the edge of platform carbonate deposition.
2) mudstones, cherts and resedimented conglomerates.
3) platform carbonates.

These facies are distinctive and traceable with varying degrees of accuracy across Nares Strait into western North Greenland (Figs 3 and 4). The linear intrabasinal horst (the site of the pre-Silurian platform margin, see Dawes, this volume) and the facies front between mudstone and platform carbonates are important vertical markers traceable across Nares Strait.

Linear intrabasinal horst

The abrupt change from platform carbonates along the horst to trough clastic facies is well documented in eastern Ellesmere Island (Kerr 1976, Trettin & Balkwill 1979, Figs 3 and 4). The horst forms a linear feature from Cañon Fiord to northern Judge Daly Promontory, across Nares Strait to the northern coast of Hall Land and possibly to western Nyeboe Land, North Greenland.

Limited graptolite evidence from northern Warming Land (Fig. 1) indicates that mudstones were deposited contemporaneously with and south of the northern Hall Land (and Nyeboe Land?) carbonates. These limestones were apparently isolated from the southerly platform sequences as in Ellesmere Island, and represent the easterly extension of the linear horst (Fig. 4). Thus, the spatial distribution of the lower Silurian facies in western North Greenland is extremely similar to that in eastern Ellesmere Island.

The isolated belt of platform carbonates in Ellesmere Island and Hall Land is a narrow and remarkably linear feature. It is very similar to the platform margin in Peary Land, which is the site of a fault zone (Hurst & Surlyk 1980, Surlyk et al. 1980). The northwest edge of this carbonate belt of Ellesmere Island is directly in line with the northern coast of Hall Land and Nyeboe Land

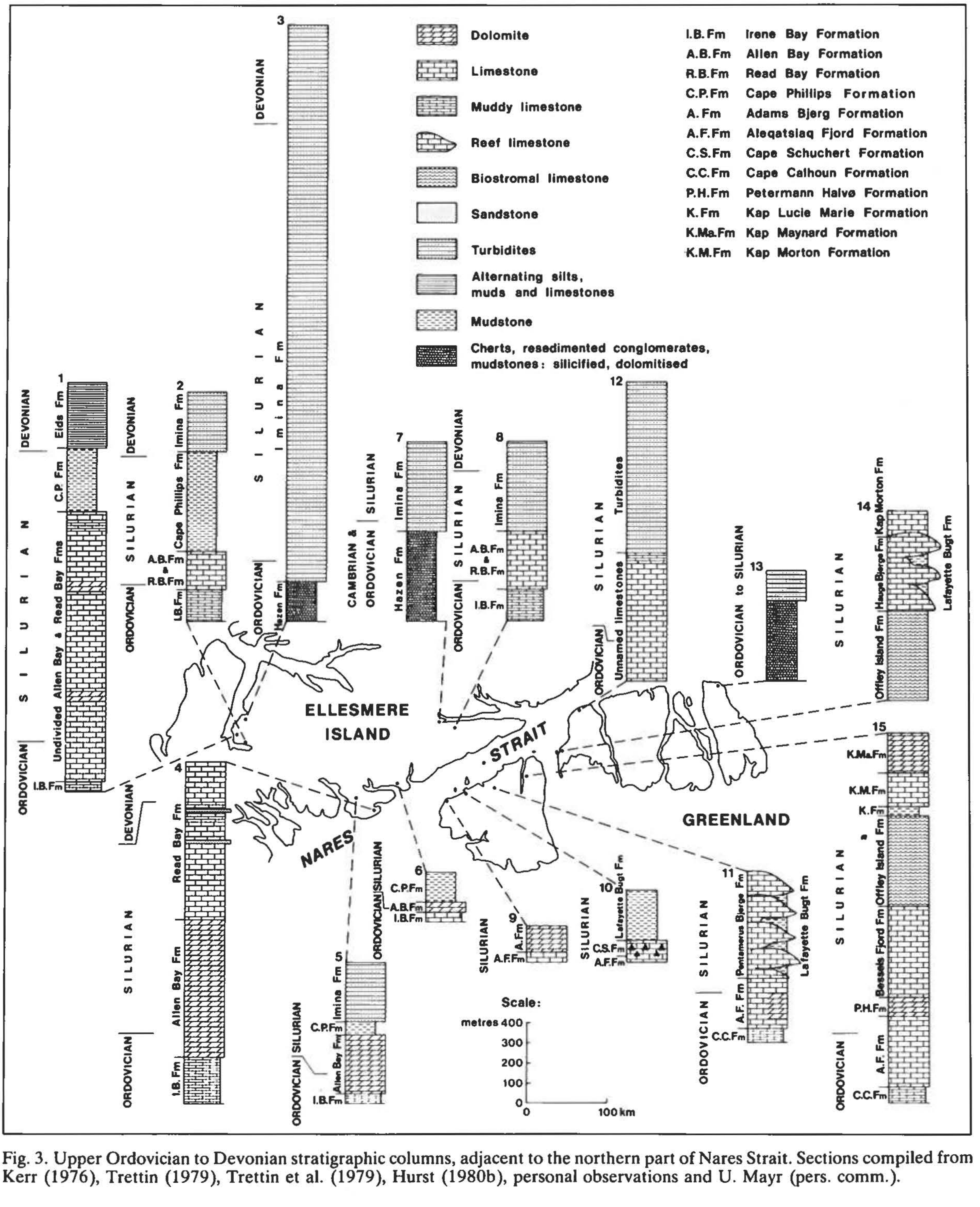

Fig. 3. Upper Ordovician to Devonian stratigraphic columns, adjacent to the northern part of Nares Strait. Sections compiled from Kerr (1976), Trettin (1979), Trettin et al. (1979), Hurst (1980b), personal observations and U. Mayr (pers. comm.).

(Figs 1 and 4). The straightness implies some form of fault control (see also Dawes, this volume).

Further evidence suggesting that the coastline of northern Hall Land is the extension of the Judge Daly Promontory platform margin and horst can be gained from the nature of the margin itself. From the aerial photographic mapping of Dawes (1976) some carbonate buildups (reefs) were thought to be associated with

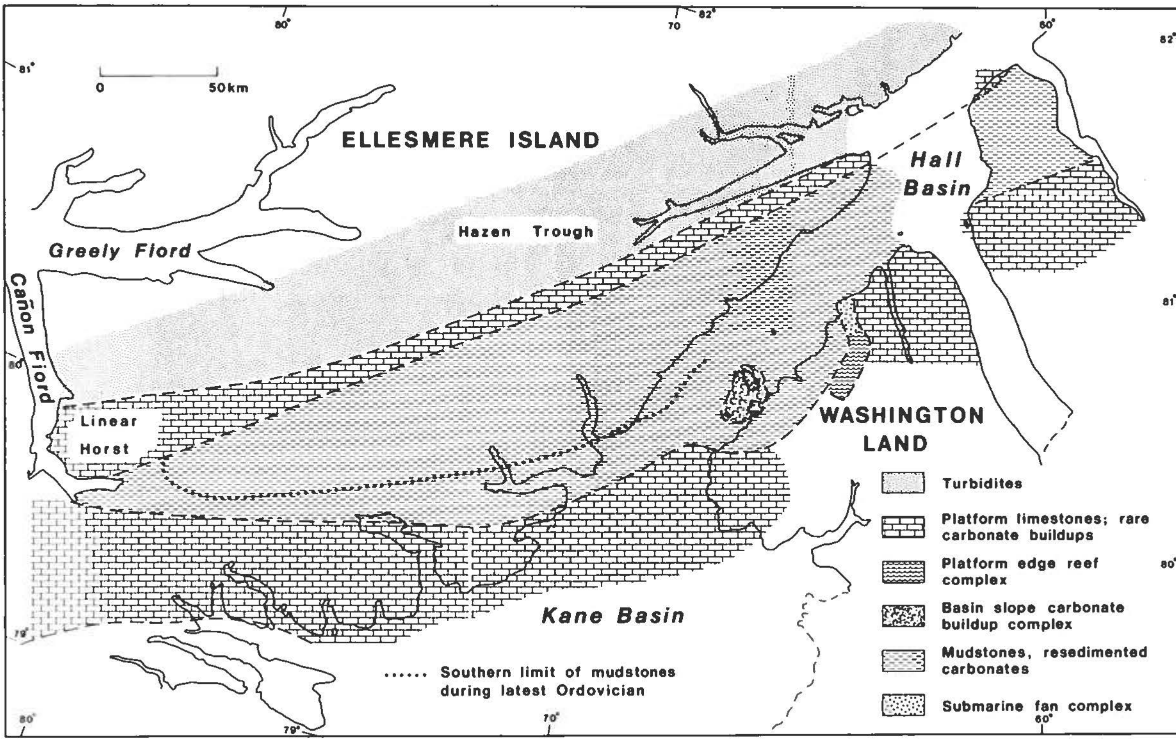

Fig. 4. Facies belts adjacent to the northern part of Nares Strait during the lower Silurian (middle Llandovery and later). The southern boundary between carbonates and mudstones is precisely located in Washington Land. In Ellesmere Island the facies front is not as precise and may be up to 10 km north or south of the line shown. Either way does not disturb the general facies trend across Nares Strait.

the transition from platform to trough. From the work of Hurst (1980a) some of the carbonate buildups at the platform margin are now known to be faulted, sheared and slumped carbonate masses which weather into smooth glaciated banks, simulating true carbonate buildups. These are restricted to the platform margin (Fig. 5A, D). In northern Hall Land a similar carbonate mass is known at the coastline (Fig. 5A) suggesting the edge of the platform margin.

In summary, the northwest edge of the platform margin with the linear horst is an important marker across Nares Strait and it appears to have little or no offset.

Middle Llandovery facies boundaries

During latest Ordovician time (Richmondian) mudstones succeeded platform carbonates between Darling Peninsula and central to eastern Judge Daly Promontory (Fig. 4). No mudstones of Ordovician age occur in Washington Land or Hall Land (Figs 3 and 4). By middle Llandovery time (lower Silurian) mudstones interdigitate with platform carbonates along a line from Cañon Fiord to Darling Peninsula in eastern Ellesmere Island (Fig. 4, Kerr 1976). Similarly in western Washington Land cherty lime mudstones, cherts and calcarenites followed by a thick mudstone, chert and resedimented conglomerate unit, all of middle Llandovery and younger age, interdigitate with platform carbonates and platform edge reefs (Figs 3, 4 and 5B, C, Hurst 1980a, b).

The progressive diachronous spread of mudstones southeastwards in eastern Ellesmere Island and eventually into western Washington Land indicates that both areas were part of the same depositional regime (Fig. 6). Subsequently, turbidites spread south in eastern Ellesmere Island (Kerr 1976). A thick turbidite succession is not known from Washington Land but according to Koch (1920, 1929) some sands do occur in the highest part of the mudstone sequence. This again emphasises the facies continuity between eastern Ellesmere Island and western North Greenland (Fig. 6).

The facies front (Figs 5B, C) between mudstones and platform carbonates had a stable geographic position from middle Llandovery to Devonian time in Ellesmere Island (Kerr 1976). The present-day alignment of the facies boundary across Nares Strait involves only a slight kink which is entirely consistent with primary depositional characteristics (Fig. 4).

Isopachs are further evidence that the mudstone formed in a single discrete basin (Fig. 7). The true sedimentary thickness of the mudstones in Washington Land is not possible to determine because the upper

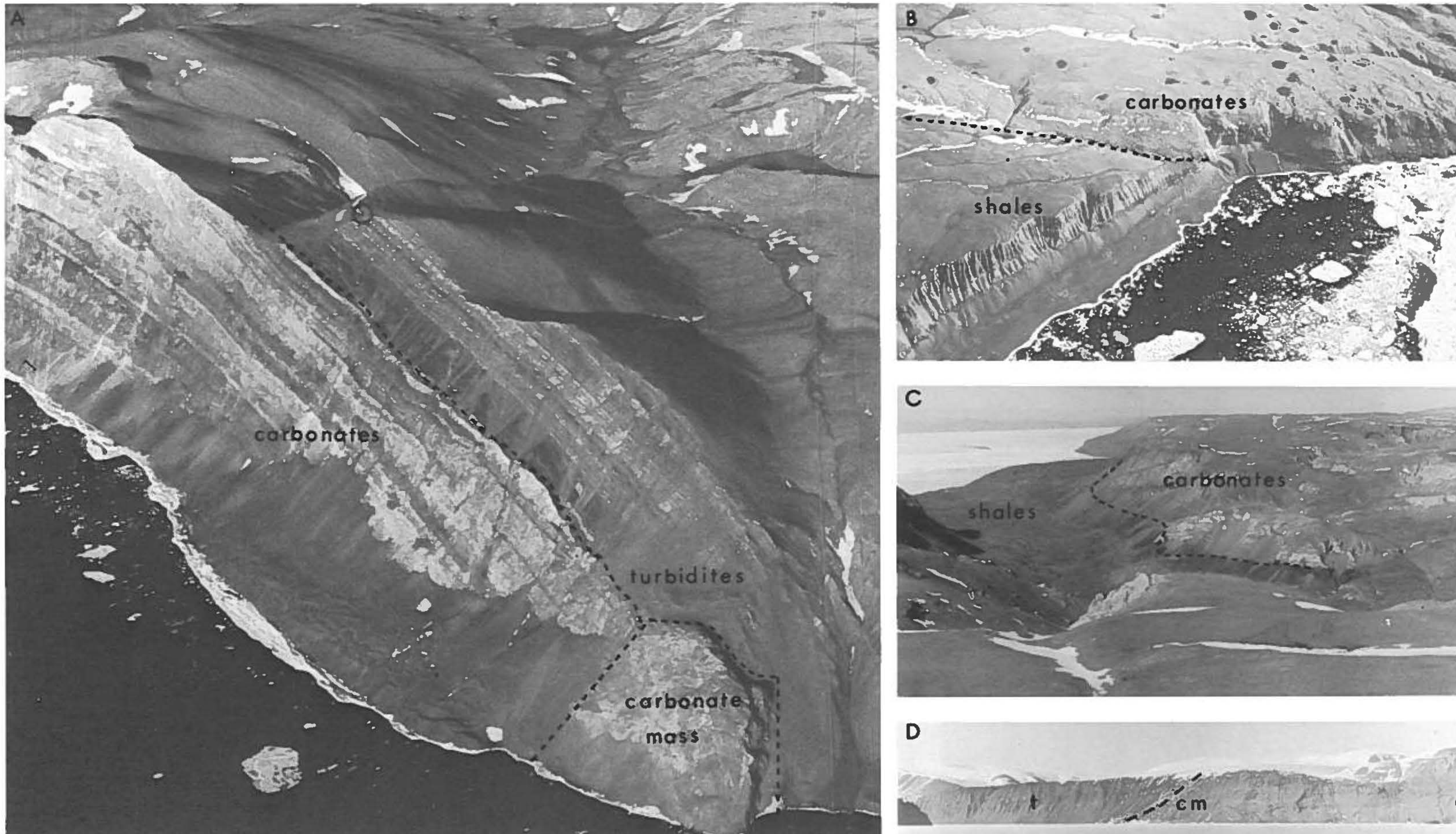

Fig. 5. A. Northern coastline of Hall Land west of Kap Ammen, Greenland, showing upper Ordovician to lower Silurian carbonates overlain by turbidites. Note the large carbonate mass which simulates a platform margin carbonate buildup and resembles that in Fig. 5D. Aerial photograph 546 K–SØ, no. 2199; copyright Geodætisk Institut, Denmark.
B. Interdigitation of platform carbonates with shales of Llandovery age at Kap Jefferson, Washington Land, Greenland. Aerial photograph 545 H–S, no. 11781; copyright Geodætisk Institut, Denmark.
C. Interdigitation of platform carbonates with marginal carbonate buildups with shales in the Pentamerus Bjerge of Washington Land, Greenland. Llandovery to Wenlock age.
D. Cambrian to Silurian platform margin in J. P. Koch Fjord, Peary Land, Greenland. Note development of a simulated carbonate buildup (cm) at the edge of the carbonate platform (c) and turbidite (t) trough. Note that the platform margin and facies interdigitation are vertical or near vertical features.

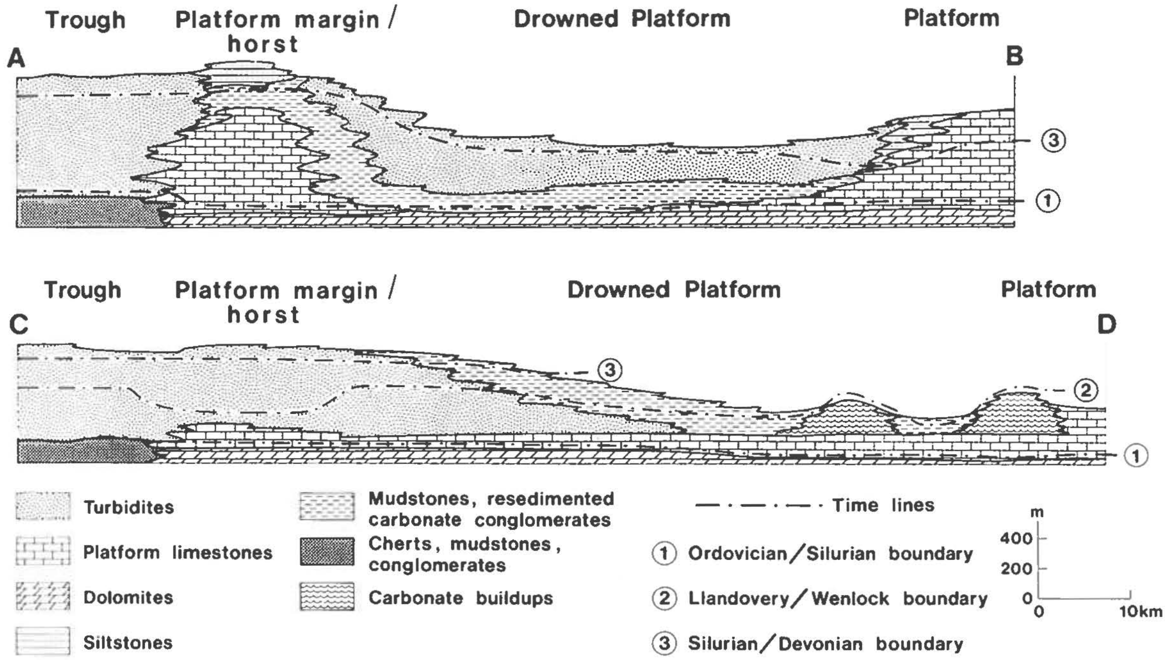

Fig. 6. Schematic cross-section of upper Ordovician to Silurian platform trough facies. Line of sections shown on Fig. 7. Note similarity of sections emphasising continuity of sedimentary regimes across Nares Strait. The line A–B is composite with the northerly parts based on the sections in Cañon Fiord (see Trettin 1979).

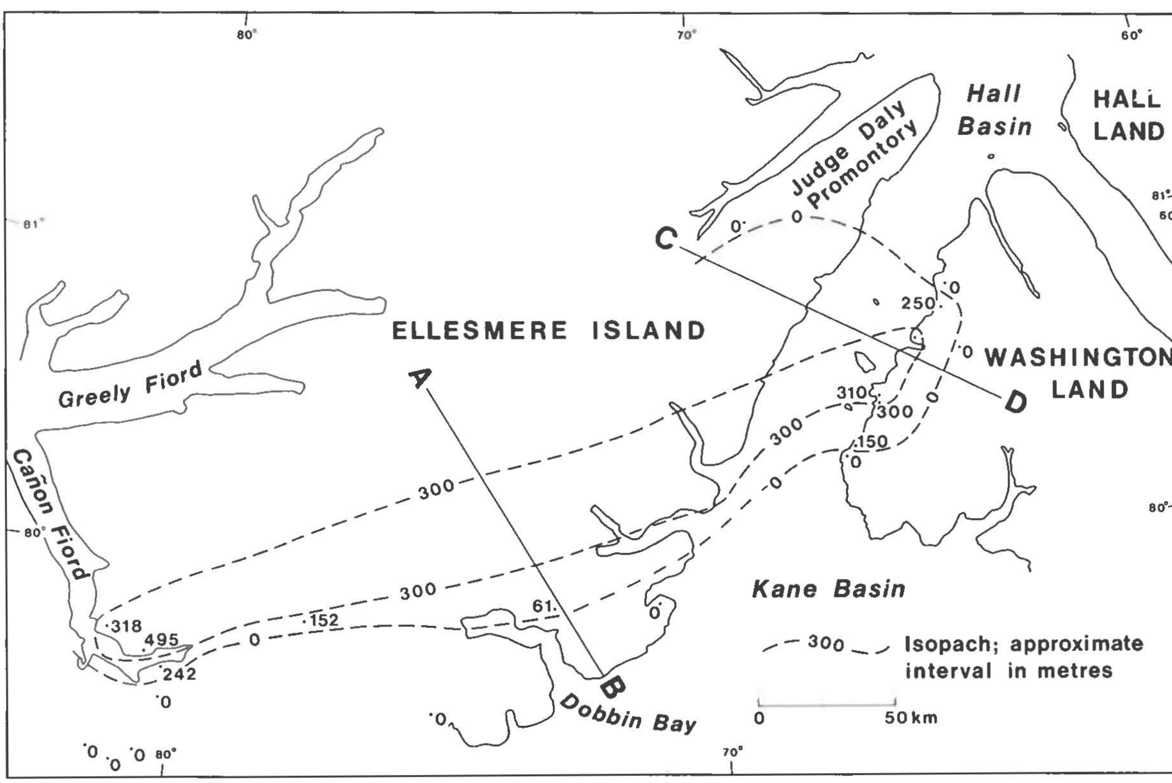

Fig. 7. Isopach map indicating thicknesses (in metres) of the upper Ordovician to Devonian mudstone (shale) facies of eastern Ellesmere Island and Washington Land, Greenland. Lines A–B, C–D locate the cross-sections shown in Fig. 6.

surface is eroded. Nevertheless, the minimum thicknesses indicate that the axis of mudstone deposition trends from Cañon Fiord in Ellesmere Island into Washington Land.

Conclusions and constraints

The upper Ordovician and Silurian successions of eastern Ellesmere Island and western North Greenland show two geological features which can be used with precision to correlate across Nares Strait. These are 1) the long persisting platform margin with linear horst that persisted during the upper Ordovician and lower Silurian, and which bounded the southern margin of the trough turbidites, and 2) the facies interdigitation between the platform carbonates (with marginal carbonate buildups in Washington Land) and mudstones from the middle Llandovery (lower Silurian) to Devonian.

These features together with the present-day distribution of upper Ordovician and Silurian sediments demonstrate clearly that suggestions of 220 km or more of left-lateral displacement along Nares Strait are highly improbable. Assuming left-lateral displacement between 100 and 220 km there is a great mismatch of the geological features, and displacements of this amount can be discounted. Because of the uncertainty of the precise original shape of facies boundaries it is not possible to be absolutely accurate about displacement. The two markers discussed here argue strongly that displacement was no more than 25 km.

In conclusion the present-day distribution of upper Ordovician and lower Silurian sediments and marker horizons in eastern Ellesmere Island and western North Greenland is consistent with no strike-slip displacement along Nares Strait since Silurian time.

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