Polarforschung 68: 131 - 140, 1998 (erschienen 2000)

Early Palaeozoic Basin Development of North Greenland - Part of the Franklinian Basin

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THEME 7: Problems of the Caldonian / Ellesmerian Junction

Summary: The North Greenland segment of the Franklinian Basin bordering the present Arctic Ocean accumulated up to 8 km of Cambrian–Devon strata, which are well exposed and permit recognition of seven stages in the evolution of the basin. Each stage (except the first) is characterized by differentiation into a southern shelf and slope and a northern deep-water trough. With time the basin expanded southwards leading to final foundering of the shelf areas in the late Silurian. Some stratigraphical developments in the basin can be linked to the rising Caledonian mountains in East and North-East Greenland. Accumulation in the Franklinian Basin was brought to a close in the latest Devonian by the Ellesmerian orogeny.

INTRODUCTION

At the end of the Neoproterozoic Greenland was a part of the continent of Laurentia and situated in the southern hemisphere where it formed a part of the supercontinent Rodinia (CONDIE 1997). The position of Greenland in Laurentia, corresponding to the present north-eastern corner of the North American shield, was such that it was bordered by opening oceans - the Iapetus Ocean between Laurentia and Baltica east of present-day Greenland, and an ocean across what is now North Greenland approximately perpendicular to the northern part of Iapetus (GOLONKA et al. 1994, MCKERROW et al. 1991). Along the continental margins adjacent to these oceans two extensive sedimentary basins developed. Along East Greenland up to 18.5 km of ensialic sediments of Neoproterozoic to Middle Ordovician age accumulated in a N–S trending basin, of which the most important element was the Neoproterozoic Eleonore Bay Supergroup (SØNDERHOLM & TIRSGAARD 1993); this succession was involved in the early Silurian Caledonian orogeny (e.g. HIGGINS et al. 2000, this vol.). In North-East Greenland Proterozoic successions present both in the foreland to the Caledonian fold belt and within Caledonian nappe sheets include the Independence Fjord Group and Zig-Zag Dal Basalt Formation (COLLINSON 1980, KALSBEEK & JEPSEN 1983, 1984, SØNDERHOLM & JEPSEN 1991), disconformably overlapped by the late Proterozoic Hagen Fjord Group (CLEMMENSEN & JEPSEN 1992, JEPSEN & KALSBEEK 200). Along North Greenland the deposits laid down in the Franklinian Basin span the period from the latest Proterozoic to the earliest Devonian and reach a thickness of more than 8 km; they crop out in an almost 900 km long E–W trending zone up to 200 km in width across North Greenland (Fig. 1). The Franklinian Basin continues westwards into the Canadian Arctic Islands for a further 1000 km (TRETTIN 1991). Sedimentation in the Franklinian Basin in both North Greenland and Canada was brought to a close by the latest Devonian Ellesmerian orogeny, which in North Greenland produced the North Greenland fold belt (HIGGINS et al. 2000, this vol).

This paper deals with the development of the Franklinian Basin in North Greenland, and is a review of data mainly collected by participants in the Geological Survey of Greenland mapping projects in North Greenland with field work between 1975 and 1985. These projects resulted in publication of more than 200 scientific papers, two published regional maps in the Survey's 1 : 500 000 series, and more detailed maps of selected areas. General regional descriptions include a volume on the sedimentary basins of North Greenland (PEEL & SØNDERHOLM 1991) and a description to accompany the two 1 : 500 000 geological maps (HENRIKSEN 1992).

THE FRANKLINIAN BASIN

The Franklinian Basin was probably initiated by rifting in latest Proterozoic times, although the timing of this event is poorly defined. The oldest exposed Franklinian deposits are of early Cambrian age, but deposition may have begun in the latest Proterozoic. Basic late Proterozoic volcanics reported in Arctic Canada as possibly representing initial rifting (TRETTIN 1989) are not known in North Greenland where the earliest deposits are of marine shelf origin with an unknown base. The Franklinian sea appears to have transgressed across an eroded land surface in North Greenland, following a hiatus of 10-30 Ma between formation of the Vendian glacial sediments deposited on the marginal platform of the Greenland shield (SØNDERHOLM & JEPSEN 1991). The slight unconformity may reflect uplift, block faulting and erosion of the latest Proterozoic sediments. However, there is no evidence for Proterozoic orogenic events in North or North-East Greenland subsequent to deposition of the Mesoproterozoic Independence Fjord Group and Zig-Zag Dal Basalt Formation on the margin of the Greenland shield (HANSEN et al. 1987, KALSBEEK et al. 1993); the latter make up the southern borderland to the Franklinian Basin.

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Manuscript received 14 October 1998, accepted 22 June 1999

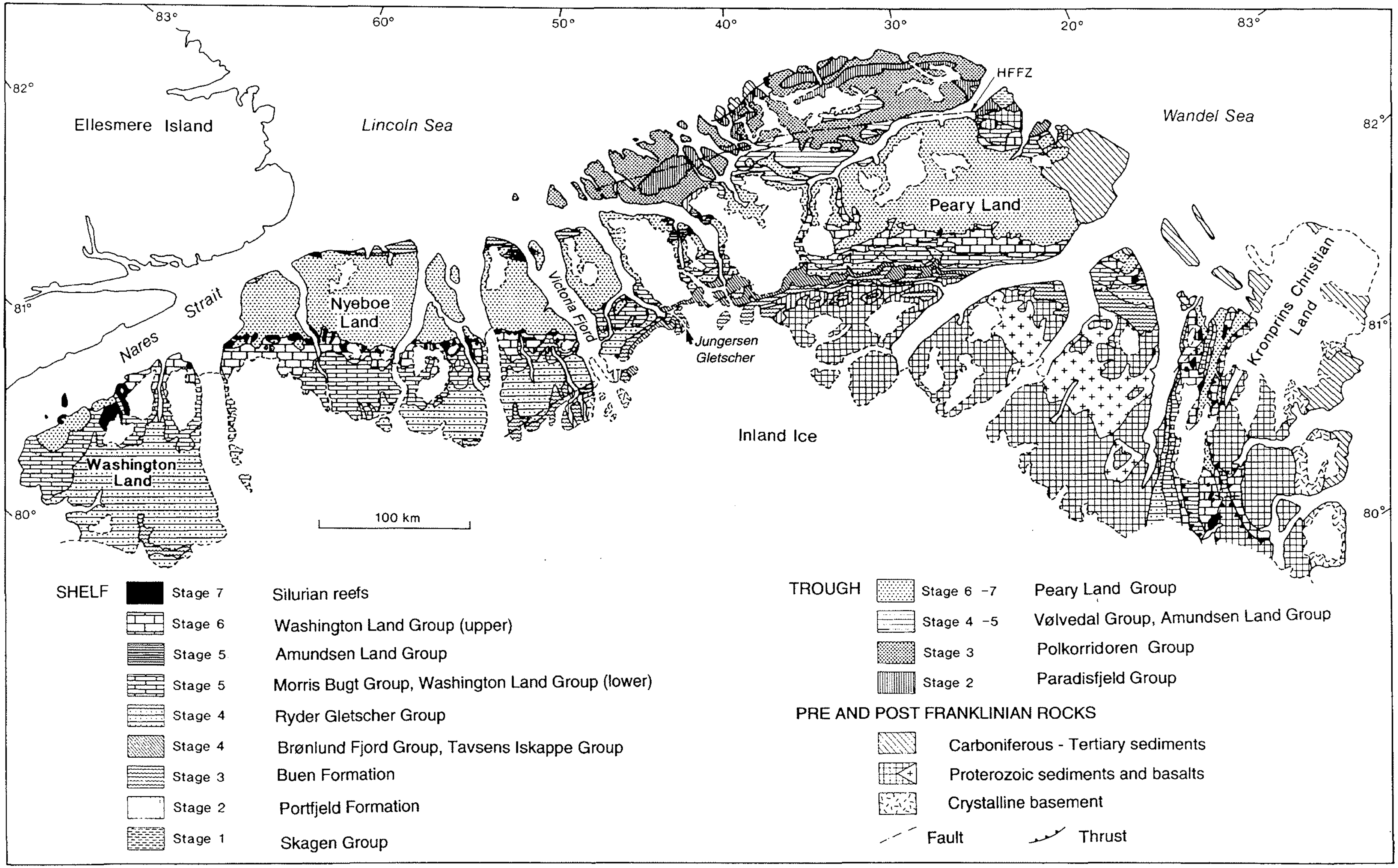

Fig. 1: Regional geological map of North Greenland showing major stratigraphic units of the Franklinian Basin corresponding to the seven basin evolutionary stages of Higgins et al. (1991a, b) described in the text. HFFZ = Harder Fjord fault zone.

In North Greenland only the southern border of the Franklinian Basin is preserved, although the existence of a northern border can be inferred from the pronounced longitudinal east to west transport of turbidites during the Silurian. SURLYK & HURST (1983) discuss whether the basin was a narrow ocean basin representing continental break-up, or formed by rift-controlled subsidence. The dominantly ensialic nature of the Franklinian Basin favours interpretation as an aulacogen, formed by rifting extending deeply into an old continental land mass and at right-angles to the Iapatus Ocean to the east. The marked differentiation into a wide shallow marine shelf bordered by a deep-water basin suggests that a spreading centre may have formed, reaching the narrow ocean stage in Early Cambrian times (SURLYK 1991).

Deposition in the Franklinian Basin in North Greenland can be considered as taking place along a passive continental margin, and its evolution during the Early Palaeozoic resulted in a distinctive differentiation into a broad shallow water shelf, a slope with medium water depths and a deep water basin or trough (HIGGINS et al. 1991a, b, HURST & SURLYK 1983, SURLYK 1991). The shelf-slope-trough formed linked depositional systems during Cambro–Ordovician times, whereas independent shelf and deep water trough depositional systems were developed in the Silurian. The distinction of seven stages in the evolution of the Franklinian Basin in North Greenland presented by HIGGINS et al. (1991a, b) is followed here; these stages mark major changes in the sedimentary regime linked to expansion of the basin by southward shift of the southern margin. The boundaries between shelf, slope and deep-water trough segments of the Franklinian Basin trend E–W, parallel to the continental margin. During the Early Palaeozoic the deep-water trough expanded southwards by foundering of the outer shelf - upper slope along E-W lineaments, which may reflect deep-seated faults or flexures. The most dramatic phase at the Llandoverian–Wenlockian boundary is marked by the incoming of Silurian turbidites which rapidly filled the trough and encroached southwards to cover much of the former carbonate shelf. This general pattern of evolution for the Franklinian Basin has also been recognised in the Canadian Arctic Islands (TRETTIN et al. 1991).

Stage 1: Late Proterozoic? – Early Cambrian shelf

The oldest known sediments in the Franklinian Basin in North Greenland are an up to 600 m thick sequence of dominantly siliciclastic and dolomitic sediments known as the Skagen Group, which were deposited in a marine shelf environment (Figs 1, 2). The occurrence of the Skagen Group sediments is limited to a few localities in central North Greenland which later became part of the deep-water trough, and the base is not known (FRIDERICHSEN et al. 1982). By comparison with equivalent strata on Ellesmere Island (Canada) the age of the Skagen Group is thought to be Early Cambrian (Atdabanian) (HIGGINS et al. 1991a).

Stage 2: Early Cambrian platform and incipient trough

This stage marks a gradual differentiation into southern shelf and northern deeper water settings; platform carbonates of the Portfjeld Formation pass northwards into slope to incipient trough carbonate mudstones and conglomerates of the Paradisfjeld Group (Fig. 2).

The Portfjeld Formation is a 200-700 m thick sequence of poorly fossiliferous, mainly dolomitic sediments which in the south (where the Skagen Group is absent) rest unconformably on a peneplained surface of either crystalline basement or Proterozoic sediments, including Vendian tillites. The formation comprises typically dolomites, silty dolomites and algal-laminated dolomites, often with conspicuous stromatolite developments. The association reflects deposition on a shallow tidal and intertidal marine platform. Northwards towards the platform edge the formation thickens, and grades abruptly into the trough equivalents of the Paradisfjeld Group (the transition is hidden nearly everywhere). Southwards at the southern edge of the outcrop, where it overlies crystalline basement, large blocks and slabs of Portfjeld Formation lithologies form a remarkable megabreccia together with basement crystalline blocks, interpreted as formed by violent earthquakes associated with faults along the southern hinge line of the Franklinian Basin (SURLYK & INESON 1987).

The Paradisfjeld Group (FRIDERICHSEN et al. 1982), at least 1 km thick, is the slope and deep water equivalent of the Portfjeld Formation. It consists of calcareous mudstones, dolomites and conglomerates and accumulated in deeper water north of the developing steep escarpment of the carbonate platform (SOPER & HIGGINS 1987, SURLYK & HURST 1984). At the end of Portfjeld - Paradisfjeld time there was a major fall in sea-level, and the Portfjeld Formation platform was exposed and to some extent developed a karst surface. No unconformity has been observed at the top of the Paradisfjeld Group, which was not exposed above sea level.

Stage 3: Early Cambrian siliciclastic shelf and turbidite trough

A major sea-level rise transgressed the subaerial surface of the Portfjeld Formation and sandstones and mudstones of the Buen Formation were deposited. At the same time the deep-sea part of the basin subsided more strongly than previously (Fig. 3) and the shelf-slope boundary retracted closer to the continent margin.

The Buen Formation is up to 500 m thick. Fossil assemblages, including an important Burgess Shale-like soft-bodied fossil fauna (CONWAY MORRIS et al. 1987, PEEL et al. 1992), indicate a late Early Cambrian age for the middle part of the formation (PALMER & PEEL 1979, INESON & PEEL 1997). The deep-water equivalents of the Buen Formation are the turbiditic deposits of the Polkorridoren Group, which are well exposed in northern Peary Land fringing the Arctic Ocean (Figs 1, 2); they reflect increased subsidence in the trough, probably controlled by trough-parallel faulting (SUR-

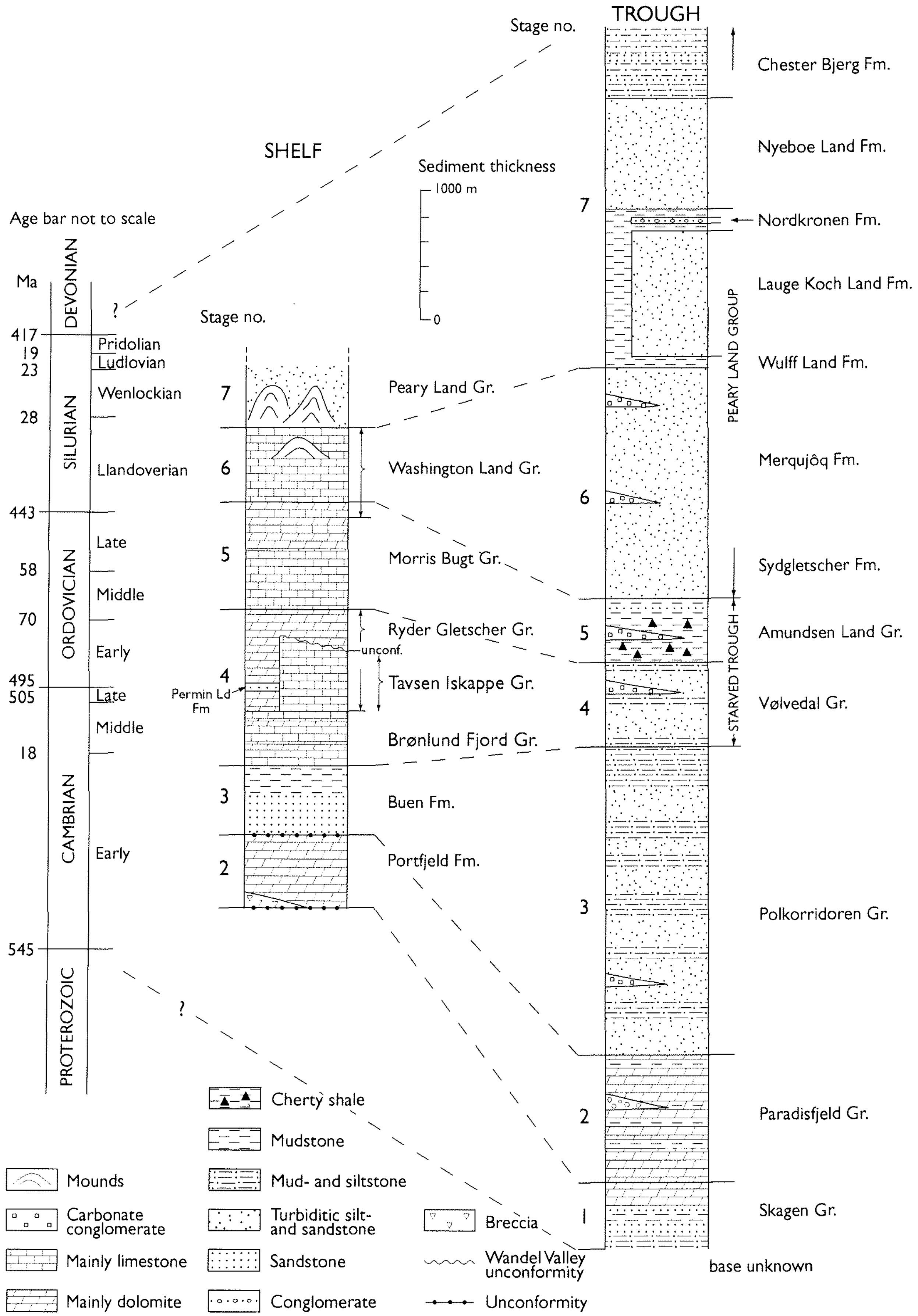

Fig. 2: Simplified stratigraphy and lithological development of the shelf and trough regions of the Franklinian Basin in North Greenland. Numbers 1 through 7 refer to the seven evoloutionary stages of the basin.

LYK & HURST 1984). The source area of these turbidites, which yielded great quantities of immature feldspar-rich sandstones, are still unknown; accumulation rates are estimated at 200 m/Ma. The lowest parts of the Polkorridoren Group may correspond to a hiatus at the base of the Buen Formation (Fig. 3; DAVIS & HIGGINS 1987). The Polkorridoren Group is estimated to total 2-3 km in thickness and is comprised of alternating units of mudstones and sandy turbidites. About 600 m above the base a series of large carbonate blocks (olistoliths), some more than 100 m across, can be traced along strike for several tens of kilometres. They have been interpreted as derived from submarine canyons (FRIDERICHSEN & BENGAARD 1985), or a consequence of active faulting along the platform margin escarpment (SOPER & HIGGINS 1987).

Stage 4: Late Early Cambrian – Middle Ordovician shelf and sediment-starved trough

During stages 4 and 5, the period from late Early Cambrian to earliest Early Silurian (Llandoverian), thick carbonate sequences were deposited on the shelf (25 m/Ma) whereas the slope and trough were characterised by low sedimentation rates with deposition of black shales and chert (10-15 m/Ma) (Fig. 3). This is the only phase in the development of the Franklinian Basin when sediment accumulation was greatest on the shelf.

During stage 4 the carbonate sequences on the shelf varied considerably from east to west, reflecting a progressive shelf uplift and erosion in eastern North Greenland which terminated in the Early - Middle Ordovician, and produced the Wandel Valley unconformity (Fig. 3). In western North Greenland there was no uplift, and deposition on a uniformly subsiding, aggradational shelf is mainly represented by the Ryder Gletscher Group, a 1500 m thick sequence dominated by shallow water subtidal dolomites and intertidal to supratidal units. The transition from platform to outer shelf-slope is often marked by slope deposits with a primary dip of up to 30°. A persistent thin horizon (circa 50 m) of shallow marine sandstones (Permin Land Formation, Fig. 2), at about the Cambrian–Ordovician boundary, can be traced over most of western North Greenland. This widespread clastic incursion is correlated with the maximum regression in eastern North Greenland and with a eustatic lowstand in sea-level (BRYANT & SMITH 1990).

The northern rim of the carbonate platform developed as a distinctive escarpment, the Navarana Fjord escarpment, trending approximately parallel to the longitudinal axis of the Franklinian Basin.This long-lived feature, possibly initiated on an original basin margin fault, formed the boundary between the carbonate platform and the trough from latest Cambrian to late Early Silurian time (HIGGINS et al. 2000, this vol.).

Deposition in the trough during stage 4 is represented by outer slope and trough-floor mudstones, cherts, turbidites and conglomerates of the Vølvedal Group (FRIDERICHSEN et al. 1982). Their deposition may be linked to the uplift of eastern areas of North Greenland in the Cambrian (SURLYK & HURST 1984).

Stage 5: Middle Ordovician – Early Silurian aggradational carbonate platform, starved slope and trough

Stage 5 is a continuation of the development trend of the upper part of stage 4, with stable carbonate deposition and subsidence on the platform, and low sedimentation rates on the slope and trough. The Navarana Fjord platform escarpment attained a steep scarp-like front up to 1300 m high, with a narrow slope area at its foot grading northwards into the trough. The slope received very little sediment, while trough deposition was greater but still with the character of starved sedimentation.

The carbonate platform sequence comprises the Morris Bugt Group and the basal part of the Washington Land Group (HURST 1984, SMITH et al. 1989, SØNDERHOLM et al. 1987), which have a constant thickness of circa 650 m throughout the region. The lower part includes lime mudstones and wackestones from low energy environments, and the upper part massive limestones, with small dolomite and limestone mounds. Distinction of eastern and western facies has been made in North Greenland, but good stratigraphic correlation can be made. Rapid accretion towards the end of the Early Silurian appears to have led to a general shallowing of the platform sea, and a change in carbonate sedimentation with stage 6.

The starved slope sequence of stage 5 comprises cherts and cherty shales with chertified siltstones, limestones and dolomitic mudstones (HIGGINS & SOPER 1985). The sequence is only 50-150 m thick and was deposited over a period of circa 60 Ma between the Tremadocian and late Llandoverian (1-2 m/Ma). The equivalent trough sequence, only preserved in parts of northern Peary Land, comprises black and green radiolarian cherts and mudstones of the Amundsen Land Group, formed by slow sedimentation under anoxic conditions. The sequence is periodically interrupted by thick wedges of carbonate conglomerates, up to 200 m thick, comprising Ordovician carbonate debris derived from unroofing of the carbonate platform to the south.

Stage 6: Early Silurian ramp and rimmed shelf, and turbidite trough

This stage marks a dramatic change in the development of the Franklinian Basin, which can be linked with the uplift of the Caledonian mountain chain in East Greenland, and erosion and deposition of denudation products into the deep water trough of the Franklinian Basin (HURST et al. 1983). Throughout North Greenland the abrupt change from starved basin sedimentation to rapid deposition of thick bedded turbidites can be dated on the basis of graptolites to the late Llandoverian (HIGGINS & SOPER 1985, HURST & SURLYK 1982, LARSEN & ESCHER 1985). The trough filled rapidly, and by the Llandoverian-Wenlockian boundary the Navarana Fjord escarpment which had formerly marked the platform edge was buried and the trough expanded southwards (stage 7, see below). Foundering of the platform due to the loading effect of the thick sequences of turbidites led to drowning of the outer shelf across all of North Greenland,

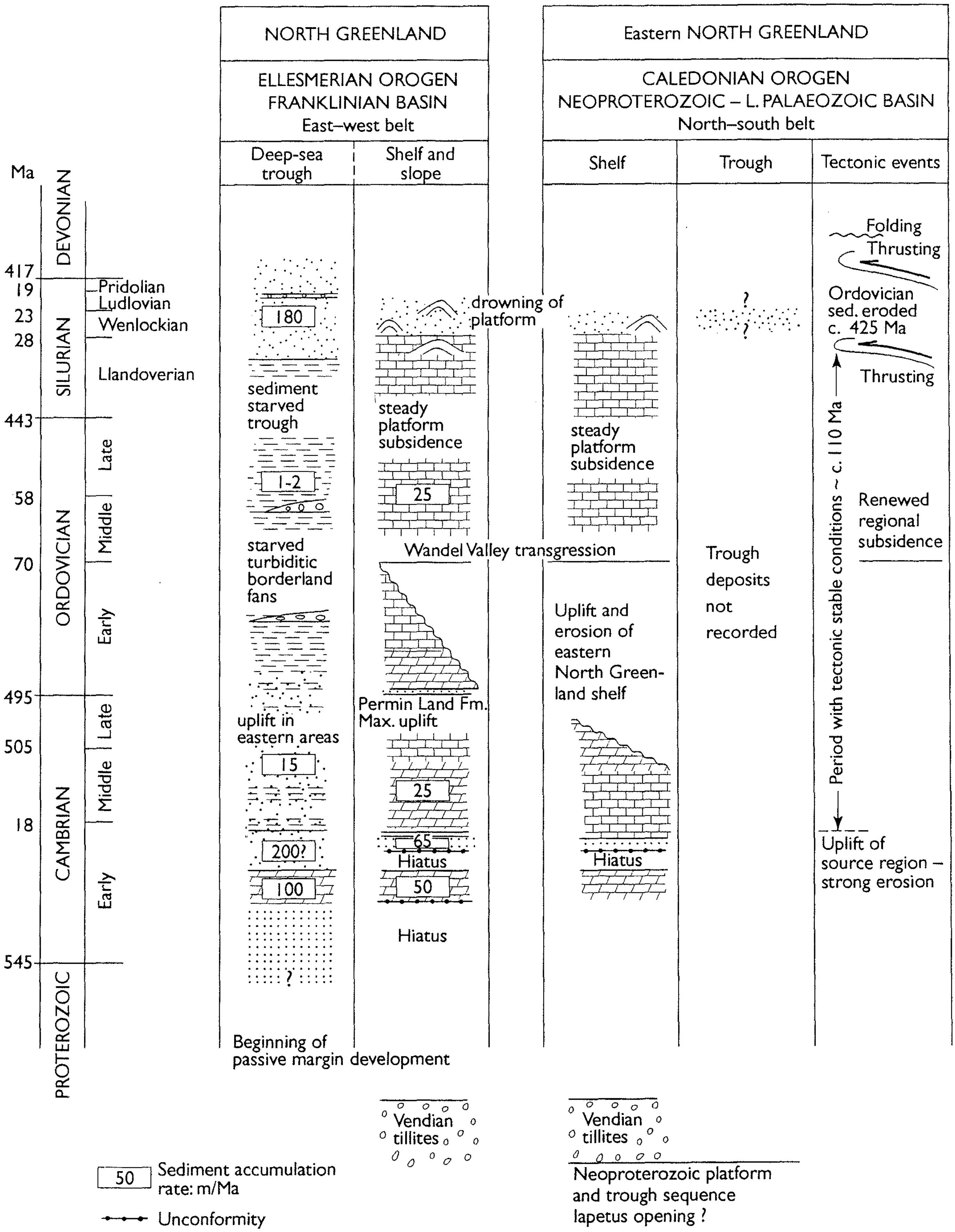

Fig. 3: Relationships between the sedimentological basin development in adjacent parts of the East Greenland Caledonian fold belt and the North Greenland (Ellesmerian) fold belt. Absolute time scale at left after Gradstein & Ogg (1996). Note great range in calculated accumulation rates (m/Ma = metres per million years), from 1-2 m/Ma during the Ordovician starved basin phase to 180-200 m/Ma or more during turbidite deposition in the Early Cambrian and Silurian.

although carbonate deposition continued in a reef belt traceable along the entire southern boundary of the Franklinian Basin (stage 7, see below).

The carbonate platform sediments of stage 6 vary in facies from east to west. They are all assigned to the Washington Land Group, which thickens towards the west and is characterised by limestones, lime-mudstones and wackestones. In the western areas intra-shelf mounds are widespread, together with intermound carbonates. The mound complexes did not form a complete barrier, and a steep indented margin developed with re-entrants infilled with dark, cherty lime muds and shales. South of the shelf margin an essentially flat carbonate platform was maintained.

In the deep water trough a sequence of up to 5 km of sediments accumulated between the late Early Llandoverian and the earliest Devonian (stages 6 and 7), and the whole sequence is assigned to the Peary Land Group (Fig. 2). According to SURLYK & HURST (1984) the huge deep-sea turbidite fan system responsible for these deposits may represent the world's largest ancient deep-sea fan system. With its extension into Canada it is estimated to have had a length of 1500-2000 km and a width of over 200 km, and to have had a total fan volume of more than two million km^3.

The stage 6 part of the trough succession comprises a sandstone turbidite sequence up to 2800 m thick known as the Merqujôq Formation, interpreted as laid down in outer fan and trough floor environments. This enormous thickness was probably deposited entirely within the Late Llandoverian (Fromian-Telychian; LARSEN & ESCHER 1987, 1991). Palaeocurrent directions are uniformly towards the west-south-west, parallel to the platform margin formed by the Navarana Fjord escarpment. A prominent feature of the basin deposits of this stage is the occurrence of several large carbonate conglomerate deposits interbedded with the turbidites in units up to 50 m thick. In contrast to the turbidites, the carbonate conglomerate fans were derived from the platform margin area to the south.

Stage 7: Late Silurian trough expansion – final drowning of the platform

By the end of the latest Llandoverian the deep water trough was filled, and the trough expanded southwards onlapping and burying the Navarana Fjord escarpment. The shelf was inundated by mudstones and siltstone turbidites, with carbonate sedimentation only maintained around major mound complexes along the distal rim of the platform; these reef mounds reach up to 300 m in height and formed during late Llandoverian to Early Ludlovian time. The foundering of 30 000 - 40 000 km^2 of the former carbonate shelf is ascribed to the effects of the down-flexing of the crust caused by the load of turbiditic sediments in the trough, combined with a major eustatic sea-level rise (SURLYK 1991).

Flooding of the former platform is marked by deposition of an up to 100 m thick dark mudstone unit at the base of the Wulff Land Formation (Fig. 2). Inundation of the northern part of the shelf margin by clastic sediments occurred in the late Llandoverian, whereas the southern part was overlain by clastic sediments at the Llandoverian-Wenlockian boundary. After this initial phase of trough expansion and submarine fan starvation, turbidite depositional systems rapidly built up again as extensive, westwards prograding submarine fans.

The turbidite deposits of stage 7 are mainly represented by the Lauge Koch Land Formation which varies in thickness from circa 850 m in the west to more than 2 km in the east (HURST & SURLYK 1982, LARSEN & ESCHER 1987). The turbidites are characterised by sandstones and mudstones in 50-100 m thick fining upwards cycles. Grain size and bed thickness decrease in the down-current direction westwards. The entire depositional setting has been interpreted as a submarine fan passing gradually westwards into a basin plain (HURST & SURLYK 1982, SURLYK & HURST 1984). Pulses of turbidite deposition alternated with periods of fan starvation.

Several very persistent conglomerate units can be traced from east to west across North Greenland, and make up the Nordkronen Formation (HURST & SURLYK 1982, LARSEN & ESCHER 1987, SURLYK & HURST 1984). The conglomerate units are interbedded with sandstone turbidites and vary in thickness from 32 m to several hundred metres. In contrast to other conglomeratic units in the Franklinian Basin, they are characterised by well rounded and well sorted chert clasts in a sandstone matrix. The chert conglomerates were deposited from high density turbidity currents which travelled distances of 600-800 km westwards along the trough axis, and were most likely derived from erosion of uplifted cherty sequences of the Ordovician Vølvedal and Amundsen Land Groups in the rising Caledonian mountains to the east. The conglomerates are of Early to Late Ludlovian age.

The uppermost units of the trough succession in North Greenland are represented by up to 1000 m of medium to thickly bedded sandy turbidites (Nyeboe Land Formation) and 500-800 m of laminated mudstones and siltstones (Chester Bjerg Formation). Graptolite assemblages indicate a Ludlovian to Pridolian age, but the youngest part of the sequence is thought to range up into the Lower Devonian (LARSEN & ESCHER 1987).

The age of the Ellesmerian orogeny in North Greenland is constrained to between the age of the youngest sediments in the basin (Lower Devonian?) and the age of the oldest post-Ellesmerian deposits, which are of Late Carboniferous age (Early Moscovian, 312 Ma). In Ellesmere Island, Canada, the age of the Ellesmerian orogeny *sensu stricto* is dated as Late Devonian - Early Carboniferous (TRETTIN 1991).

STRATIGRAPHICAL EVIDENCE OF CALEDONIAN TECTONIC EVENTS

The junction of the two Palaeozoic orogenic belts in Greenland, the East Greenland Caledonides and the North Greenland fold belt (Ellesmerian), is obscured in the region offshore eastern North Greenland. Their relationship cannot be observed directly, and the only evidence of the nature of the junction is from geophysical observations (Schlindwein & Meyer 1999). However, the development of the Franklinian Basin and the character of its deposits are clearly related in some respects to the Caledonian tectonic developments in North-East Greenland (Fig. 3).

The time of opening of Iapetus is not well defined. There are no recorded Neoproterozoic volcanic rocks in North-East Greenland, and the age of the only sedimentary sequences which might be basinal deposits in an early Iapetus Ocean, the Rivieradal sandstones of Kronprins Christian Land (Sønderholm & Jepsen 1991), is not well constrained. Their deposition may have begun circa 700-800 Ma ago, but they might also be as young as 600-650 Ma old (Jepsen & Kalsbeek 2000, this vol.).

The opening of the ocean off North Greenland that initiated the Franklinian Basin can only be indicated as post-Vendian (circa 600 Ma) from evidence in North Greenland; it began to develop as a distinctive passive margin by Early Cambrian time (545-530? Ma). This is probably somewhat younger than the break-up outside North-East Greenland's continental margin.

The Early Cambrian turbiditic trough deposits (Polkorridoren Group) in the Franklinian Basin and their siliciclastic correlatives on the platform to the south (Buen Formation) rest on the underlying carbonates with a minor erosional unconformity marking a hiatus. The marked change in sedimentological environment from carbonate dominated to siliciclastic sequences reflects an uplift in the source regions, which probably included thick sequences of Mesoproterozoic and Neoproterozoic sediments as well as crystalline basement of the Greenland shield areas, and uplifted Cambrian strata in the east (Surlyk & Hurst 1984). Surlyk (1991) has linked this change in depositional character to a late rift peripheral bulge migrating southwards.

Regional uplift of the eastern shelf of the Franklinian Basin was probably initiated in the late Early Cambrian and created a westwards decreasing hiatus in the succession. This episode of uplift persisted into the earliest Ordovician and has been interpreted as the effects of a peripheral bulge migrating westwards as a consequence of an early Caledonian collision event (circa 520-470 Ma ago) along the western margin of the Iapetus Ocean (Surlyk & Hurst 1984, Surlyk 1991); for an alternative extensional scenario see Smith et al. (1999).

Evidence of the unroofing of the pre-Wandel Valley Formation succession is seen in thick Early Ordovician carbonate conglomerates in the eastern part of the Franklinian Basin. In the Late Ordovician - Early Llandoverian thin-bedded silty turbidites interupted the starved basin deposition locally (Amundsen Land Group), the precursor to the basin-wide turbidite influx which began abruptly in the early Late Llandoverian. There is compelling evidence that these deposits are erosion products from the rising Caledonian mountain belt to the east (Surlyk 1982, Hurst et al. 1983, Higgins et al. 1991a). Studies of conodont alteration indices in the parautochthonous Palaeozoic carbonates in front of, and underlying, the Caledonian nappes of Kronprins Christian Land indicate that the overlying nappe pile forming the Caledonian mountains reached thicknesses of at least 8-10 km (J.A. Rasmussen & M.P. Smith personal communications 1998; Higgins et al. 2000, this vol.), and it is the erosion products from these advancing Caledonian nappes that provided the vast quantities of detritus that filled the Franklinian Basin during the Silurian - Early Devonian.

The distinctive chert pebble conglomerates of middle Wenlockian to Ludlovian age (Nordkronen Formation) within the turbiditic trough sequence of the Franklinian Basin can be linked to the uplift and erosion of specific stratigraphical units in the Caledonian nappes of Kronprins Christian Land, eastern North Greenland; the only source of significant chert is the Ordovician starved basin sequence of the Amundsen Land Group (Larsen & Escher 1985, 1987, Surlyk & Hurst 1984).

In Kronprins Christian Land middle Wenlockian turbidites occur in the thrust sheets of the parautochthonous thrust belt, and are structurally overlain by a major thrust sheet comprising Proterozoic sediments. These middle Wenlockian strata are the youngest recorded sediments of the Iapetus succession in North-East Greenland, but are circa 10 Ma younger than the inferred earliest thrusting and uplift. This demonstrates that deposition continued for an extensive period in this region after the onset of Caledonian thrusting, until brought to a close by the westward advance of the Caledonian nappes.

The sedimentary basins affected by the Caledonian deformation in Kronprins Christian Land and the almost perpendicular trending Ellesmerian fold belt in North Greenland show different styles of deposition and deformation. The Iapetus margin includes deposits which may have begun to form 700-800 Ma ago, with a Middle Cambrian to Middle Ordovician hiatus being followed by sedimentation up to the Early Silurian (middle Wenlock). The main Caledonian orogenesis had begun by the Early Silurian (early Late Llandoverian, circa 435-430 Ma ago). $^{40}Ar/^{39}Ar$ mineral ages from the Caledonides suggest that thrust-related regional deformation and metamorphism continued into the Early Devonian (Dallmeyer & Strachan 1994, Dallmeyer et al. 1994). Deposition in the Franklinian Basin in North Greenland began at around the Proterozoic-Cambrian boundary and continued to the earliest Devonian. The following Ellesmerian orogenic deformation is not closely constrained in North Greenland, but took place between the middle Devonian and late Carboniferous time. The North Greenland (Ellesmerian) fold belt thus reflects continental closure which may be up to 100 Ma later than the final phases of the North-East Greenland Caledonides. It may be concluded that the two Palaeozoic orogenic belts of North Greenland and East Greenland were essentially two separate geotectonic systems, but both affected sediments of the Franklinian Basin in eastern North Greenland.

ACKNOWLEDGMENTS

We thank J. Golonka and U. Mayr for valuable referee comments and suggestions. This paper is published with the permission of the Geological Survey of Denmark and Greenland.

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