Palaeogeographic evolution

The shallow marine sediments of the Pliensbachian – Early Bajocian Neill Klinter Group were deposited in a more than 200 km long and 100 km wide fault-bounded embayment. Deposition was influenced by tidal and storm wave currents.

The embayment was restricted to the same depositional basin as the underlying Rhaetian–Sinemurian lake complex of the Kap Stewart Group (Surlyk *et al.*, 1981; Surlyk, 1990b; Dam, 1991; Dam & Surlyk, 1990, 1993). In the central, northern, and north-western parts of the basin the change from lacustrine to shallow marine conditions resulted in a succession in which lacustrine mudstones, with clear non-marine indicators, coarsen-upward into fine-grained sandstones with marine body and trace fossils, associated with a marked increase of the ratio of total sulphur to total organic carbon (Dam & Christiansen, 1990; Dam & Surlyk, 1993). This coarsening-upward succession is remarkable in that it reflects a shallowing-upward tendency at the same time as it marks a change from freshwater to marine conditions. This suggests that the lacustrine basin and probably much of the rift complex between Greenland and Norway was low-lying and that the basin was separated from the nearby sea by shallow barriers. The barriers were flooded during the Early Jurassic eustatic rise, resulting in increased sediment supply and changed circulation patterns within the basin that could give rise to the coarsening-upward succession. The marine link was probably established through a south-eastern entrance along the present-day Scoresby Sund or a southwards extension of the basin. However, this cannot be clearly determined on the basis of the present-day exposures. The Early Jurassic marine inundation has been recorded throughout the North Atlantic rift complex and coincides with a long term Late Triassic – Early Jurassic eustatic sea-level rise (e.g. Haq *et al.*, 1987; Hallam, 1988; Surlyk, 1990a).

A striking feature of the Lower – lower Middle Jurassic Neill Klinter Group is the marked sheet-like geometry of both members and formations on several scales along the exposed basin margins (Fig. 46). This indicates that the Lower – lower Middle Jurassic sediments in the Jameson Land Basin were deposited during a period of relative tectonic quiescence, and facies patterns were mainly controlled by relative sea-level fluctuations, sedimentary influx and marine dispersal systems. However, reflection seismic data (Christiansen *et al.,* 1991) clearly indicate that the Upper Triassic – lower Middle Jurassic Kap Stewart and Neill Klinter Groups show a general thickness increase towards the central parts of the basin, with additional minor depocentres in the eastern part of the basin. The latter are aligned parallel to deep Devonian NW–SE trending transverse basement faults (Dam *et al.,* 1995). The trend of the faults is also clearly visible on Landsat images as major topographic lineaments and are linked to present-day topographic lineaments along which gentle large-scale flexures are commonly developed. These flexures are related to minor Mesozoic and younger deformations. The deep faults also exerted an important control on facies distribution throughout Rhaetian – Pliensbachian times without actually truncating the Mesozoic succession (Dam *et al.,* 1995). The Upper Triassic – lower Middle Jurassic succession thus demonstrates evidence of subtle fault control on subsidence, as seen from isopach maps. However, possible direct field evidence of Early Jurassic tectonic activity along the bounding faults includes the presence of extensive debris flow deposits associated with the storm-dominated offshore deposits of the Albuen Member and the establishment of an apparently structurally controlled lagoon (Horsedal Member) in the northern part of the basin during latest Pliensbachian times.

The changing palaeogeography of the basin through Early – early Middle Jurassic times is described in the following section. Three palaeogeographical reconstructions have been made based on lithostratigraphic, palaeoenvironmental and tectonic evidence.

Latest Sinemurian – Early Pliensbachian marine inundation and establishment of a shallow marine embayment (Rævekløft Formation and Elis Bjerg Member)

The lower 74 m of the Elis Bjerg Member in the north-western part of the basin (Ranunkeldal), are well-exposed and comprise a succession of storm-dominated offshore transition zone, wave and storm-dominated shoreface and tidal channel deposits (Figs 10, 11). The sediments can be divided into six well-defined coarsening-upward units, 5–35 m thick, formed

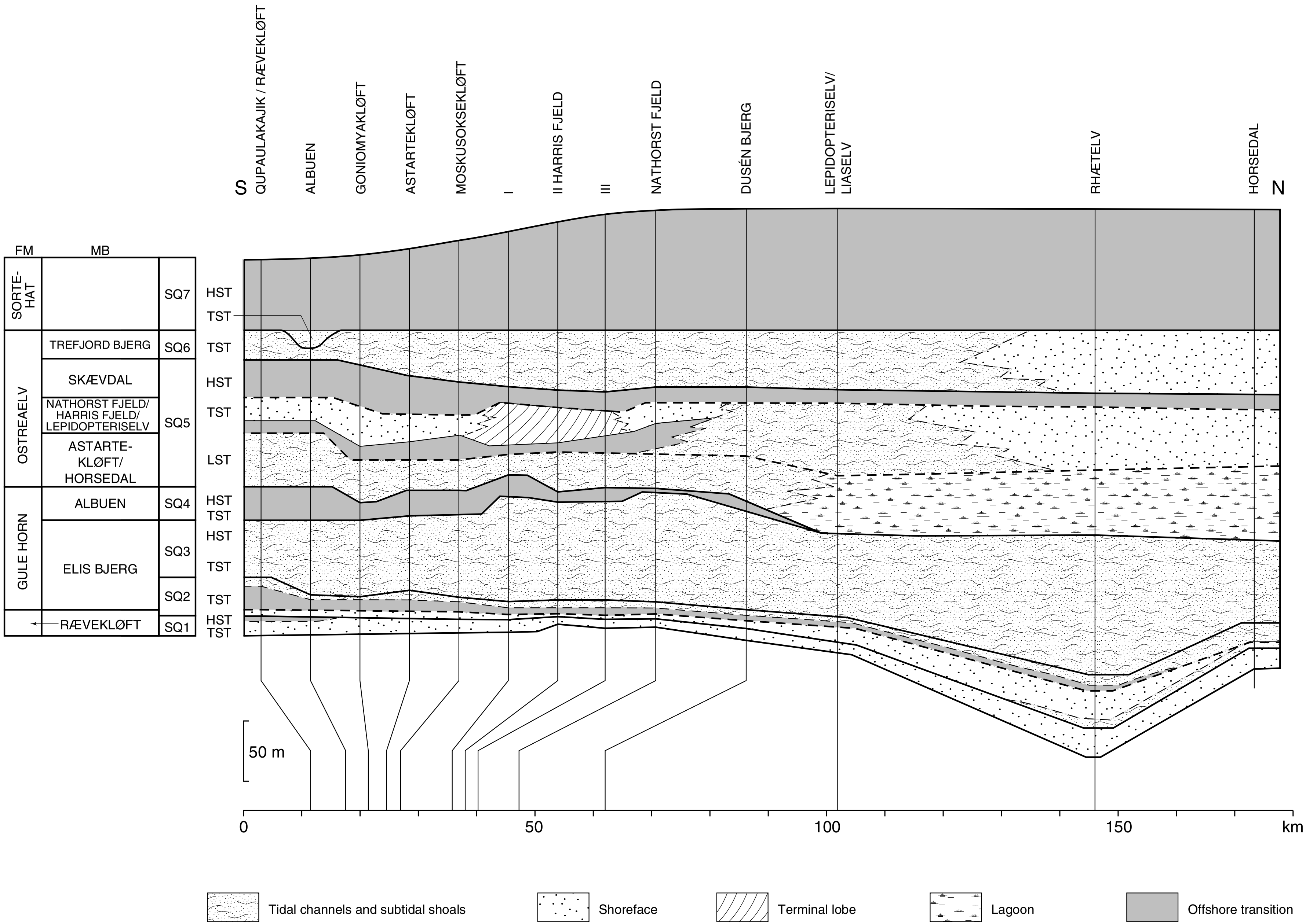


Fig. 46. Sequence stratigraphic and depositional environment correlation panel of the Lower – lower Middle Jurassic Neill Klinter Group, East Greenland. Position of measured sections are marked. Bold-faced line = sequence boundary; Stippled bold-faced line = major flooding surface.

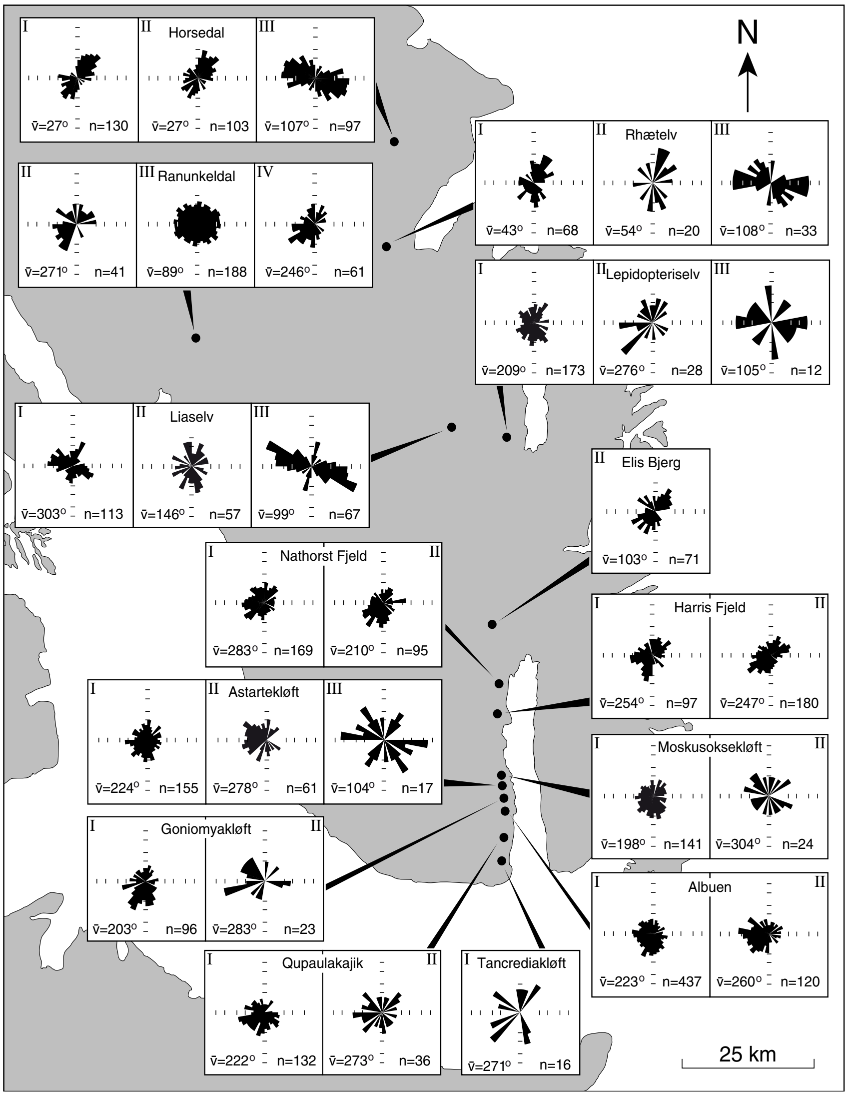


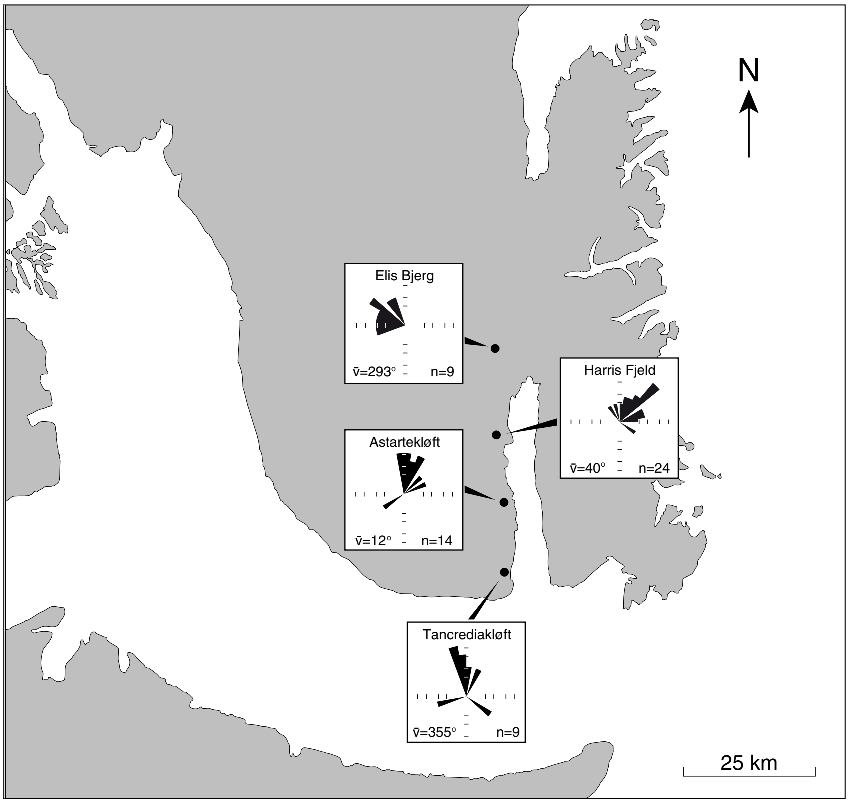
Fig. 47. Palaeocurrent and wave ripple data from the Elis Bjerg Member.
I = foreset azimuths of cross-lamination;
II = foreset azimuths of cross-bedding;
III = crestline orientation of wave ripples;
IV = foreset azimuths of wave-ripple cross-bedding.
Rose diagrams are shown as true area plots. Marks at 5, 10, 20 and 30 % frequency.
v = vector mean;
n̄ = number of measurements.

by progradation of wave and storm-dominated shoreface (Facies association e) across a storm-dominated lower shoreface transitional environment (Facies association d). Tidal channel deposits may top the successions (Facies association g). Crest line orientations of wave ripples in the shoreface and storm-dominated lower shoreface transitional deposits show a rather large scatter with a preferred NW–SE orientation, perpendicular to the western basin margin (Fig. 47). Palaeocurrent data from the cross-bedded shoreface sandstones indicate asymmetrical bipolar NE and SW current directions, roughly parallel to the western basin margin (Fig. 47). No tidal features are present and the close association with wave ripples suggest that the dominant mode of transportation was by wind-driven coast-parallel currents.

Along the south-eastern part of the basin the succession is initiated with the coarse-grained foreshore and shoreface deposits of the Lower Pliensbachian Rævekløft Formation (Facies association a and b) (Figs 6, 7). At the south-easternmost localities (Tancrediakløft and Qupaulakajik) the foreshore and shoreface sandstones are separated by a unit of offshore transition mudstones (Facies association c) (Fig. 7). The mudstones represent a flooding event coincident with an apparent hiatus corresponding to the Ibex Zone between the Jamesoni and Davoei Zones. Palaeocurrent data from the cross-bedded shoreface sandstones show unimodal directions towards N–NE, parallel to the eastern basin margin, suggesting deposition from coast-parallel currents (Fig. 48).

In the south-eastern part of the basin the Elis Bjerg Member is 73–95 m thick and shows a general increase in thickness towards the north (Plate 2). The member is initiated with an offshore transition mudstone unit, 5–13 m thick (Facies association c) which extends along

Fig. 48. Palaeocurrent data (foreset azimuths) from the Rævekløft Formation. Rose diagrams are shown as true area plots. Marks at 5, 10, 20 and 30% frequency; ∇ = vector mean; n = number of measurements.



the Neill Klinter and at least as far north as Elis Bjerg. The mudstones pass upward into closely interbedded deposits of extensive subtidal sand sheets, storm-dominated sandy shoals and relatively deep, actively migrating tidal channels (Facies associations f, g and h). One of the most common sedimentological features is the along-strike lateral transition between the sandy subtidal sand sheet, tidal channel, and storm-dominated shoal associations. The coarsening-upward part of the sandstone bodies reflects progradation of tidal channels where lower shoreface and offshore transition zone deposits pass upwards into subtidal dune field and tidal channel sandstones. The sandstone bodies commonly consist of several smaller cycles of limited lateral extent (1–2 km) which are probably due to autocyclic shift in depocentres. The Elis Bjerg Member appears to thicken along strike towards Harris Fjeld (Plate 2). The thickness increase is associated with an increased amount of tidal channel deposits and a major tidal channel complex is suggested to have been situated in the present-day Harris Fjeld area.

Combined palaeocurrent data from the tidally-influenced facies show two bipolar populations, suggesting reversing currents approximately perpendicular and parallel to the eastern basin margin, respectively (Fig. 47). The N–S to NE–SW population, parallel to the basin margin, is associated with subtidal sand sheet deposits, whereas the E–SE to W–NW population is associated with tidal channel deposits. The latter population is strongly asymmetric with dominantly offshore directed palaeocurrent directions, suggesting an eastern source area covering parts of the present-day Liverpool Land area and bedform migration in response to offshore (ebb) flows.

In the north-eastern (Lepidopteriselv, Liaselv) and northern (Horsedal) parts of the basin, the Elis Bjerg Member is 95–100 m thick. It consists of 5–6 poorly developed coarsening-upward or coarsening-fining upward successions, 4–44 m thick. The coarsening-upward successions were formed by progradation of a subtidal dune field across a ripple field or storm-dominated lower shoreface. Tidal channel deposits only top the Elis Bjerg Member in the Horsedal section. The member thickens towards the central parts of the basin and is 185 m thick at Rhætelv, but the nature of the exposure does not allow study of number and nature of cyclic successions.

Wave ripple data from the north-eastern (Lepidopteriselv and Liaselv), northern (Horsedal) and central (Rhætelv) parts of the basin show dominant ESE–WNW and ENE–WSW crestline orientations, parallel to the northern basin margin and perpendicular to the east-

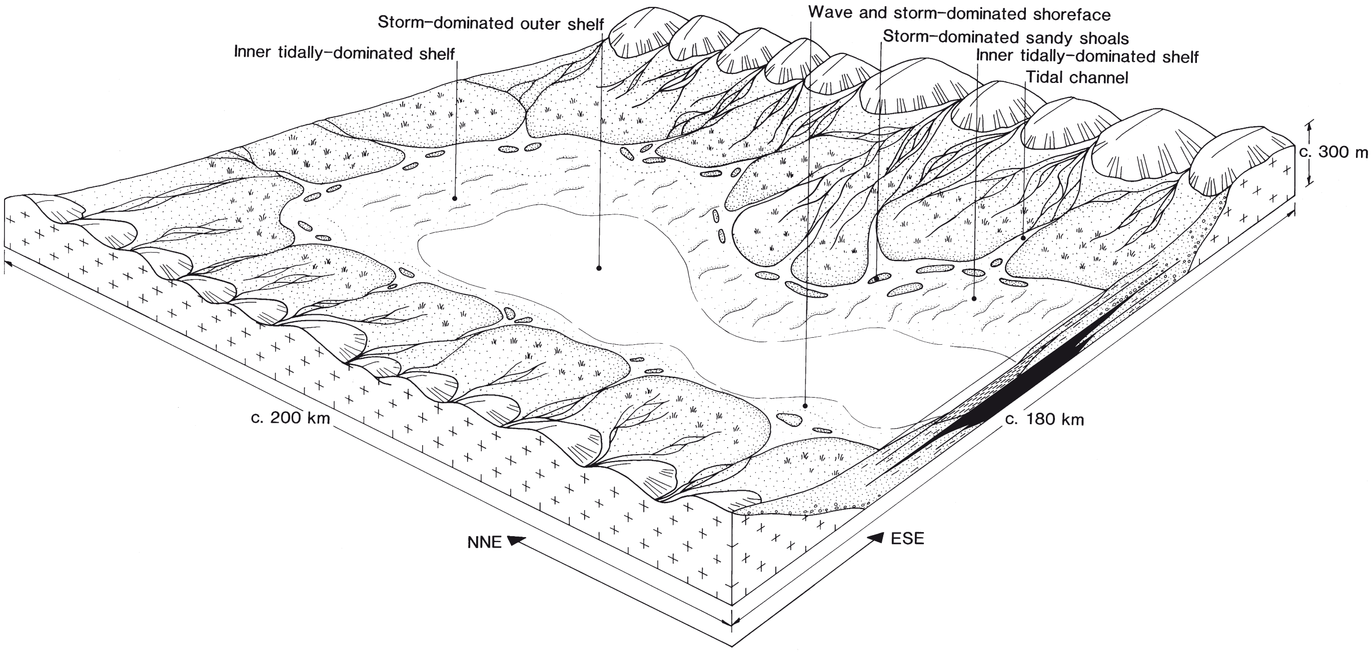


Fig. 49. Palaeogeographical reconstruction of the Jameson Land Basin during Early Pliensbachian times.

ern and western basin margins (Fig. 47). Palaeocurrent data from the cross-bedded and cross-laminated subtidal sandstone sheets show generally bipolar NNE–SSW directions, parallel to the eastern and western basin margins (Fig. 47).

An Early Pliensbachian palaeogeographic reconstruction of the Jameson Land Basin is shown in Fig. 49. Material was transported into the shallow marine embayment from northern, eastern and western land areas. Along the eastern and northern parts of the embayment sediment was evenly distributed via ebb-dominated tidal channels into extensive subtidal dune fields driven mainly by tide-enhanced currents. An important source area appears to have been present east of the present-day Harris Fjeld area. The dune fields passed basinwards into restricted or wave and storm-dominated shelf environments.

Along the western part of the basin the dominant mode of sand transport appears to have been in northwards and southwards migrating dune fields mainly driven by wind-induced coast-parallel currents. The dune fields passed basinwards into a storm-dominated offshore shelf with deposition of sheet sands from downwelling flows during storms.

Late Pliensbachian sea-level rise and establishment of a storm-dominated offshore shelf (Albuen Member)

Following the deposition of the Elis Bjerg Member, a major landward shift of facies occurred, and in the south-eastern part of the basin a wedge of storm-dominated lower shoreface sediments (Facies association i), associated with submarine debris flow deposits (Facies association j), were deposited in a shallow shelf environment (Fig. 20). The wedge is 25 m thick at Qupaulakajik, thins to less than 2 m at Nathorst Fjeld and disappears north of this location. The lower boundary of the wedge is a prominent flooding surface and the wedge appears to onlap the top of the Elis Bjerg Member. At Nathorst Fjeld the Albuen Member is erosionally overlain by the Astartekløft Member.

At Nathorst Fjeld the crestline of wave ripples from the offshore sandstones of the Albuen Member shows preferred E–W orientations, perpendicular to the eastern basin margin (Fig. 50). The debris flow deposits associated with the storm-dominated lower shoreface deposits may have been triggered by either major storms, tectonic activity or catastrophic floods in the sediment source area. As prominent submarine debris

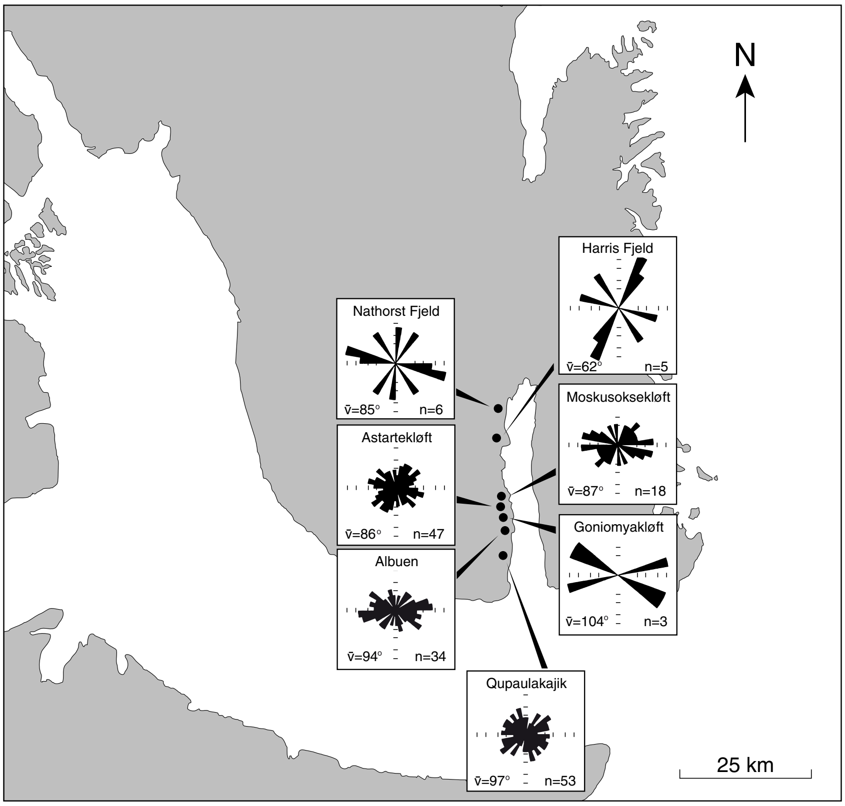


Fig. 50. Palaeowave ripple data from the Albuen Member. Rose diagrams are shown as true area plots. Marks at 5, 10, 20 and 30% frequency.
$\bar{v}$ = vector mean;
n = number of measurements.

flow deposits only occur in this interval where they are relatively common, it is suggested that they reflect tectonic activity along the margin of the eastern borderland.

Establishment of a latest Pliensbachian lagoon controlled by deep Devonian faults (Astartekløft and Horsedal Members)

A major basinward shift in facies took place in the latest Pliensbachian and comprises two spatially separated successions of subtidal channels and subtidal shoals (Astartekløft Member), and wave and storm-dominated lagoonal deposits (Horsedal Member).

At Nathorst Fjeld the base of the Astartekløft Member is marked by a major erosional unconformity, and the Albuen Member is almost completely eroded away. At this locality the Astartekløft Member consists of a single fining-upward tidal channel succession (Facies association m) overlain by a thin coarsening-upward succession (Fig. 28). The palaeocurrent data from this locality indicate flows towards the west suggesting bedform migration in response to offshore directed (ebb) currents, from an eastern source area covering the present-day Liverpool area (Fig. 51).

Further south along Neill Klinter, the unconformity between the Albuen and Astartekløft Members disappears and passes into a correlative conformity, and the shoreface deposits of the Albuen Member pass into subtidal sand sheet deposits arranged in an overall coarsening-upward succession (Facies association f) (Fig. 27). The combined palaeocurrent data from the Astartekløft Member at Neill Klinter show two bipolar populations, suggesting reversing currents approximately perpendicular and parallel to the eastern basin margin, respectively (Fig. 51).

The Horsedal Member has been traced for more than 75 km in the northern and north-eastern parts of the basin and shows an extremely uniform thickness (ranging between 50 and 60 m) and facies development, very different from the contemporaneous Astarte-kløft Member. The sediments are arranged in stacked coarsening-upward units, 1–6 m thick, produced by wave and storm-dominated shoreface progradation into a protected lagoon (Facies association k) that probably covered more than 8000 km^2 (Figs 24, 25, 52). A single ephemeral stream delta succession is interbedded with the shoreface deposits (Facies association l; Figs 24, 26). Wave ripple data indicate an E–W to ESE–

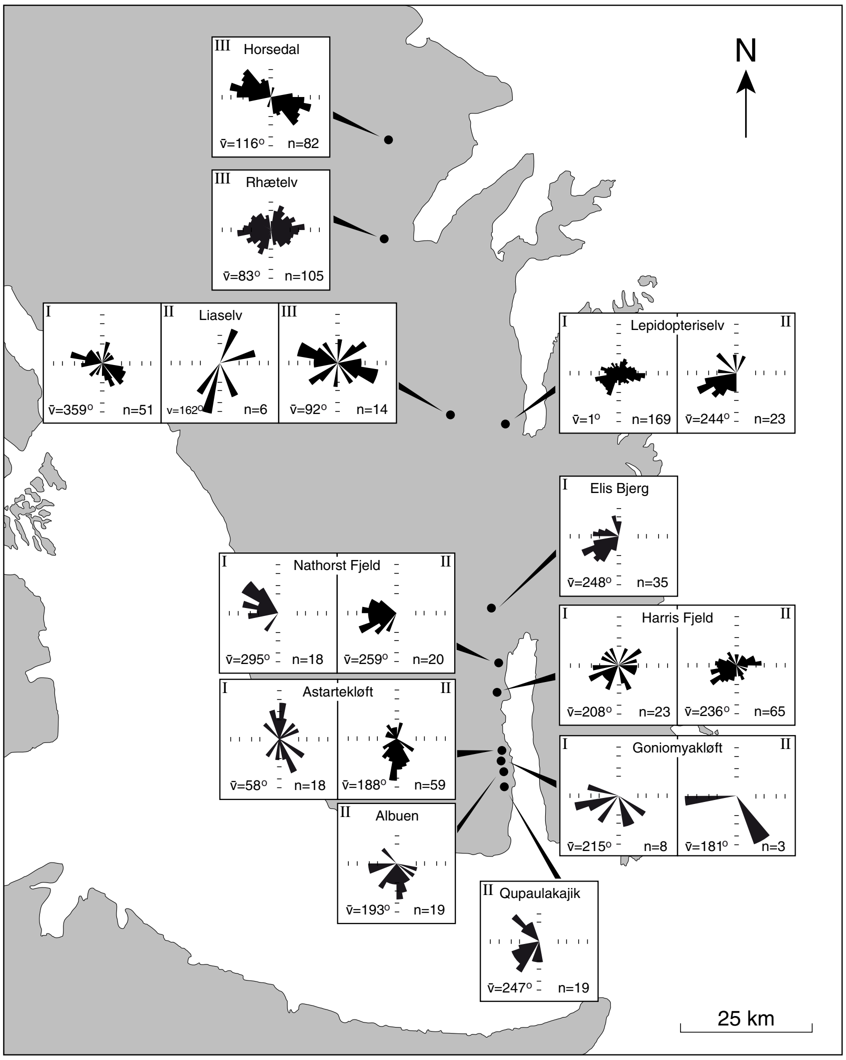


Fig. 51. Palaeocurrent and wave ripple data from the Astartekløft and Horsedal Members.
I = foreset azimuths of current cross-lamination;
II = foreset azimuths of current cross-bedding;
III = crestline orientation of wave ripples.
Rose diagrams are shown as true area plots. Marks at 5, 10, 20 and 30% frequency.
v = vector mean;
π = number of measurements.

WNW trending shoreline, parallel to the northern basin margin (Fig. 51). No major vertical facies changes occur and the successions form an aggradational unit.

Widespread lagoonal deposition in the northern part of the basin took place contemporaneously with tidal channel and subtidal shoal deposition, without lagoonal influence in the south-eastern part of the basin. A barrier complex must thus have been situated in the present-day Dusén Bjerg – Skansen area during Late Pliensbachian times (Fig. 52). The nature and depositional strike of the barrier complex is not known, but crestline orientation of wave ripples in the lagoonal deposits suggest that the barrier had a NW–SE orientation (Fig. 52). The barrier was apparently situated above a major Devonian transverse fault, suggesting structural control of the position and formation of the barrier. A major tidal channel, situated in the Nathorst Fjeld area, was the source of a southward prograding subtidal shoal along the present-day Neill Klinter. A Late Pliensbachian palaeogeographic reconstruction of the Jameson Land Basin is shown in Fig. 52.

Early Toarcian sea-level rise and establishment of a shelf (Nathorst Fjeld, Harris Fjeld and Lepidopteriselv Members)

In the Early Toarcian the tidal channels, subtidal sand sheets and lagoonal environments were drowned and an offshore transition zone environment was established in the southern part of the basin (Facies association p). In the Harris Fjeld area the drowning was followed by progradation of ebb-tidal deltas towards the west (Facies association r), suggesting that a major tidal channel complex was still situated in this area (Figs 34–36). Further south, along Neill Klinter, and in the Nathorst Fjeld area the offshore transition deposits

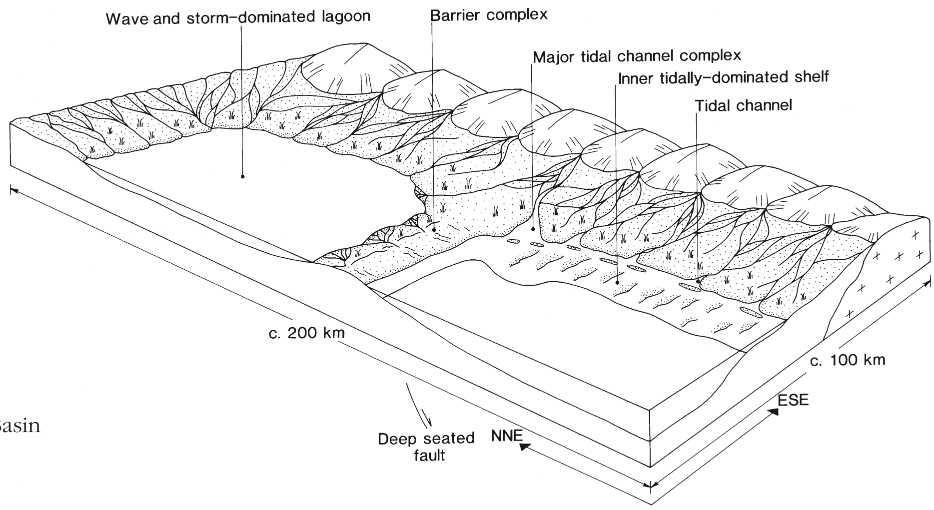


Fig. 52. Palaeogeographical reconstruction of the Jameson Land Basin during Late Pliensbachian times.

pass upward into a sheet of shoreface sandstones (Facies association q) which reflects the same progradational event as recorded by the ebb-tidal delta succession in the Harris Fjeld area (Fig. 32). Foreset dip directions of the cross-bedded shoreface sandstones are bipolar towards N and S, indicating currents roughly parallel to the eastern basin margin (Fig. 53). Wave ripple crestlines in the Nathorst Fjeld Member are oriented either N–S or E–W, parallel and perpendicular to the basin margin, respectively (Fig. 53).

At Lepidopteriselv a large tidal channel complex was established in the Early Toarcian (Facies association m). The channel deposits consist of stacked dune field sandstones (Fig. 30). Palaeocurrent data show a preferred orientation towards the west, indicating deposition from dominantly offshore directed currents (Fig. 53).

Further north, the Lepidopteriselv Member is separated from the overlying lagoonal deposits of the Horsedal Member by a transgressive surface of erosion. In this area a large shallow wave and storm-dominated

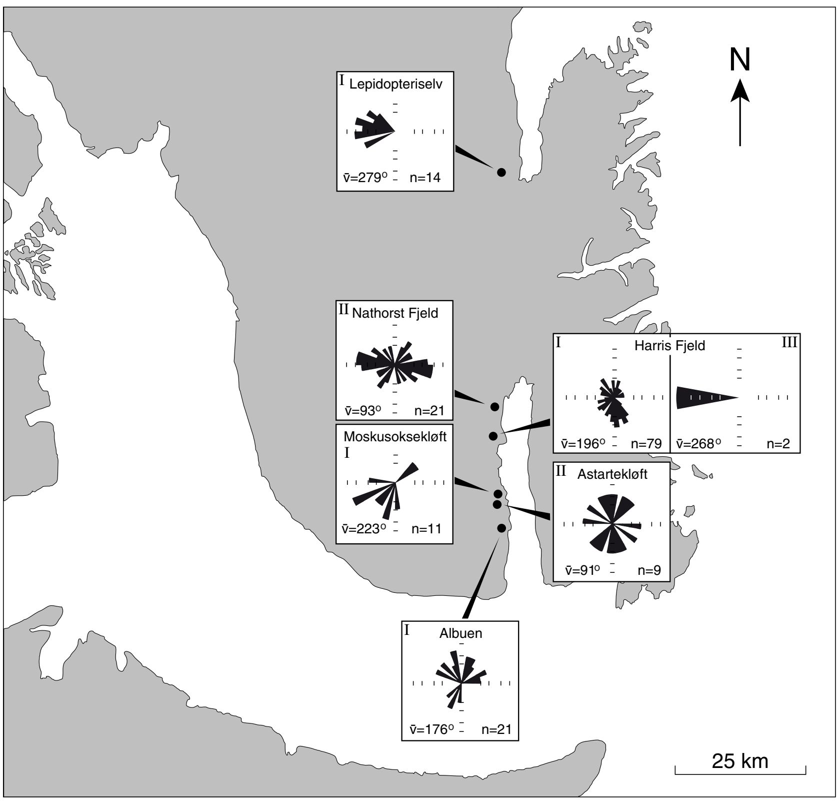


Fig. 53. Palaeocurrent and wave ripple data from the Nathorst Fjeld, Harris Fjeld and Lepidopteriselv Members.
I = foreset azimuths of cross-bedding and cross-lamination;
II = crestline orientation of wave ripples;
III = foreset azimuths of giant-scale cross-bedding.
Rose diagrams are shown as true area plots. Marks at 5, 10, 20 and 30% frequency;
v̄ = vector mean;
n = number of measurements.

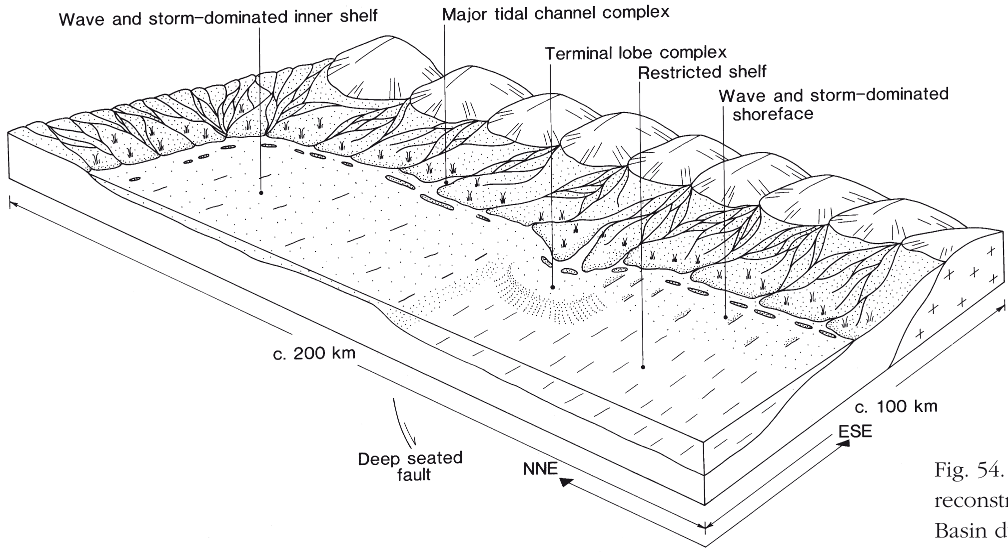


Fig. 54. Palaeogeographical reconstruction of the Jameson Land Basin during Early Toarcian times.

shelf was established that later developed into an interfingering dune field and bioturbated shallow marine environment (Facies associations n and o).

An Early Toarcian palaeogeographic reconstruction of the Jameson Land Basin is shown in Fig. 54.

Toarcian bioturbated shelf and tidal channel deposits (Skævdal and Trefjord Bjerg Members)

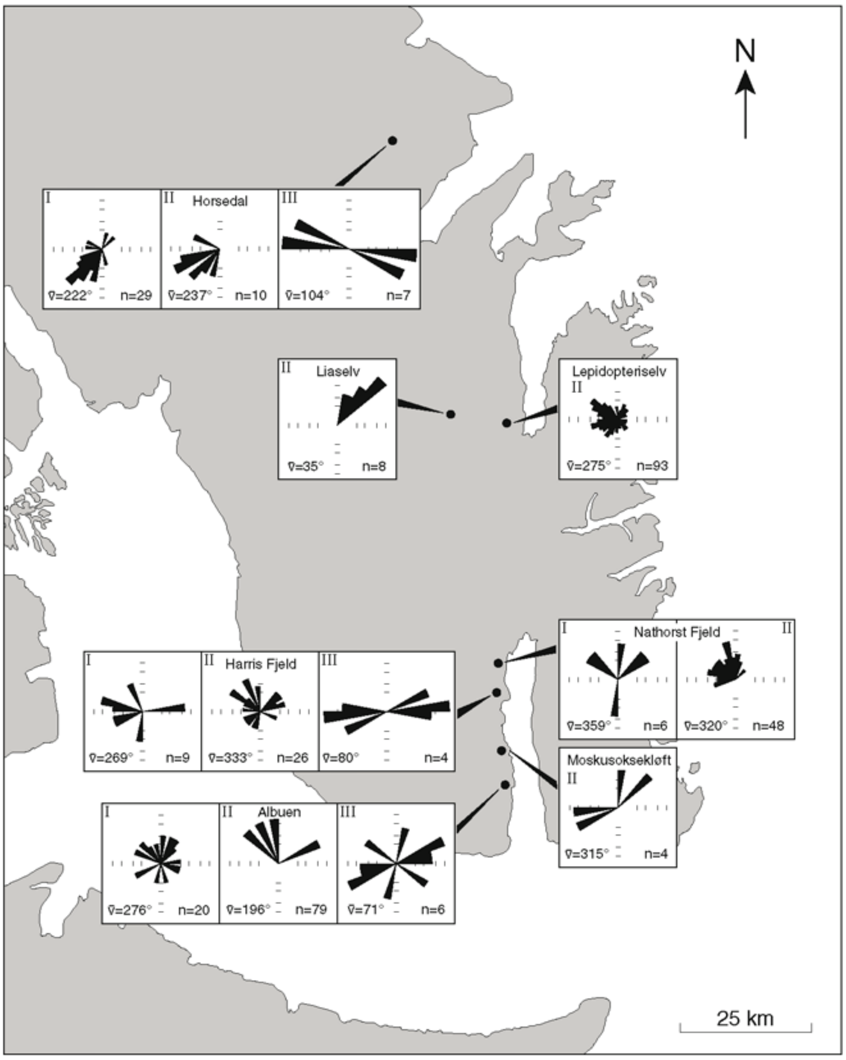
A major landward shift in facies took place in the Late Toarcian, and a uniform basin-wide sheet of bioturbated sandy mudstones and muddy fine-grained sandstones of the Skævdal Member was deposited (Facies association o; Figs 39, 46).

This landward shift in facies was followed by a basinward shift in facies throughout the basin represented by sheets of tidal channel, interbedded dune field and bioturbated shoreface sandstones (Facies associations m, n and o) of the Trefjord Bjerg Member. At Lepidopteriselv, the Trefjord Bjerg Member has a sharp lower contact to the muddy sandstones, and a lag conglomerate containing belemnites, bivalves, quartzite pebbles and bored siderite clasts occurs at the boundary. The presence of tidal channel deposits composed of stacked dune field sandstones, arranged in a thinning-upward succession, indicates that a major tidal channel complex still existed in this area (Figs 38, 41, 42). Palaeocurrent data from the cross-bedded sandstones show a preferred orientation towards the west, indicating deposition from dominantly offshore directed currents (Fig. 55).

West of Lepidopteriselv the cross-bedded sandstones pass into increasingly bioturbated sandstones, and at Liaselv, 8 km west of Lepidopteriselv, the sandstones are bioturbated throughout. In the south-eastern and northern parts of the basin the Trefjord Bjerg Member consists of interbedded dune field and bioturbated shoreface deposits (Fig. 38). In the south-eastern part of the basin foreset dip directions of the dune field deposits are generally towards SW, NW and N–NE indicating deposition from coast-parallel and offshore directed currents (Fig. 55). In the northern part of the basin (Horsedal) the foreset dip directions are towards SW (Fig. 55). In Horsedal the dune field sandstones pass into alternating bioturbated and wave and storm-dominated shoreface sandstones.

The upper surface between the dune field and bioturbated shoreface deposits of the Trefjord Bjerg Member and the mudstones of the Sortehat Formation is sharp throughout the basin. *Diplocraterion parallelum* and *Diplocraterion habichi* may in places penetrate down from the formation boundary and lag gravels, containing well-sorted, well-rounded quartzite pebbles with a maximum diameter of 1 cm are common at the boundary or occur dispersed in the lower 20 cm of the mudstones of the Sortehat Formation. In the Skævdal area the mudstones just above the Trefjord Bjerg Member (basal Sortehat Formation) contain abundant inarticulate brachiopods. In Horsedal, in the northern part of the basin, the interbedded dune field and bioturbated shoreface deposits are overlain by a lag conglomerate, containing flat, well-sorted, well-rounded quartzite pebbles with a maximum diameter of 8 cm. The sandstones just above the conglomerate are densely burrowed by *Diplocraterion parallelum* and are suc-

Fig. 55. Palaeocurrent and wave ripple data from the Trefjord Bjerg Member.
I = foreset azimuths of cross-lamination;
II = foreset azimuths of cross-bedding;
III = crestline orientation of wave ripples.
Rose diagrams are shown as true area plots. Marks at 5, 10, 20 and 30% frequency;
∇ = vector mean;
n = number of measurements.



ceeded by wave and storm-dominated shoreface deposits (Facies association n). Wave ripple crestlines trend WNW–ESE parallel to the northern basin margin (Fig. 55). The boundary between the Trefjord Bjerg Member and Sortehat Formation is not exposed in this area.

The dominant mode of sand transport during deposition of the Trefjord Bjerg Member appears to have been associated with extensive southwards, westwards and northwards-migrating dune fields initiated by wind-driven and tide-enhanced coast-parallel and offshore directed currents. The dune fields passed basinwards into bioturbated shoreface environments. A major tidal channel complex in the Lepidopteriselv area was the source of a large part of the sand delivered to the basin in the Late Toarcian.

Aalenian sea-level rise and establishment of a restricted embayment (Sortehat Formation)

Following deposition of the sandstones of the Trefjord Bjerg Member, a major landward shift of facies occurred throughout the basin and a thick succession of offshore mudstones and lower shoreface siltstones and very fine to fine-grained sandstones were deposited (Facies association s), arranged in one or two coarsening-upward successions (Krabbe *et al.*, 1994). A detailed sedimentological and palynological study of the formation is presented by Koppelhus & Hansen (in press).